J Korean Med Sci. 2022 Feb 14;37(6):e41
https://doi.org/10.3346/jkms.2022.37.e41
eISSN 1598-6357·pISSN 1011-8934

JKMS

Original Article

Musculoskeletal Disorders, Rehabilitation & Sports Medicine

Do Cementless Short Tapered Stems Reduce the Incidence of Thigh Pain After Hip Arthroplasty? Systematic Review and Meta-Analysis

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OPEN ACCESS

Received: Nov 9, 2021
Accepted: Dec 21, 2021
Published online: Jan 27, 2022

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Trial Registration
PROSPERO Identifier: CRD42021231240

ABSTRACT

Background: The purpose of this study was to determine whether short tapered stems reduce the rate of thigh pain through a systematic review and meta-analysis of comparative studies between short tapered stems and standard-length tapered stems.
Methods: We conducted a meta-analysis of comparative studies: 1) retrospective studies and 2) randomized controlled trials (RCTs), on 2 stem designs: short tapered stem versus standard-length tapered stem. Studies were selected by means of the following criteria: 1) study design: retrospective comparative studies, prospective comparative studies, RCTs; 2) study population: patients with total hip arthroplasty or hemiarthroplasty for hip disease or hip fracture; 3) intervention: short tapered stem and standard tapered stem; and 4) outcomes; thigh pain, other clinical results.
Results: Among the 250 articles that were identified at the initial search, 6 studies, 4 RCTs and 2 retrospective comparative studies, were included in this meta-analysis. In the analysis of retrospective studies, the short tapered stem reduced the risk of thigh pain compared to the standard tapered stem (risk ratio [RR] = 0.13; 95% confidence interval [CI], 0.02–0.09; Z = −2.07; P = 0.039). However, in the analysis of RCTs, the incidence of thigh pain was similar between the two stem designs (RR = 1.21; 95% CI, 0.76–1.93; Z = 0.82; P = 0.410). Overall meta-analysis including all studies showed that the short tapered stem did not reduce the incidence of thigh pain compared to the standard-length tapered stem (RR = 0.91; 95% CI, 0.59–1.40; Z = −0.44, P = 0.663).
Conclusions: We did not find a significant difference in the incidence of thigh pain between short tapered stem and standard tapered stem in hip arthroplasty.

Trial Registration: PROSPERO Identifier: CRD42021231240

Keywords: Hip Arthroplasty; Short Tapered Stem; Standard Tapered Stem; Thigh Pain

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Disclosure
The authors have no potential conflicts of interest to disclose.

Author Contributions
Conceptualization: Ha YC. Data curation: Cha Y. Formal analysis: Yoo JI. Investigation: Yoo JI. Methodology: Ha YC, Cha Y. Validation: Lee YK. Writing - original draft: Ha YC, Cha Y. Writing - review & editing: Koo KH.

INTRODUCTION

Total hip arthroplasty (THA) is an effective and favored surgery procedure to treat advanced degenerative arthritis in the hip joint.[1] As the aging population increases, the frequency of performing THA for hip arthritis and hip fracture is increasing.[2-4] Also, the frequency of THA at a young age is increasing due to the increase in steroid-induced osteonecrosis of femoral head.[5,6] Therefore, securing the longevity of THA and decreasing postoperative complications rate are important issues in hip arthroplasty.

Cementless THA has been popularized worldwide.[7-9] However, postoperative bone loss of the proximal femur and thigh pain remain matters of concern of cementless THA.[10,11] Thigh pain is an annoying problem to patients, which compromises their activity and satisfaction. Theoretically, a more physiologic load transfer to the proximal metaphysis of the femur can be obtained by shortening the stem length.[12] With an expectation to reduce the stress shielding and the thigh pain, various short stem designs with different shape, length and taper angle, have been introduced over the last two decades and are currently in use.[8,13-15]

In the literature, short stems provided excellent clinical and radiological results.[8,13,15,16] However, the incidence of thigh pain after the use of short stems widely varied from 1% to 24%,[11,17,18] and there is a serious debate as to whether these short stems really reduce the incidence of thigh pain.[19,20] While earlier studies reported that the use of short stems reduced the thigh pain incidence compared to standard-length stems,[21,22] a recent study showed no significant difference between the two stem designs.[11]

Khanuja et al.[23] classified short stem designs into 4 categories: 1) femoral neck only, 2) calcar loading, 3) calcar loading with lateral flare and 4) short tapered. In North America, the most favored short stem design is type 4 short tapered stem, which is shorter than their counterpart standard length stem by 30 to 35 mm.[11,24] There is a paucity of studies comparing the thigh pain incidence of type 1, 2, 3 short stems with standard length stems.

