Comparative Analysis of the Tibial Component Migration After Cemented and Uncemented Total Knee Arthroplasty with a Hydroxyapatite Coating in Two, Five, and Ten Years: A Meta-Analysis*

Análise comparativa da migração do componente tibial da artroplastia total do joelho cimentada versus não cimentada versus não cimentada com revestimento de hidroxapatita por dois, cinco e dez anos: uma metanálise

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Abstract

Objective This study evaluated and compared the tibial component migration in cemented and uncemented total knee arthroplasty (TKA) with no hydroxyapatite coating 2, 5, and 10 years after surgery.

Methods This meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) based on PubMed and MeSH database queries from June to July 2022.

Results The meta-analysis included eight randomized clinical studies evaluating 668 knees undergoing TKA. The maximum total point motion (MTPM) in cemented TKAs was higher in 5 years, with a mean value of 0.67 mm (95% confidence interval [CI], 0.52 to 0.87). Uncemented TKAs also presented higher mean MTPM in 5 years (1 mm; 95% CI, 0.82 to 1.22). Uncemented coated ATKs had a higher mean MTPM in 10 years (1.30 mm; 95% CI, 0.70 to 2.39). MTPM was statistically similar in the short- and long-term for cemented and uncemented techniques, with a standardized mean difference of -0.65 (95% CI, -1.65 to 0.35).

Conclusion Tibial component migration in TKA was statistically similar at 2, 5, and 10 years in cemented and uncemented techniques, either with or without coating. However, due to the scarce literature, further studies are required with a longer follow-up time.

Keywords
- arthroplasty, replacement, Knee
- durapatite
- bone cements
- prognostic

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Resumo

Objetivo Avaliar e comparar a migração obtida pelo componente tibial na Artroplastia Total de Joelho (ATJ) cimentada, não cimentada sem revestimento e não cimentada com revestimento de hidroxapatita aos 2, 5 e 10 anos pós operatório.

Métodos Esta metanálise foi conduzida de acordo com o Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Foi realizada busca a partir das bases de dados PubMed e MeSH no período de junho a julho de 2022.

Resultados Oito ensaios clínicos randomizados foram incluídos. Um total de 668 joelhos submetidos a ATJ foram avaliados. Observou-se que a média de *Maximun Total Point Motion* (MTPM) nas ATJ cimentada foi maior em experimentos com cinco anos com média de 0,67 mm (IC95% - 0,52 a 0,87), as ATJ não cimentadas com revestimento de hidroxapatita também obtiveram maior média neste período (1mm; IC95% - 0,82 a 1,22). Em ATJ não cimentada sem revestimento o maior MTPM médio ocorreu no período de 10 anos (1,30mm; IC95% - 0,70 a 2,39). O MTPM foi estatisticamente semelhante no curto e longo prazo ao comparar as técnicas cimentada e não cimentada, com diferença média padronizada -0,65 (IC95%, -1,65 a 0,35).

Conclusão A migração obtida pelo componente tibial na artroplastia total de joelho (ATJ) foi estatisticamente semelhante em 2 5 e 10 anos ao comparar as técnicas cimentada e não cimentada (com e sem revestimento). Entretanto devido ao pequeno número de artigos existentes são necessários mais estudos clínicos sobre tais técnicas e com maior tempo de acompanhamento.

Palavras-chave

- artroplastia do joelho
- durapatita
- cimentos ósseos
- prognóstico

Introduction

The demand for arthroplasties is growing all over the world. Indication for these procedures is increasing, especially in younger subjects. Kurtz et al.[1] predicted that by 2030, 55% of total knee arthroplasties (TKA) will occur in patients younger than 65. In addition, the scientific community is searching for surgical methods and strategies to increase implant longevity and stability.

The ideal fixation method for TKA remains uncertain. Although bone cement is the most accepted and used method by knee surgeons, a growing number of studies show better, or equivalent outcomes compared with uncemented components.

Bercovy et al.[2] include the lack of toxicity at the bone-implant interface, reduced surgical time, and decrease risk of polyethylene wear as advantages of uncemented components. On the other hand, theoretically, uncemented fixation is more vulnerable because it allows more micromotion in the immediate postoperative period.

