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*REVIEW ARTICLE*

# Wound closure in flexion versus extension following total knee arthroplasty : A systematic review

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**Optimising knee range of motion following total knee arthroplasty (TKA) is important for patient satisfaction, functional outcome and early rehabilitation to promote accelerated discharge. Historically, wound closure following TKA has been performed in extension. It has been suggested that knee position during wound closure may influence range of motion and clinical outcomes following TKA. The purpose of this study was to determine whether TKA wounds should be closed in flexion or extension.**

**An electronic search of MEDLINE, EMBASE, CINAHL and AMED databases was made in addition to a review of unpublished material. All included papers were critically appraised using a modified PEDro (Physiotherapy Evidence Database) critical appraisal tool.**

**Three papers were eligible, assessing 237 TKAs. On analysis, patients with TKA wounds closed in flexion had greater flexion range of motion and required less domiciliary physiotherapy compared to those with wounds closed in full extension.**

**The specific degree of knee flexion used when closing total knee replacement wounds may be an important variable to clinical outcome. However, the present evidence-base is limited in both size and methodological quality.**

**Keyword** : total knee replacement ; wound closure ; knee angle ; flexion ; extension ; range of motion ; systematic review.

## INTRODUCTION

Total knee arthroplasty (TKA) is one of the most common arthroplasty procedures performed in orthopaedic surgery (*21*). A major limitation to an accelerated rehabilitation and short hospital stay is that of limited knee range of motion and pain (*3,23*). Difficulties in obtaining acceptable knee motion during the early rehabilitation following a TKA may necessitate further surgical intervention such as manipulation under anaesthesia or arthrolysis (*9,20,24*). Furthermore, patients who have problems in regaining range of motion require additional aggressive physiotherapy (*11,17*). Various factors have been related with the development of poor early range of motion. These have included poor preoperative range of motion, obesity, incorrect surgical technique, excessive patellar height and insufficient post-operative rehabilitation (*1,6,8,17, 24,26*).

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Traditionally, the surgical wound closure following a TKA has been performed with the patient supine and the knee in full extension (*4,19*). However, some authors have suggested that closure of the knee in flexion may be advantageous. King *et al* (*16*) suggested that skin tightness, attributed to wound closure in terminal knee extension, may lead to increased post-operative pain and limit a patient's ability to regain his/her range of motion. It was speculated that wound closure in extension could cause a relative shortening of the extensor mechanism and skin, which would contribute to increased discomfort compared to wound closure performed in flexion (*16*). As a consequence, King *et al* (*16*) suggested that TKA wounds should be closed in some degree of knee flexion.

No studies have previously reviewed the literature to determine the optimal knee position for wound closure after TKA. Accordingly, the purpose of this paper is to address this shortcoming in the evidence base, to assess the outcomes of wound closure performed in flexion compared to extension, following TKA.

## MATERIALS AND METHODS

### Eligibility criteria

Articles which satisfied the following criteria were included : (1) intervention – studies which compared TKA wound closure in flexion and extension ; (2) population – primary and revision TKA patients assessed separately ; (3) outcome – knee range of motion and other clinical or economic outcomes ; (4) methods – randomised and non-randomised clinical trials ; (5) exclusion – cadaver and animal studies were excluded.

### Study identification

A database search was performed via Ovid or Medline (1950 to January 2010), CINAHL (1982 to January 2010), AMED (1985 to January 2010) and EMBASE (1974 to January 2010) using key word terms and Boolean operators "total knee replacement" OR "total knee arthroplasty" AND "wound closure" AND "flexion" OR "extension" OR "position". We also searched Scopus and the Cochrane Library. A search of unpublished literature was made using the search term "total knee" AND "wound closure" using the databases SIGLE (System for Information on Grey Literature in Europe), the National Technical Information Service, the National Research Register (UK) and Current Controlled Trials databases. The reference lists of all eligible articles were reviewed for additional relevant papers. We contacted the corresponding authors of each included paper to identify any papers which may have been missed during the initial search strategy. The eligibility of studies was then independently judged by two investigators (TS, LD).