Therefore, we conducted a systematic review and meta-analysis to determine whether short tapered stems reduce the incidence of thigh pain compared to the standard-length tapered stems.

METHODS

The current review and meta-analysis were done according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[25] This protocol has been registered in the International Prospective Register of Systematic Reviews (PROSPERO Number CRD42021231240).

Study eligibility criteria

Studies were selected by means of the following criteria:

(1) Study design: retrospective comparative studies, prospective comparative studies, randomized controlled trials (RCT)s;

(2) Study population: patients with total hip arthroplasty or hemiarthroplasty for hip diseases or hip fractures;

(3) Intervention: hip arthroplasty using type 4 short tapered stems according to the classification by Loppini et al.[8] and Khanuja et al.[23] and standard tapered stem;

(4) Outcomes: postoperative thigh pain, demographic factors, and other clinical results.

(5) Studies were excluded if they 1) did not meet the above criteria or 2) were posters, letters, or review articles.

Search methods for identification of studies

We used PubMed Central, OVID MEDLINE, Cochrane Collaboration Library, and Embase for a comprehensive search for all relevant studies, up to January 2021. We used the following search terms: ("short" [All Fields] OR "shorts" [All Fields]) AND ("stems" [All Fields] OR "stem" [All Fields]) AND ("conventional" [All Fields] OR "conventionals" [All Fields]) AND ("arthroplasty" [MeSH Terms] OR "arthroplasty" [All Fields] OR "arthroplasties" [All Fields]) AND ("hip" [MeSH Terms] OR "hip" [All Fields]) (**Supplementary Table 1**). We also did a manual search of possibly related references. Two of us reviewed the titles, abstracts, and full texts of all potentially relevant studies independently, as recommended by the Cochrane Collaboration.[26] Any disagreement was resolved by the third reviewer. We performed full-text review of screened studies according to the predefined inclusion/exclusion criteria, and then selected eligible articles. The reviewers were not blinded to authors or institutions of the studies.

Data extraction

The data that were extracted from the articles included: authors, date of publication, design of the study, demographic features (number of hips, age, sex), postoperative follow-up period, specific interventions (hip arthroplasty with short tapered stem versus standard tapered stem), definition and incidence of thigh pain.

Data analysis

For dichotomous results, we calculated the risk ratio (RR) and the confidence interval (CI) of 95%. The heterogeneities of the studies were tested using Higgins I^2 statistics and the χ^2 test.[27] When P value was < 0.10 and I^2 was > 50%, the studies were considered heterogeneous. Otherwise, the studies were considered not to have definite heterogeneity. When there was little evidence of heterogeneity, the risk of thigh pain was assessed using fixed-effects models. Otherwise, random-effects models were used.[28,29] Sensitivity analysis was conducted by omitting a single study each time and building data from the remaining studies to explore possible high heterogeneity and to assess the outcome stability.

We used subgroup meta-analysis on comparative studies or RCTs between short tapered stem and standard tapered stem. The trim and fill method was used for estimating and adjusting for the number and outcomes of missing studies in the meta-analysis.[30] Statistical analysis was done using R software 3.02 (R Foundation for Statistical Computing, Vienna, Austria) and the meaning was set to $P < 0.05$.

Methodological quality assessment

Two authors independently evaluated the risk of bias. In RCTs, biases of 5 elements: selection, performance, detection, attrition, and reporting were assessed using the Cochrane Risk-of-Bias Tool and crossover design according to the Cochrane Handbook.[31] For assessing of non-RCT studies, the risk of bias was assessed using Joanna Briggs Institution (JBI) critical-appraisal checklist adapted for case control.[32] Studies were considered as low risk when the quality assessment of the checklist criteria was 50% or above. A trim-and-fill plot was used for the estimation and adjustment of publication bias.[30]

RESULTS

Search results

Among the 250 articles, which were identified at the initial search, 200 duplicates were excluded. By the screening process, 24 references: no comparative studies (n = 16), review articles or comments (n = 6), article written in language other than English (n = 1), unrelated subject (n = 1), were excluded. The remaining 26 studies underwent full-text review, and we excluded 20 studies: 11 studies, which did not evaluate thigh pain, and 9 studies, which involved short stems other than type 4 short tapered stem.[23] Finally, 6 studies: 4 RCTs and 2 retrospective comparative studies were included in this meta-analysis (**Fig. 1**, **Tables 1** and **2**).[10,11,21,22,33,34]

Comparison of the incidence of thigh pain between short stem and standard-length stem

The 6 articles analyzed the incidence of thigh pain in 594 hips of 524 patients (282 hips with short tapered stems and 312 hips with standard tapered stems) (**Table 1**).