A hydroxyapatite coating around the porous surface of the component may improve uncemented TKA fixation. Freitas et al.[3] highlighted that thanks to its biocompatibility and bioactivity properties, hydroxyapatite has a notorious application in implant areas and bone grafts, increasing biological fixation and prosthetic stability.

The most investigated factor in TKA is tibial component migration since it directly influences prosthetic longevity, loosening rates, the need for revision, and, consequently, the clinical success of the procedure. Therefore, this meta-analysis of randomized clinical studies published in the last 10 years is an effective and necessary tool to determine the benefits or indifferences among the three available fixation methods. Previous similar papers did not group these fixation methods in a meta-analysis. Thus, this study aimed to quantitatively evaluate and compare the tibial component migration in cemented TKA, uncemented TKA with no coating, and uncemented TKA with hydroxyapatite coating.

Materials and Method

This meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA methodology).

Query Strategy

We performed a systematic search in the literature on the PubMed and MeSH databases from June to July 2022. An advanced search employed the Medical Subject Headings (MeSH) tool with the keywords "randomized controls trial" AND ("hydroxyapatite" OR "durapatite") AND ("knee arthroplasty" OR "Arthroplasty, Replacement, Knee"). In addition, a PubMed search used free terms not found in the Health Sciences Descriptors (DeCS) or MeSH: "knee cemented uncemented" OR "knee cemented uncemented rsa."

Eligibility Criteria

We retrieved randomized clinical trials published in the last 10 years analyzing tibial component migration through

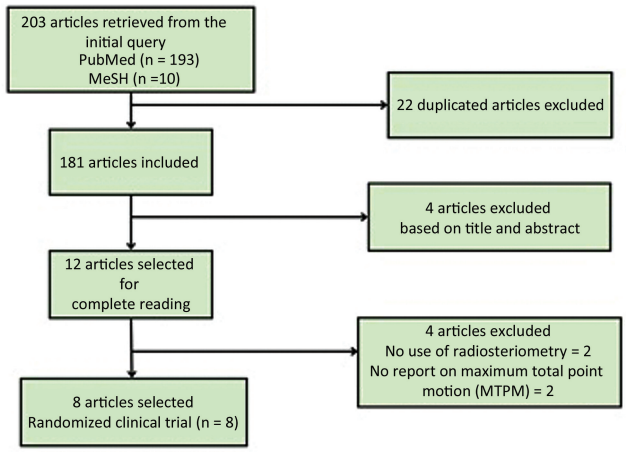

Fig. 1 Flowchart of articles identification and selection.

radiosteriometry in cemented, uncemented, and uncemented TKAs with hydroxyapatite coating over time. No language limitations were applied.

We excluded animal studies and papers analyzing revision prostheses or not incorporating the maximum total point motion (MTPM) in their results.

Article Selection

Papers were downloaded in the Mozilla Firefox browser. Two different authors individually selected the files. Discordances in paper selection were set in common agreement.

Statistical Analysis

After study selection and compilation of sample number, mean MPTM, and MPTM standard deviation (mm), we estimated the difference in weighted means with a 95% confidence interval (CI) between two exposures: cemented and uncemented TKA with no coating. We used the random effects model and tested the heterogeneity between studies per I^2 and the chi-square test.

We established three categories regarding the time after TKA: 2, 5, and 10 years.

One study[4] estimated the standard deviation based on the upper and lower limits of the confidence interval. The three other studies [5–7] calculated the standard deviation from the mean values reported in other publications (Cochrane Handbook).

We prepared a spreadsheet in Excel software and processed the data in R software version 4.1.2 with the Rstudio interface. We did forest plots for meta-analysis and funnel plots to evaluate publication bias (►**Fig. 1**).

Results

Eight randomized clinical trials met the eligibility criteria for this meta-analysis. Among them, six compared cemented TKA with uncoated uncemented TKA; one compared cemented TKA with uncemented TKA with hydroxyapatite coating, and another compared uncemented uncoated TKA with uncemented TKA with hydroxyapatite coating. All these studies comprised 668 knees (►**Table 1**).

