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Systematic Review

Cemented versus uncemented tibial components in primary total knee arthroplasty: A systematic review and meta-analysis of long-term outcomes

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ABSTRACT

Uncemented total knee arthroplasty (TKA) is an emerging alternative to the traditional cemented TKA to improve biological ingrowth and reduce cement-related adverse effects. This study aimed to provide a comparative analysis of the cemented and uncemented tibial fixation for TKA. We searched PubMed, Embase, and Cochrane Library on April 15, 2024; after the extensive screening and risk of bias assessment, we extracted the relevant data and pooled the data as mean difference (MD) or odds ratio with a 95% confidence interval (CI). Ten randomized controlled trials were finally included in our meta-analysis. There was no significant difference between cemented and uncemented tibial components in terms of knee society score at 5 years (MD = −1.14, 95% CI [−3.77, 1.49], $P = 0.39$), range of motion (MD = 0.73, 95% CI [−2.47, 3.93], $P = 0.65$), flexion (MD = −1.23, 95% CI [−3.37, 0.92], $P = 0.26$), and extension (MD = 0.11, 95% CI [−0.21, 0.42], $P = 0.51$). However, there was a significantly greater maximum total point motion (MTPM) with uncemented fixation at 2 years (MD = −0.39, 95% CI [−0.68, −0.11], $P = 0.007$). Uncemented tibial fixation showed comparable outcomes to the cemented tibial fixation in TKA with significantly greater initial MTPM.

Keywords: Cemented fixation, Tibial component, Total knee arthroplasty, Uncemented fixation

INTRODUCTION

Knee osteoarthritis (OA) is a debilitating, degenerative joint disease characterized by progressive articular cartilage loss, synovitis, and bony remodeling, leading to significant pain and functional impairment.[1] Total knee arthroplasty (TKA) has emerged as a successful surgical intervention for end-stage knee OA, aiming to restore pain-free joint motion and improve quality of life.[2] A crucial aspect of TKA procedures is achieving durable implant fixation, which directly influences long-term outcomes and patient satisfaction.[3] Conventionally, cemented fixation with polymethylmethacrylate bone cement has been the gold standard for implant stability in TKA.[4] However, concerns regarding periprosthetic osteolysis, aseptic loosening, and potential stress shielding of bone due to the rigid cement interface have driven the development and exploration of cementless fixation techniques.[5]

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Cementless fixation relies on biological ingrowth for implant stability, promoting bone apposition onto a porous implant surface. This theoretically offers advantages such as preservation of bone stock for potential future revision surgery, a more physiologic load transfer reducing stress shielding, and potentially improved long-term implant stability due to continuous bone remodeling.[6] The choice between cemented and cementless fixation in TKA remains a subject of ongoing debate. However, achieving initial implant stability and osseointegration can be a slower process with cementless techniques, potentially leading to increased micromotion and higher early aseptic loosening rates compared to cemented fixation.[7,8] Radiostereometric analysis (RSA) of new implants has been widely used to assess the risk of medium- to long-term failure due to aseptic loosening.[9] Implants showing continuous migration, i.e., more than 0.2 mm maximum total point motion (MTPM) in the 2nd year postoperatively, are considered at risk for aseptic loosening.[10,11]

Despite the growing body of literature comparing cemented and cementless fixation of tibial components in TKA, the evidence remains inconclusive. Existing studies often have small sample sizes, limited follow-up durations, and methodological heterogeneity, making it challenging to draw definitive conclusions about each technique's comparative advantages and disadvantages. Therefore, this study aims to elucidate the comparative effectiveness of cemented versus uncemented tibial fixation in TKA.