### Data extraction and methodological quality assessment

Two investigators (TS, LD) independently extracted the data from each included paper using a standardised extraction form. The methodological quality of these papers was assessed by the same reviewers independently using a tool based on the eleven-item PEDro scoring system. This methodological appraisal tool has previously been shown to be a reliable and valid assessment of randomised controlled trials (*7,18*). The results of each reviewer's extraction database and PEDro score were then amalgamated to formulate an agreed extraction database and quality assessment results table. Any disagreements regarding study selection, data extraction or appraisal score between the reviewers were resolved through discussion until a consensus was met.

### Statistical analysis

A meta-analysis using REVMAN software (version 5.0 for Windows. Copenhagen : The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) was initially planned to assess the outcomes of knee range of motion, functional outcomes and complication rates between wounds closed in flexion compared to extension, following total knee replacement. However, on appraisal of the literature, there was considerable heterogeneity in the outcome measures used and insufficient details were provided on standard deviation for knee range of motion even after consulting the corresponding authors. Accordingly, we adopted a narrative review to assess the evidence.

## RESULTS

### Literature search

The results of the search strategy are summarised in figure 1. A total of 103 citations were identified. Three papers were identified as satisfying the eligibility criteria. Of the three papers included, two

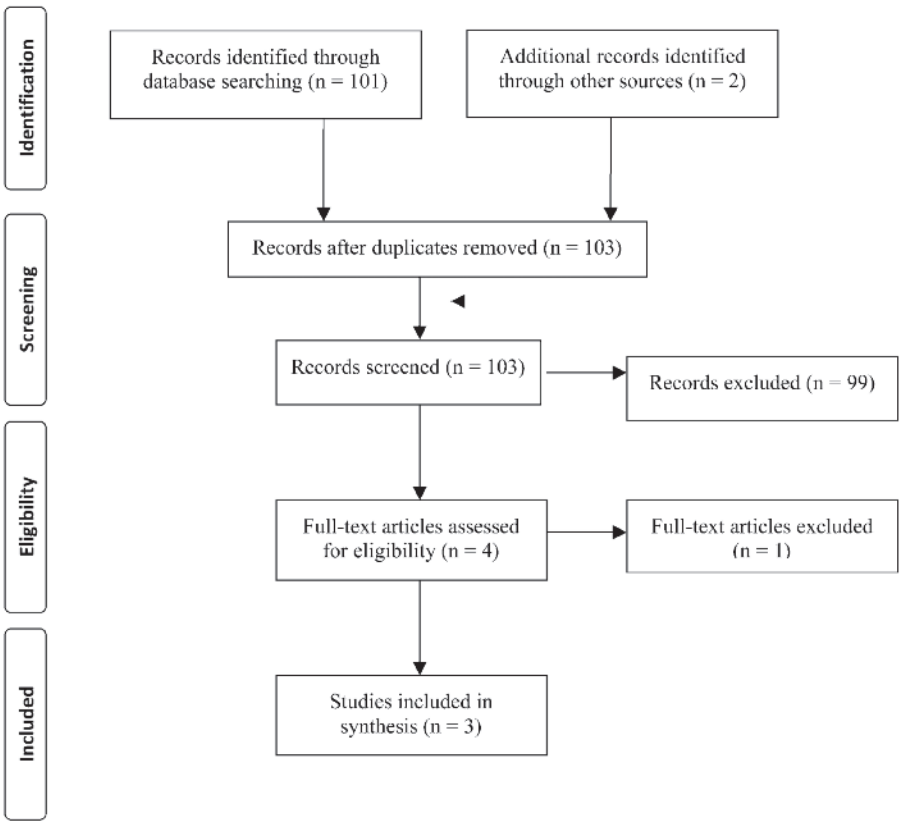


**Fig. 1.** — PRISMA Flow-Chart

papers presented the results of the same cohort. Emerson *et al* (*4*) presented the 6 month results of their primary TKA cohort, whilst Emerson *et al* (*5*) presented the 1 year results of this cohort's range of motion and complication data in addition to the results of a revision TKA cohort. We therefore excluded Emerson *et al*'s (*4*) paper for these outcomes, but used this earlier paper to extract data assessing the domiciliary physiotherapy requirements, as this was not reported in the later (*5*) paper. We analysed the results of Emerson et *al*'s (*5*) primary TKA cohort separately to their revision TKR cohort to differentiate between these two populations.