Six studies in the meta-analysis compared cemented TKA and uncoated uncemented TKA techniques. The standardized mean difference was -1.20 (95% CI, -1.39 to -1.02) with the common model effect and -0.55 (95% CI, -1.26 to 0.17) with the random effect model. Although this result favored the cemented technique, there was no significant difference (►**Fig. 2**). The funnel plot (►**Fig. 3**) and I^2 estimate revealed high heterogeneity at 97% (p-value < 0.01).

Next, we analyzed mean MTPM values for each technique type and follow-up time. The cemented TKA presented higher mean MTPM (0.67 mm [95% CI, 0.52 to 0.87]) at 5 years of follow-up. On the other hand, the mean MTPM was lower in the 2-year follow-up (0.28 mm [95% CI, 0.10 to 0.79]). Despite the differences in mean MTPM, there was no statistical significance. In the 10-year follow-up, MTPM values were intermediate, with a mean of 0.41 mm (95% CI, 0.16 to 1.04) (►**Fig. 4**).

Mean MTPM in uncemented and uncoated TKAs was higher in the 10-year follow-up (1.30 mm [95% CI, 0.70 to 2.39]). The lowest mean occurred in the 2-year follow-up (0.70 mm [95% CI, 0.30 to 1.60). MPTM was intermediate in

Table 1 Characteristics of the included studies

Author	Samples	Technique	N	Follow-up (months)
Laend et al. (2019) [8]	222/138	CEM x UCWNC	360	12 e 24
Henricson & Nilsson (2016) [5]	21/26	CEM x UCWNC	47	3, 24 e 60
Henricson, Rõsmar, & Nilsson (2013) [11]	21/26	CEM x UCWNC	47	120
Pijls (2012) [6]	24/20	CEM x UCWNC	44	120
Wilson et al. (2012) [4]	18/27	CEM x UCWNC	45	6, 12, 24 e 60
Heesterbeek et al. (2016) [7]	16/17	CEM x UCWNC	33	24
van Hamersveld et al. (2017) [9]	30/30	CEM x UCWC	60	3, 12, 24 e 60
van Hamersveld et al. (2018) [10]	17/16	UCWNC x UCWC	33	12, 24 e 120
		Total	669	

Abbreviations: CEM, Cemented; UCWC, uncemented with coating; UCWNC, uncemented with no coating.

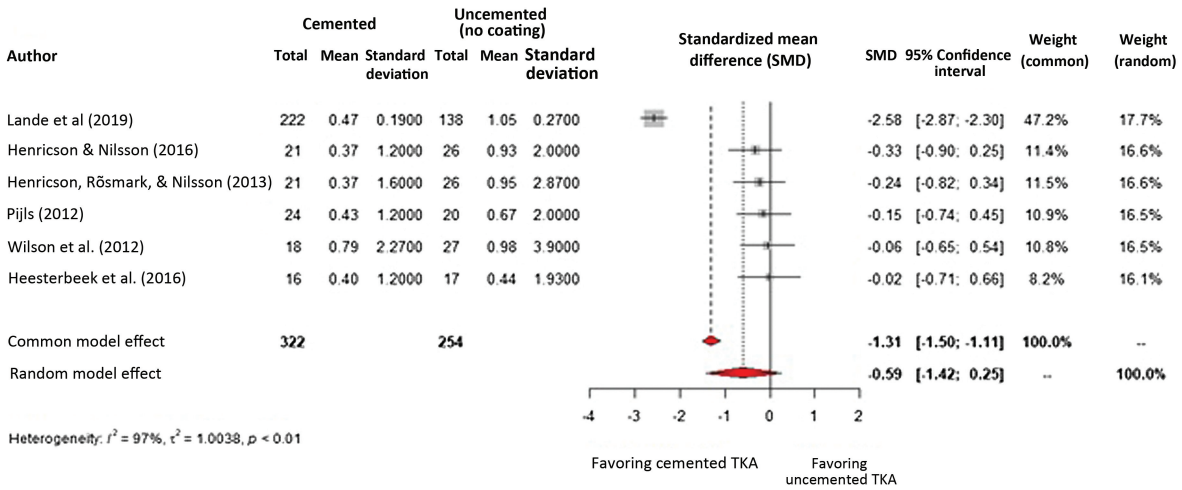

Fig. 2 Maximum total point motion (MTPM) forest plot comparing cemented total knee arthroplasty (TKA) and uncemented TKA with no coating.