MATERIALS AND METHODS

The study was conducted according to the preferred reporting items for systematic review and meta-analysis guidelines and checklist [Figure 1].[12] We also followed the rules of the Cochrane Handbook for Systematic Reviews of Interventions.[13]

Literature search

We searched PubMed, Cochrane Library, and Scopus on June 15, 2024, for published randomized controlled trials using the following search strategy: ([("Knee Replacement Arthroplasties") OR ("Knee Replacement Arthroplasty") OR ("Total Knee Replacement") OR ("Total Knee Arthroplasty")] AND [("Uncemented" OR "uncement" OR "Cementless" OR "Non-cemented" OR Cemented OR cement*)]), also we manually screened the reference lists of the included studies for any eligible articles.

Eligibility criteria and study selection

We included randomized controlled trials that compared cemented and uncemented tibial component fixation in patients undergoing TKA. We excluded animal studies, cohort or case-control reports, *in vitro* studies, overlapped datasets, conference abstracts, reviews, book chapters, theses, editorial letters, and abstract-only papers. After duplicate removal using Endnote, two authors independently performed the title and abstract screening, then the full-text screening. Conflicts were solved by consulting a third author.

Data extraction

We extracted the patients' baseline demographic characteristics, a summary of the main results of the included studies, and the following outcomes: Knee society score (KSS) at 5 years, range of motion (ROM), degree of flexion, degree of extension, and MTPM at 2 years.

Risk of bias assessment

Two authors independently assessed the quality of the included studies using the Cochrane risk of bias tool as described in the Cochrane Handbook.[14] The main assessed bias domains include selection bias, performance bias, detection bias, attrition bias, reporting bias, and other potential sources of bias.

Data synthesis

We used Review Manager software version 5.4 for the meta-analysis; continuous outcomes were pooled using main difference (MD), and dichotomous outcomes were pooled using odds ratio, all with 95% confidence intervals (CIs). Heterogeneity was assessed using chi-square and I-square tests. The studies were considered heterogeneous at chi-square $P < 0.1$ and $I^2 > 50\%$. A fixed effect model was used for the analysis unless heterogeneity was detected, in which case a random effect model was used.

RESULTS

We located 1636 articles through a literature search, and then after the title and abstract and full-text screening, 10 articles were finally included in the meta-analysis [Figure 1].[15-24]

Baseline characteristics of the included studies are shown in Table 1; they include age, sex, body mass index, and physical status. According to the authors' judgment of the risk of bias, the overall quality of the included studies was moderate [Figure 2].

Meta-analysis results

KSS at 5 years

The outcome was reported in five studies with 565 total patients, the pooled mean difference (MD) showed no statistically significant difference between the cemented