## Methodological quality assessment

A summary of the methodological assessment results is presented in table I. On critical appraisal of the current evidence base, both studies clearly defined their research question. One study adopted a randomised controlled trial methodology (*19*) whilst Emerson *et al's* (*5*) study was an observation study. Whilst the populations were defined and largely matched for important variables such as age, sex and weight, between the groups in both studies, neither study clearly defined how patients were recruited or where these cohorts originated from. Neither study blinded assessors or patients to their group allocation. The surgical interventions were not standardised in the two studies, with variation in prostheses used, surgeons operating and additional surgical techniques undertaken such as lateral release procedures. A power calculation was not employed in either study to base the sample size upon. Whilst inferential statistics were appropriately used, neither papers provided confidence intervals to assess statistical variance. The interpretation and application of the findings from each study were appropriately grounded in the evidence-base.

Table I. — Methodological quality assessment

| Criteria | Emerson et al (5) | Masri et al (19) |
|---|---|---|
| Focused question | Y | Y |
| Was it a randomised controlled trial | N | Y |
| Method of randomisation clearly described | N | Y |
| Were the two groups characteristics balanced | Y | Y |
| Population defined | Y | Y |
| Recruitment methods acknowledged | N | N |
| Assessor blinded | N | N |
| Patients blinded | N | N |
| Intention-to-treat | N | N |
| Were all subjects accounted for at the end of the trial | N | N |
| Did all subjects receive the same treatments except the study intervention | N | N |
| Sample size defined | N | N |
| Inferential stats employed | Y | Y |
| Confidence Intervals presented | N | N |
| Appropriate interpretation | Y | Y |
| Generalisability | Y | Y |
| Clinical relevance discussed | Y | Y |
| **Total** | **7/17** | **9/17** |

N : No Y : Yes

## Subject characteristics

The demographic characteristics of the cohorts reviewed are presented in table II. In total, 237 knees were reviewed ; 125 knees of 102 patients were closed in flexion, compared to 112 knees of 96 patients closed in extension. Mean age of the flexion group was 70.5 years, and 68.8 years in the extension group. The flexion cohort consisted of 42 males and 60 females, which was comparable to the extension group with 40 males and 56 females.

Knee wounds were closed in 60 to 90° of flexion in Masri *et al's* (*19*) flexion group and 90 to 110° in Emerson *et al's* (*5*) cohorts. Wounds were closed in full terminal extension in the extension closure groups in both studies. Posterior cruciate ligament retaining prostheses (Genesis, Smith and Nephew Richards, Memphis, TN, USA) and posterior stabilising prostheses (Insall-Burstein II, Zimmer, Warsaw, IN, USA) were used in Masri *et al's* (*19*) study. Both posterior cruciate retaining and posterior cruciate sacrificing prostheses were used in Emerson *et al's* (*5*) study, although they did not state the specific prostheses used. The patellar was resurfaced in all cases in Masri *et al's* (*19*) study, but this was not stated in Emerson *et al's* (*5*) paper.

As stated, Emerson *et al* (*5*) assessed both primary and revision TKR separately, whilst Masri *et al* (*19*) solely assessed the outcomes of primary TKR. The indication for revision TKR in Emerson *et al's* (*5*) study was aseptic loosening. In this cohort, two patients received cruciate retaining components, three received rotating hinge prostheses, whilst the remaining subjects underwent posterior cruciate sacrificing components.

Emerson *et al* (*5*) reported that all subjects underwent a rectus splitting exposure, whilst Masri *et al's* (*19*) subjects underwent a medial parapatellar capsular incision. Emerson *et al* (*5*) stated that all wounds were closed with sutures performed after tourniquet release. Masri *et al* (*19*) did not state what wound closure method was used, and whether this was performed with the tourniquet inflated or not.