Overall incidence of thigh pain in all studies

There was little evidence of heterogeneity across the studies (I^2 = 44%; P = 0.150) and the fixed-effects model was used for the comparison. There was no significant diffenrece in the

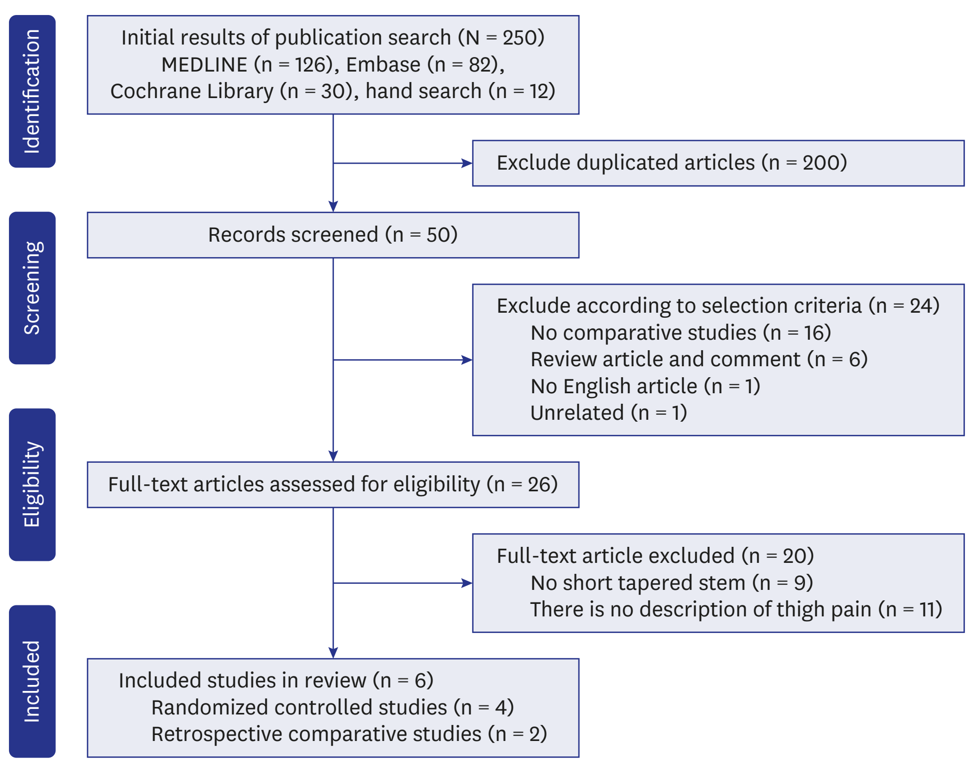

Fig. 1. PRISMA flow diagram outlining the clinical study selection process.
PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Table 1. Characteristics of the included studies

Studies	Year of publication	Study type	Type of hip arthroplasty	Metaphyseal short stem (company)	Standard length stem (company)	Surgical approach	Mean follow-up or minimum follow-up of MS/SL	No. of hips (MS/SL)	Mean age of MS/SL, yr	Risk of bias[a]
Del Piccolo et al. [21]	2016	Retrospective comparative study	Total hip arthroplasty	SMF (Smith & Nephew)	Apta (Adler)	Anterolateral or anterior	54.1/52.7 months	24/66	38.7/39.5	Low risk
Yu et al. [22]	2016	Retrospective comparative study	Total hip arthroplasty	Tri-lock (Depuy)	Corail (Depuy)	Posterolateral	40/42 months	55/58	74/74	Low risk
Won et al. [11]	2020	Randomized controlled study	Total hip arthroplasty	TaperLoc Microplasty (Zimmer Biomet)	TaperLoc (Zimmer Biomet)	Posterolateral	Minimum 5 years	56/44	50/45	Low risk
Hirao et al. [33]	2020	Randomized controlled study	Total hip arthroplasty	Taperloc Microplasty stem (Zimmer Biomet)	Taperloc (Zimmer Biomet)	Direct anterior or anterolateral	Minimum 5 years	29 (1-stage bilateral)	58.3	Low risk
Lim et al. [10]	2020	Randomized controlled study	Hemiarthro-plasty	Bencox M (Corentec)	Bencox ID (Corentec)	Posterolateral	24.8/26.7 months	77/74	81.2/80.8	Low risk
Koyano et al. [34]	2017	Randomized controlled study	Total hip arthroplasty	CentPillar GBHA (Stryker)	Super Secur-Fit HA (Stryker)	Posterolateral	9.2 years	41 (1-stage bilateral)	51.7	Low risk