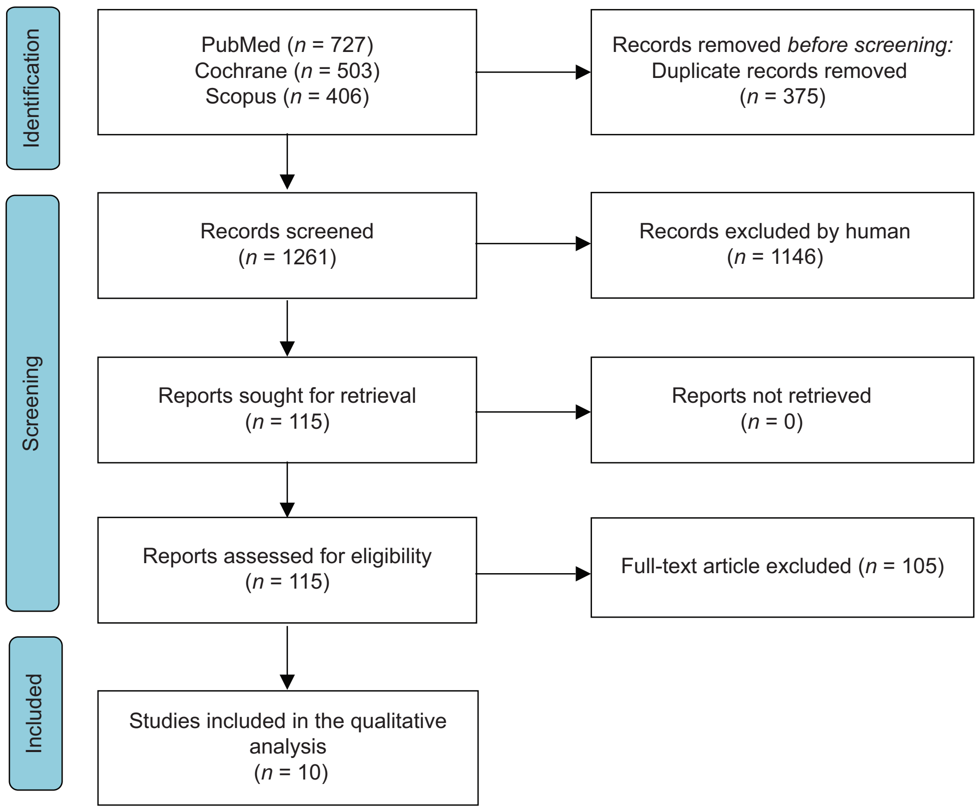

Figure 1: Preferred reporting items for systematic review and meta-analysis follow-chart.

Table 1: Baseline characteristics of the included studies.

Study ID	Sample size	Study group	Age (year) Mean (SD)	BMI (kg/m²) Mean (SD)	Sex, No. of females (%)	Physical status		
						ASA I n (%)	ASA II n (%)	ASA III n (%)
Nilsson *et al.*, 2006[21]	34	Cemented	55.5 (7.5)		20 (59)			
	35	Uncemented	56 (6.25)		23 (65)			
Wilson *et al.*, 2012[23]	18	Cemented	61 (9)	34 (5)	10 (56)			
	27	Uncemented	60 (8)	32 (5)	17 (63)			
Fernandez-Fairen *et al.* 2013[16]	63	Cemented	60 (4.6)	30.5 (4.90)	54 (76)			
	69	Uncemented	61 (5.0)	29.1 (5.2)	55 (74)			
Choy *et al.*, 2014[15]	86	Cemented	69 (6.8)	29 (4)	62 (72)			
	82	Uncemented	65 (5)	30 (6)	60 (73)			
Pulido *et al.*, 2015[20]	126	Cemented	68.4 (8.3)	31.8 (6.5)	71 (56)			
	106	Uncemented	68.1 (8.8)	31.4 (6.3)	51 (48)			
Van Hamersveld *et al.*, 2017[24]	30	Cemented	65.7 (6.3)	28.6 (3.6)	13 (43.3)	8 (26.7)	20 (66.7)	2 (6.7)
	30	Uncemented	66.8 (9.1)	28.0 (3.3)	19 (63.3)	5 (16.7)	18 (60)	7 (23.3)
Hampton *et al.*, 2020[17]	45	Cemented	63 (3.5)	30.7 (3.25)	23 (51.1)			
	45	Uncemented	64 (5)	30.1 (3.5)	25 (44.4)			
Nivbrant *et al.*, 2020[22]	51	Cemented	67.8 (8.0)	30.9 (4.6)				
	49	Uncemented	68.8 (7.5)	30.3 (5.1)				
van der Lelij *et al.*, 2023[19]	34	Cemented	66 (6.3)	30 (3.1)	16 (47)	4 (12)	26 (77)	4 (12)
	35	Uncemented	65 (5.7)	28 (3.1)	17 (49)	13 (37)	21 (60)	1 (3)
Gibon *et al.*, 2023[18]	135	Cemented	68	32	77 (57)			
	126	Uncemented	68	31	60 (48)			

ASA: American Society of Anesthesiologists, BMI: Body mass index, SD: Standard deviation