Table II. — Demographic characteristics

| Paper | Design | Sample | | | | | | | | Follow-up period (months) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Knees | | Patients | | Mean age (years) | | Gender (m/f) | | |
| | | Extn | Flex | Extn | Flex | Extn | Flex | Extn | Flex | |
| Emerson et al (5) – primary | Observ | 62 | 74 | 52 | 56 | 72.5 | 69.2 | 18/34 | 21/35 | 12 |
| Emerson et al (5) – revision | Observ | 13 | 13 | 13 | 12 | 67 | 73 | 6/7 | 7/5 | 12 |
| Masri et al (19) | RCT | 37 | 38 | 31 | 34 | 66.8 | 69.2 | 16/15 | 14/20 | 3 |

Extn : extension
F : female
Flex : Flexion
M : male
Observ : Observational study
RCT : randomised controlled trial

Table III. — Average flexion range of motion at final follow-up

| Paper | Flexion ROM (degrees) | | P-value | Direction |
|---|---|---|---|---|
| | Extension | Flexion | | |
| Emerson et al (5) – primary | 113.0 | 117.9 | 0.03 | Flex > Ext group |
| Emerson et al (5) – revision | 112.7 | 118.7 | 0.03 | Flex > Ext group |
| Masri et al (19) | 103.1 | 104.7 | > 0.05 | Flex > Ext group |

ROM : range of motion

All patients were provided with continuous passive motion therapy immediately post-operatively for Masri *et al* (*19*) and Emerson *et al's* (*5*) studies. This was detailed 24 hours in Emerson *et al's* (*5*) revision cohort. All patients received prophylactic chemical anticoagulation and antibiotic cover in Masri *et al's* (*19*) study. This was not stated in Emerson *et al's* (*5*) paper.

## Clinical Outcomes

In total, the three studies included assessed seven clinical outcomes. These will now be discussed.

*Flexion range of motion*

Flexion range of motion was assessed in both Emerson *et al* (*5*) and Masri *et al's* (*19*) papers. As table III illustrates, Emerson *et al* (*5*) reported significantly greater flexion range of motion following wound closure in flexion in both their primary and revision total knee replacement cohorts compared to closure in extension ($p = 0.03$). This difference was exhibited at all assessment periods from the third post-operative week to one year follow-up. Masri *et al* (*19*) reported no significant difference in flexion range of motion between the different wound closure positions in their study ($p > 0.05$).

*Extension range of motion*

Only Emerson *et al* (*5*) specifically assessed extension range of motion. They reported no significant difference in extension range of motion or extension lag between wound closure positions at one year for primary or revision total knee replacement cohorts (tables IV & V).

*Pain*

Pain scores were measured in Masri *et al's* (*19*) study. They reported no significant difference

Table IV. — Average extension range of motion at one year follow-up

| Paper | Extension ROM (degrees) | | P-value | Direction |
|---|---|---|---|---|
| | Extension | Flexion | | |
| Emerson et al (5) - primary | 1.8 | 2.5 | >0.05 | Flex > Ext group |
| Emerson et al (5) - revision | 1.2 | 1.9 | 0.3 | Flex > Ext group |

ROM : range of motion

Table V. — Average degree of extension lag at one year follow-up

| Paper | Flexion Lag (degrees) | | P-value | Direction |
|---|---|---|---|---|
| | Extension | Flexion | | |
| Emerson et al (5) - primary | 0.3 | 0.3 | >0.05 | Same |
| Emerson et al (5) - revision | 2.3 | 2.5 | 0.4 | Flex > Ext group |

ROM : range of motion

between the wound closure positions, where the extension group reported a pain score of 44.2, compared to 43.7 in the flexion group ($p > 0.05$).

*Hospital length of stay*

Both Emerson *et al* (*5*) and Masri *et al* (*19*) assessed hospital length of stay of their cohorts. Emerson *et al* (*5*) reported that all subjects were discharged at 5 days, with no significant difference between the flexion or extension wound closure groups ($p > 0.05$). Masri *et al* (*19*) reported that their extension closure group's length of stay was 8.8 days, compared to 8.2 days ($p > 0.05$), indicating no difference in length of hospital stay between wound closure positions.