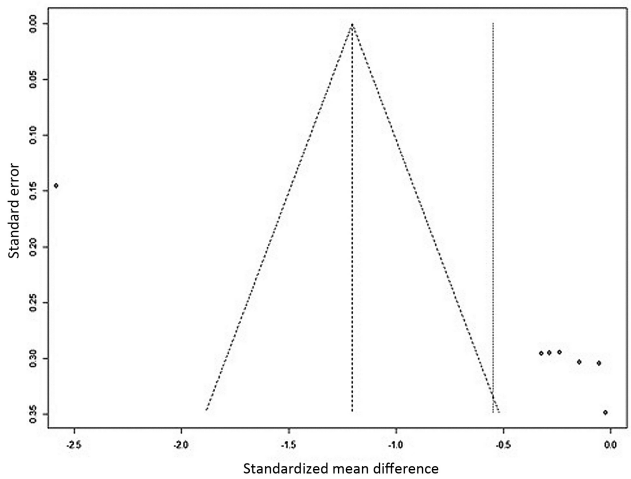

Fig. 3 Funnel plot with standard error and weighted mean difference in cemented total knee arthroplasty and uncemented total knee arthroplasty with no coating.

the 5-year follow-up, presenting a mean value of 0.96 mm. Despite the numerical differences in mean MTPM, there was no statistical significance (►**Fig. 5**).

►**Fig. 6** shows studies measuring MTPM in uncemented TKA with hydroxyapatite coating. The lowest mean value occurred at the 10-year follow-up (0.90 mm [95% CI, 0.69 to 1.18]), while the highest mean value occurred at the 5-year follow-up (1 mm [95% CI, 0.82 to 1.22]). Despite numerical differences in mean MTPM values, there was no statistical significance.

►**Fig. 6**: Forest plot of mean MTPM values of uncemented total knee arthroplasty with hydroxyapatite coating by time period in years.

Discussion

The primary objective of this study was to quantitatively evaluate and compare the tibial component migration in cemented TKA, uncemented TKA with no coating, and uncemented TKA with hydroxyapatite coating. The results favor cemented TKA (standardized mean difference, 0.65) over uncemented TKA. However, there is no significant difference (95% CI, -1.65 to 0.35), probably because of the high heterogeneity of the studies ($I^2 = 97\%$; $p < 0.01$). The study with the largest sample size and a 2-year follow-up reported significantly better results for cemented TKA.[8]

Only two studies by the same author analyzed uncemented TKA with hydroxyapatite coating.[9,10] Therefore, we cannot reach conclusive results comparing this technique with those using cemented TKA or uncemented TKA with no coating. In general, uncemented TKA with hydroxyapatite coating had the highest mean MTPM (0.94 mm), followed by uncoated TKA (0.81 mm) and cemented TKA (0.40 mm). However, van Hamersveld et al.[10] reported that the higher mean MTPM of uncemented TKA with hydroxyapatite coating results from the greater migration of coated components in the first postoperative weeks, which decreases after 3 months. Our study found a lower mean MTPM for uncemented TKA with hydroxyapatite coating (0.9 mm) compared with uncemented TKA with no coating (1.7 mm) in 10 years. Nevertheless, a single study analyzed TKAs with hydroxyapatite coating for 10 years. We did not include a study about TKA with coating in our meta-analysis because of the lack of absolute MTPM data; still, it reports a reduced tibial component migration with hydroxyapatite coating compared with the uncemented TKA and TKA with no coating.[6]

We analyzed the mean MTPM for each technique (cemented TKA, uncemented TKA with no coating, and uncemented TKA with hydroxyapatite coating) and each follow-up period. We observed a higher mean MTPM for cemented TKAs and uncemented TKAs with hydroxyapatite coating in the 5-year follow-up and uncemented TKAs with no coating in the 2-year follow-up. However, the difference in mean values was not statistically significant.