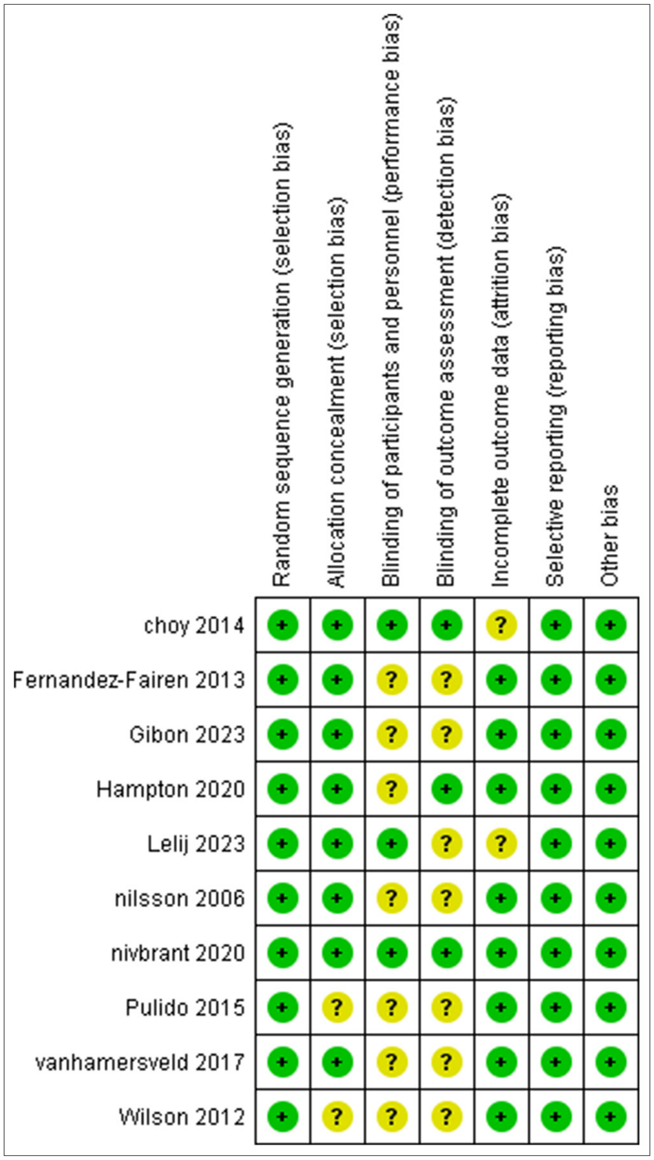

Figure 2: Risk of bias assessment for included studies. Green circles with plus sign: Low risk of bias. Yellow circles with question mark: Unclear risk of bias.

and uncemented tibial fixation in KSS score at 5 years (MD = −1.14, 95% CI [−3.77, 1.49], P = 0.39), the pooled results were heterogeneous (P = 0.09, I^2 = 50%), the heterogeneity was best solved by removing Fernandez-Fairen *et al.* 2013[16] (P = 0.50, I^2 = 0%), and the MD remained non-significant (P = 0.76) [Figure 3].

MTPM at 2 years

The outcome was reported in four studies with 232 total patients. It was measured by RSA [Figure 4]. The pooled result showed significantly higher MTPM with uncemented tibial fixation (MD = −0.39, 95%CI [−0.68, −0.11], P = 0.007), the results were heterogeneous (P = 0.007, I^2 = 75%), the heterogeneity was solved by removal of Nivbrant *et al.* 2020[22] (P = 0.33, I^2 = 11%). The effect estimate remained significant (P < 0.0001).

ROM (in degrees)

The outcome was reported in two studies with 237 patients [Figure 5]. The pooled MD showed no significant difference between cemented and uncemented tibial fixation in postoperative ROM (MD = 0.73, 95%CI [−2.47, 3.93], P = 0.65), and the pooled results were homogeneous (P = 0.91, I^2 = 0%).

Motion flexion (degrees)

The outcome was reported in three studies with 547 patients [Figure 6]. The pooled MD showed no significant difference between cemented and uncemented tibial fixation in postoperative motion flexion (MD = −1.23, 95%CI [−3.37, 0.92], P = 0.26), and the pooled results were homogeneous (P = 0.12, I^2 = 52%).