*Functional outcomes*

Only Masri *et al* (*19*) assessed the functional outcomes of their cohort. They assessed the duration from operation to being able to transfer, mobilise and negotiate stairs. They reported that there was no significant difference when patients achieved any functional milestones, between those patients whose wounds were closed in flexion compared to extension ($p > 0.05$). Masri *et al* (*19*) also used the Knee Society Scores (KSS) to assess clinical and functional outcomes. They reported that final clinical KSS was 88.4 in the extension group compared to 88.9 in the flexion group ($p > 0.05$), whilst functional KSS was assessed as 60.2 in the extension group, compared to 61.4 in the extension group at final follow-up ($p > 0.05$). Therefore, there appeared no significant difference between wound closure position in respect to functional outcomes based on Masri *et al's* (*19*) study.

*Domiciliary physiotherapy requirement*

Emerson *et al* (*4*) assessed the duration of domiciliary physiotherapy following primary total knee replacement. They reported that patients whose wounds were closed in flexion required an average of 3.4 weeks of domiciliary physiotherapy, compared to 4.9 weeks in the extension group. This was a statistically significant difference ($p < 0.001$).

## Complications

Emerson *et al* (*5*) and Masri *et al* (*19*) both reported their post-operative complications. Emerson *et al* (*5*) reported no wound complications or extensor mechanism complications in either primary or revision total knee replacement cohorts. Masri *et al* (*19*) stated that there was no statistically significant difference in the rate of major complications between the two wound closure positions ($p > 0.05$). They reported that in their extension groups, three knees required manipulation, compared to 4 in their flex-

ion groups. Two patients in the extension closure group developed deep vein thrombosis, compared to three in the flexion closure group. A wound haematoma was seen in one knee, but only in the flexion closure group (*19*).

## DISCUSSION

The findings of this systematic review indicate that when TKA wounds are closed in flexion, flexion range of motion may be greater and domiciliary physiotherapy requirements less, when compared to wounds closed in full extension. There does not presently appear to be a difference in functional outcome, length of hospital stay, pain scores or post-operative complications between TKA wounds closed in these two different positions. However, one principal limitation to this review was the potential impact that subject heterogeneity placed upon the final outcomes. Such differences between these studies include a variation in specific knee position during closure, the specific type of prosthesis, surgical approach undertaken and whether the patellar was resurfaced, whilst Emerson *et al* (*4,5*) did not state whether antibiotic or anticoagulation measures were used whereas this was stated in Masri *et al's* (*19*) study. Whilst this may be a methodological limitation to the findings of this paper, the fundamental finding of this study is that at present, it is not possible to confidently state whether knee position impacts on clinical outcomes following a total knee replacement.

As stated, the evidence base is presently founded upon two different studies. The review identified that Emerson *et al's* (*4,5*) studies indicated that knee position during total knee replacement wound closure may be a variable influencing outcome. Masri *et al*'s (*19*) study contradicted this finding, reporting that there was largely no difference in outcome. However, Emerson *et al* (*5*) positioned their patient's knees in 90 to 110° flexion, whereas Masri *et al* (*19*) closed their flexion group's wounds in 60 to 90° flexion. Accordingly, it may be speculated that the angle of knee flexion may have accounted for this difference in results. This can only be determined through further study comparing the outcomes of wound closure in different degrees of knee flexion. Only Masri *et al* (*19*) assessed pain and functional outcomes, reporting no significant difference in outcomes in respect to knee position on closure. It remains unclear whether this result would be reproducible when knee wounds with closure at greater degrees of knee flexion. Further study is therefore recommended.