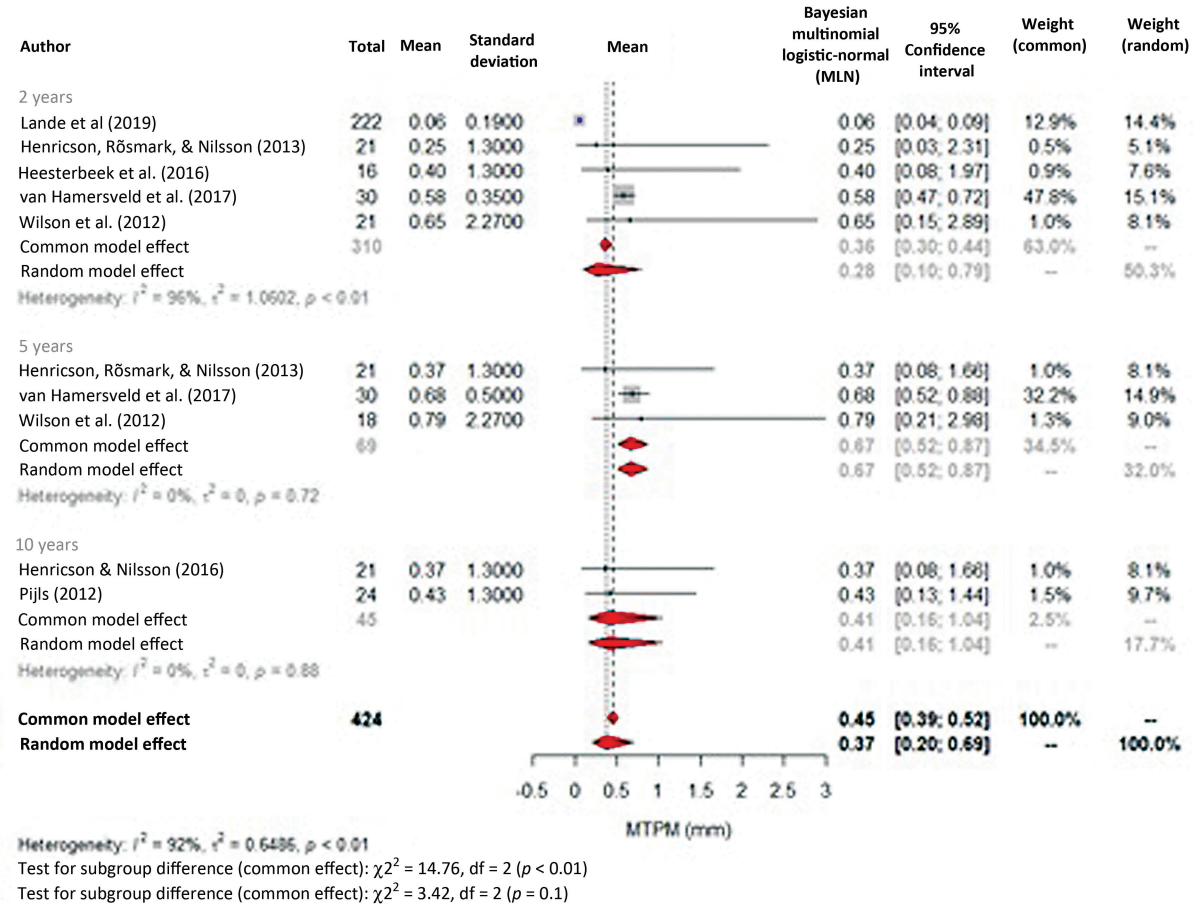

Fig. 4 Forest plot of mean maximum total point motion (MTPM) for cemented total knee arthroplasty by period and time in years.