Motion extension (degrees)

Three studies reported the outcome with 547 patients [Figure 7]. The pooled MD showed no significant difference between cemented and uncemented tibial fixation in postoperative motion extension (MD = 0.11, 95%CI [−0.21, 0.42], P = 0.51), and the pooled results were homogeneous (P = 0.23, I^2 = 31%).

DISCUSSION

Cemented designs were widely preferred for TKA. However, an uncemented fixation design was developed due to the increased aseptic loosening and loss of cement-bone interlock due to trabecular resorption along with the deformation and degradation of the cement mantle.[25,26] Uncemented TKA was thought to provide strong long-term biological fixation due to bone ingrowth.[27] Several biomaterials have been used to enhance bone ingrowth in uncemented TKA, like osteoconductive hydroxyapatite (HA) coatings, peri-apatite (PA) HA, and trabecular metal.[23,28,29] Several factors have been linked to TKA failure, one of which is the lack of fixation of the implant, especially on the tibial side, particularly in patients younger than 65 years.[30,31] This systematic review and meta-analysis compared the functional and radiological outcomes of cemented and uncemented tibial components for primary TKA.

Our results showed no significant difference between cemented and uncemented tibial fixation in a 5-year follow-up duration. This is similar to the results reported by the previous meta-analysis, which showed no significant difference between cementless porous tantalum tibial components and the

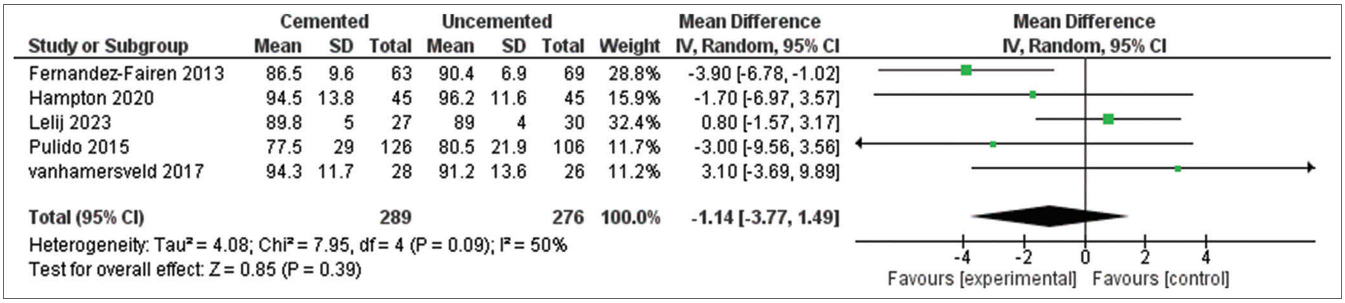

Figure 3: Knee society score at 5 years. SD: Standard deviation, CI: Confidence interval, IV: Inverse variance, df: Degree of freedom, Tau^2: Between-study variance, Chi^2: Chi-square test for heterogeneity, I^2: Inconsistency statistics (heterogeneity), Z: Z-score for overall effect, P: P-value for statistical significance.