The evidence base exhibited a number of methodological limitations. These included poorly detailing study characteristics. Whilst the papers provided information regarding patient age, height and weight, neither provided information regarding medical history such as incidence of diabetes or how many patients smoked. Whilst acknowledging that obesity may have been important, these factors have also accounted for differences in outcome, particularly in wound healing. Emerson *et al* (*5*) stated that wounds were closed using sutures, but did not state whether this was interrupted or continuous suturing ; Masri *et al* (*19*) did not state how they closed their wounds. Only Masri *et al* (*19*) stated what wound drains were used, whilst only Emerson *et al* (*5*) acknowledged the surgical approach adopted. Whilst limiting the external validity of these studies, by neglecting to provide such information, it remains unclear whether methodological differences between these two studies may have accounted for the difference in outcomes. Only Masri *et al's* (*19*) paper used a randomised controlled trial methodology. Whilst this is the gold-standard method of assessing treatment efficacy (*14*), the group allocation method used was based on hospital number. Accordingly this would be regarded as quasi-randomisation permitting the potential for allocation bias to occur. Neither study controlled the anaesthetic regime used within their cohorts, using both epidural and general anaesthetics. Accordingly, it remains unclear whether the differences in pain relief may have accounted for differences in early motion and rehabilitation. Similarly, pre-operative knee range of motion was shown to differ between the surgical groups within each study (*5,19*). Therefore, by not controlling for such important differences at baseline, it was not possible to state whether the difference between the groups at final outcome was attributed to differences in baseline characteristics, or due to an inter-

ventional effect. Finally, none of the studies based their sample sizes on a power calculation. Therefore if a difference in outcomes did exist, the potential for this to be statistical detected was low, thereby presenting a potential type II statistical error (*22*).

Emerson *et al* (*5*) concluded that patients with a substantial pre-operative quadriceps weakness with associated extension lag may be contraindicated to a flexion closure. It was hypothesised that closing the wound in extension can cause a relative shortening of the skin and extensor mechanism, thereby limiting the potential for a post-operative extension lag. However, since none of the studies reviewed presented data on pre- or post-operative quadriceps strength, it is therefore not possible to confidently state whether quadriceps weakness should really be a contraindication to wound closure in flexion.

King *et al* (*16*) recommended that total knee replacement wounds should be closed in 120° of flexion. This recommendation was based on an audit of 10 patients. They reported that wounds closed in 120° knee flexion were 42% longer than those closed in full extension. Whilst a larger scar may have accounted for poorer cosmetic result, these authors suggested that suturing the wound in extension binds the wound. They suggested that as the wound tightens with increasing flexion, it can pucker, and potentially break down to allowing dehiscence, wound blistering and therefore, an increased potential for wound infection and greater patient discomfort. However, our review suggested that there is no significant difference in the incidence of wound infection or dehiscence between flexion and extension wound closure positions. Whether King *et al's* (*16*) hypothesised reduction in patient discomfort accounted for the greater knee range of motion in Emerson et *al*'s (*5*) flexion closure group, remains unclear. Further study is therefore recommended to assess the incidence of wound complications and cosmetic results in a larger cohort, in addition to evaluating patient perceptions and satisfaction between these two wound closure methods.

None of the studies reviewed performed a formal cost-benefit analysis. Although both studies indicated that there was no significant difference in respect to hospital length of stay, Emerson *et al* (*5*) reported that the level of domiciliary physiotherapy was significantly greater for patients who underwent an extension closure, compared to flexion. Accordingly, this difference of a mean of 1.5 weeks, may have a substantial economical implication. Similarly, none of the studies attempted to assess the requirements for home help or carer costs. These too may have varied between wound closure methods. Further study is warranted in this area.

Functionally, it has been shown that 65° of knee flexion is required to permit normal gait, 90° to negotiate stairs, and 95° to transfer from a sitting to a standing position (*25*). Knee stiffness and limited motion following primary total knee replacement have been cited as presenting in up to 7% of patients (*10*). Nonetheless, total knee replacements are now considered a treatment option for younger and more physically active patients (*2,12,13*). The results of this study would suggest that flexion range of motion may be influenced by surgical closure method. Given that the demands which such more physically active patients place upon their knees are growing, it would seem appropriate that such subjects be considered for flexion closure. This may also be particularly appropriate for patients who receive high-flexion prostheses, with the aim of increasing flexion range of motion to enhance functional capabilities (*9*). Finally, none of the studies reviewed had assessed whether there was a difference in ability to kneel following total knee replacements closed in extension or flexion. Accordingly, this should be considered as a further functional outcome measure to be assessed in future, well-designed, clinical trials.

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