The use of cemented or uncemented components with different designs in the study groups may interfere with migration. The retrieved studies were not homogeneous regarding designs for fixation. Laende et al.[8] analyzed eight different implant designs, including five uncemented devices. These authors reported less favorable migration outcomes for modular implants. Migration was significantly higher in 1 year and between 1 and 2 years, indicating that the modular implant design has a greater risk of poor long-term survival. The two studies from van Hamersveld et al.[9,10] used the Triathlon implant in its cemented and uncemented with hydroxyapatite coating versions. Henricson e Nilsson[5,11] used trabecular metal monoblock (TM) tibial components for uncemented TKAs and NextGen devices in cemented TKAs. These authors reported a good prognosis for uncemented TM components for 10 years, with stabilization from 3 months after the initial early migration. Wilson et al.[4] also used TM tibial components in uncemented TKAs and NextGen devices in cemented TKAs, reporting similar outcomes in a 5-year follow-up period.

Regarding the high heterogeneity of the studies, a potential explanation for the relative variability of outcomes from studies on TKA fixation is the variety of designs used and the lack of a method to blind the analyses. In addition, due to the scarcity of articles on the subject, there were no population demographic limits, which may influence our findings.

Orthopedists still prefer cemented TKAs. However, the demand for TKA is increasing, especially in younger subjects. Recent trials have shown that uncemented TKAs have longer survival and better functional results than cemented prostheses.[12,13] However, further prospective randomized studies are required to delineate any differences between these three fixation options. It is necessary to emphasize the need for a follow-up time greater than 10 years and an improved serialization within the first year of the study. Blinding would also add value to future studies, eliminating biases such as surgeon preferences and peculiarities of surgical techniques.

Conclusion

Tibial component migration in TKA was statistically similar at 2, 5, and 10 years when comparing cemented and uncemented techniques (with and without coating). However, the scarce literature requires further clinical studies on such techniques with longer follow-up periods.