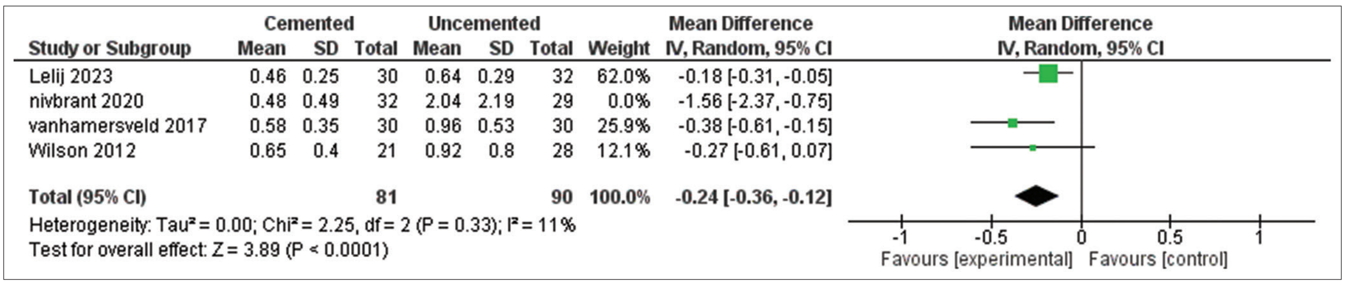

Figure 4: Maximum total point motion at 2 years. SD: Standard deviation, CI: Confidence interval, IV: Inverse variance, df: Degree of freedom, Tau^2: Between-study variance, Chi^2: Chi-square test for heterogeneity, I^2: Inconsistency statistics (heterogeneity), Z: Z-score for overall effect, P: P-value for statistical significance.

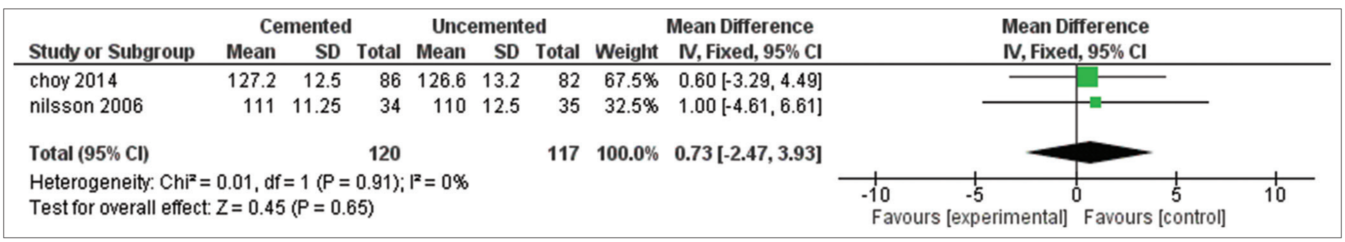

Figure 5: Range of motion (in degrees). SD: Standard deviation, CI: Confidence interval, IV: Inverse variance, df: Degree of freedom, Tau^2: Between-study variance, Chi^2: Chi-square test for heterogeneity, I^2: Inconsistency statistics (heterogeneity), Z: Z-score for overall effect, P: P-value for statistical significance.

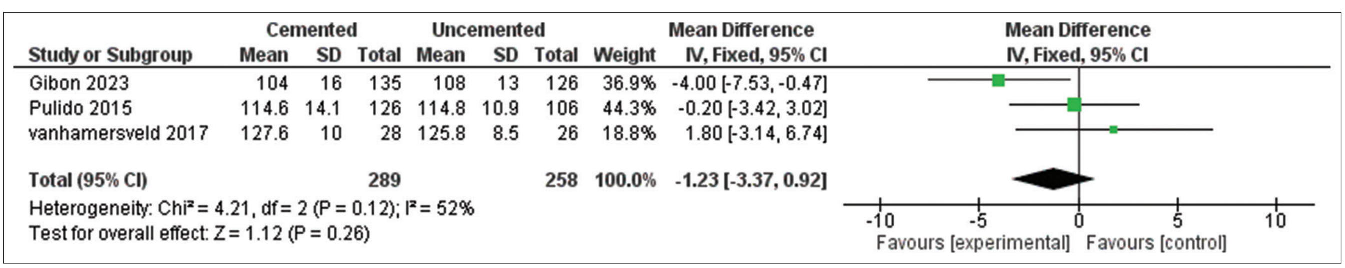

Figure 6: Motion flexion (degrees). SD: Standard deviation, CI: Confidence interval, IV: Inverse variance, df: Degree of freedom, Tau^2: Between-study variance, Chi^2: Chi-square test for heterogeneity, I^2: Inconsistency statistics (heterogeneity), Z: Z-score for overall effect, P: P-value for statistical significance.

traditional cemented tibial components in primary TKA.[32] The outcome was reported by five studies; three of them used porous tantalum for the uncemented tibial component,[16,17,20] van der Lelij *et al*. used 3D-printed Triathlon Tritanium (Stryker) cruciate retaining, and Van Hamersveld *et al*. used PA coating for the uncemented fixation.[19,24] Regardless of the different biomaterials used for uncemented tibial fixation, the studies individually reported no significant difference in KSS

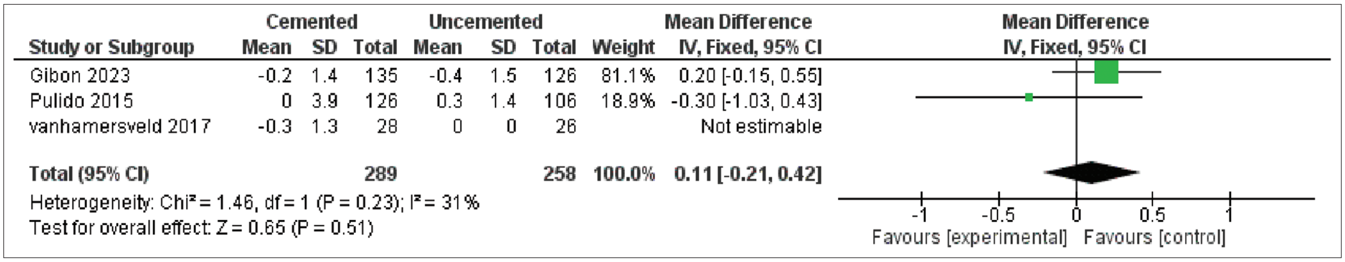

Figure 7: Motion extension (degrees). SD: Standard deviation, CI: Confidence interval, IV: Inverse variance, df: Degree of freedom, Tau^2: Between-study variance, Chi^2: Chi-square test for heterogeneity, I^2: Inconsistency statistics (heterogeneity), Z: Z-score for overall effect, P: P-value for statistical significance.

score at 5 years. However, at 11–15-year follow-up, Hampton *et al*. showed significantly better KSS scores with uncemented tibial fixation,[17] which was different from the results reported by Choy *et al*. and Li *et al*.[15,32]

Our results showed significantly higher MTPM with uncemented tibial fixation. Four included studies reported the outcome. Van der Lelij *et al*., Nivbrant *et al*. and Van Hamersveld *et al*. showed significantly higher MTPM with uncemented fixation at 2 years. However, Wilson *et al*. reported no significant difference between cemented and uncemented tibial fixation at 2 years.[19,22-24] This is similar to the results reported by the previous meta-analysis by Fozo *et al*. comparing cemented, uncemented, and hybrid techniques for both tibial and femoral components.[33] Both excessive initial migration in the 1st year and high continuous migration after 1 year are used to determine implant fixation and longevity.[9,34] However, regardless of the initial migration, highly porous and HA-coated uncemented components were found firmly fixed to the bone at long-term follow-up.[35,36] Thus, more long-term clinical trials are needed to assess the long-term stability of the uncemented tibial fixation.

One of the primary goals of TKA is pain relief and ROM restoration.[37] Moreover, knee flexion ROM after TKA is significantly associated with acute postoperative ROM.[38] Our analysis showed no significant difference in ROM, flexion, or extension between cemented and uncemented tibial components in TKA. Similar results were also reported in the previous meta-analysis.[32]

Our study provides a comprehensive overview of the outcomes of cemented and uncemented tibial components for TKA. However, notable heterogeneity was encountered in the main outcomes. Moreover, the mean duration of follow-up was relatively short, and more studies are needed to provide the long-term stability results for the uncemented tibial fixation.

CONCLUSION

Uncemented tibial fixation for TKA warrants a remarkable instability as it showed significantly greater MPTM compared to the traditional cemented fixation at 2 years. However, uncemented and cemented fixations were comparable to the other assessed outcomes.

Authors' contributions: ZA: Conceptualization, supervision, validation. YA: Writing – review and editing, supervision, validation. IA and BA: Writing – original draft preparation, data curation, visualization, and methodology. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

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Declaration of patient consent: Patient consent is not required, as there are no patients in this study.

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