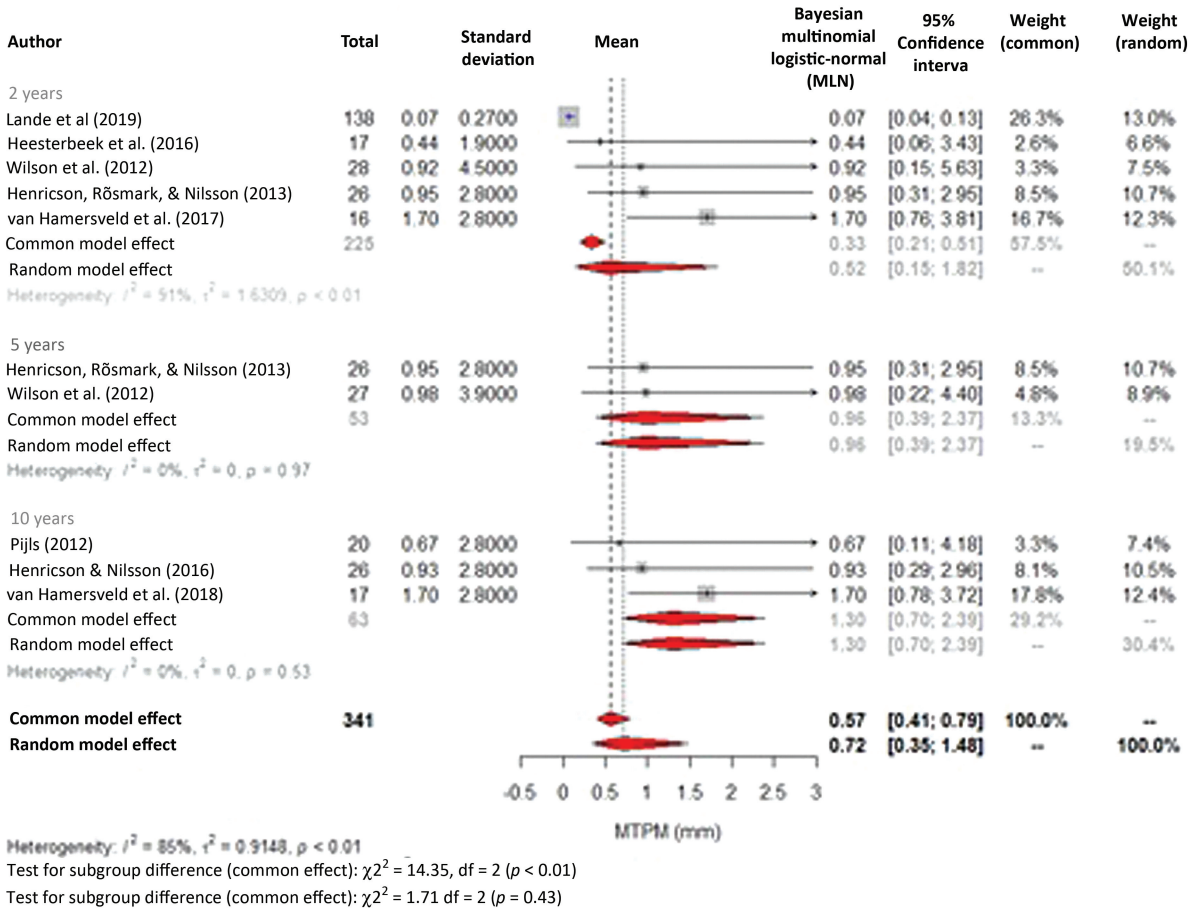

Fig. 5 Forest plot of mean maximum total point motion (MTPM) for uncemented total knee arthroplasty with no coating by period and time in years.

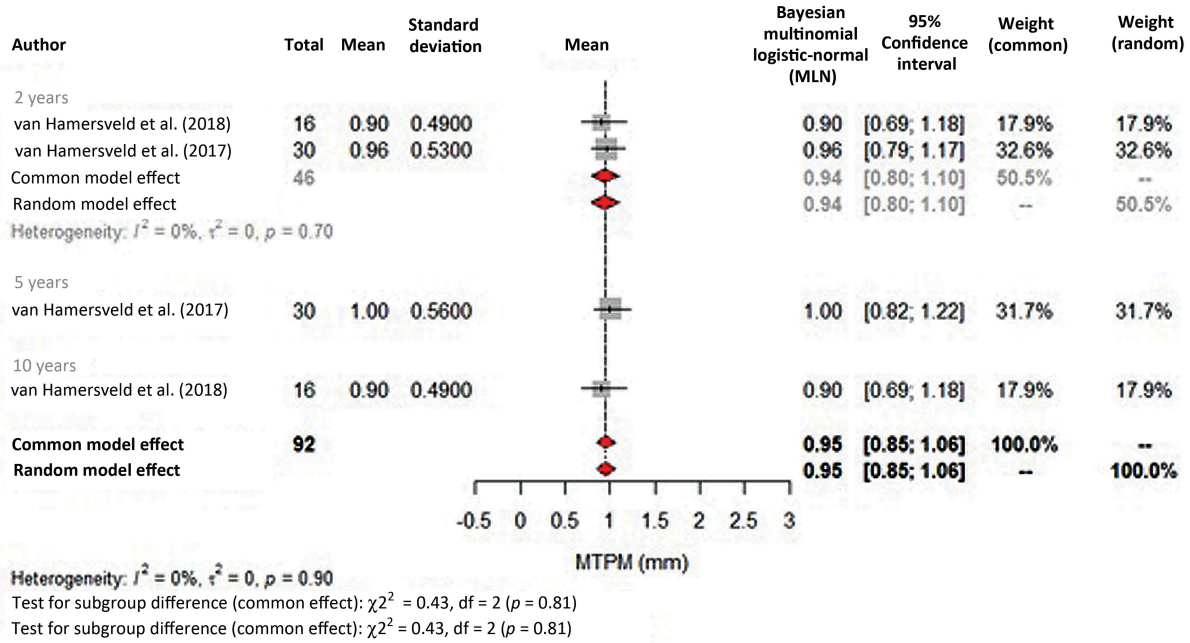

Fig. 6 Forest plot of mean maximum total point motion (MTPM) for uncemented total knee arthroplasty with hydroxyapatite coating by period and time in years.

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Conflict of Interests
The authors declare no conflict of interest.

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