MS = metaphyseal short stem, SL = standard length stem.
[a]Risk of bias; For assessing the risk of bias in the randomized clinical trial study using the Cochrane Risk-of-Bias Tool and the randomized clinical trial study using the Joanna Briggs Institution (JBI) critical appraisal checklist adapted for case–control.

Table 2. Definition of thigh pain in included studies

Studies	Definition of thigh pain	Type of stem	No. of thigh pain (%)
Del Piccolo et al. [21]	There is no comment for definition of thigh pain.	Short	0
		Standard	6 (9.1%)
Yu et al. [22]	Thigh pain was defined as pain in the anterior thigh below the inguinal area.	Short	0
		Standard	6 (8%)
Won et al. [11]	A diagnosis of thigh pain was made according to the definition of Barrack et al.: pain on the anterior and/or lateral thigh below the inguinal area.	Short	9 (16.1%)
		Standard	6 (13.6%)
Hirao et al. [33]	Any postoperative pain in the anterior thigh.	Short	0
		Standard	0
Lim et al. [10]	Thigh pain was defined as pain perception in the anterior thigh below the inguinal area.	Short	23 (29.9%)
		Standard	18 (24.3%)
Koyano et al. [34]	Any postoperative pain in the anterior thigh.	Short	0
		Standard	0

risk of thigh pain between the short tapered stem group and the standard tapered stem group (RR = 0.91; 95% CI, 0.59–1.40; Z = −0.44; P = 0.663) (**Fig. 2**).

Sensitivity analyses according to the study design

(1) Incidence of thigh pain in RCTs

Four RCTs evaluated the incidence of thigh pain in a total of 391 hips: 203 hips with short

Studies	Events	Total	Events	Total	RR	RR	95% CI	Weight (fixed)	Weight (random)
Del Piccolo et al. [21]	0	24	6	66		0.21	(0.01–3.57)	10.1%	7.7%
Yu et al. [22]	0	55	6	58		0.08	(0.00–1.41)	18.1%	7.6%
Won et al. [11]	9	56	6	44		1.18	(0.45–3.06)	19.2%	34.6%
Hirao et al. [33]	0	29	0	29				0.0%	0.0%
Lim et al. [10]	23	77	18	74		1.23	(0.72–2.08)	52.5%	50.2%
Koyano et al. [34]	0	41	0	41				0.0%	0.0%
Fixed effect model		**282**		**312**		**0.91**	**(0.59–1.40)**	**100.0%**	
Random effects model						**0.86**	**(0.37–1.99)**		**100.0%**

Heterogeneity: I^2 = 44%, τ^2 = 0.2930, P = 0.150

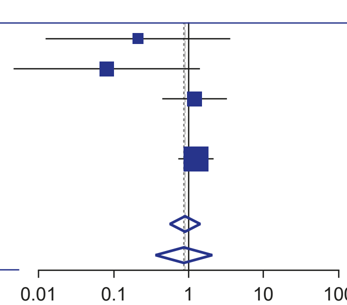

Fig. 2. A forest plot of a comparative meta-analysis between short tapered stem and standard tapered stem in all studies.
RR = risk ratio, CI = confidence interval.

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tapered stems and 188 hips with standard tapered stems.[10,11,33,34] There was little evidence of heterogeneity across the studies (I^2 = 0%; P = 0.940) and the fixed-effects model was used. There was not significant difference in the risk of thigh pain between the two groups (RR = 1.21; 95% CI, 0.76–1.93; Z = 0.82; P = 0.410) (**Fig. 3**).

(2) Incidence of thigh pain in retrospective studies

Two retrospective reviews evaluated the incidence of thigh pain in a total of 307 hips: 79 hips with short tapered stems and 124 hips with standard tapered stems.[21,22,35] There was little evidence of heterogeneity across the studies (I^2 = 0%, P = 0.640) and the fixed-effects model was used. The risk of thigh pain development was significantly lower in the short tapered stem group than in the standard tapered stem group (RR = 0.13; 95% CI, 0.02–0.09; Z = −2.07; P = 0.039) (**Fig. 4**).

Risk bias of included studies

In the quality assessment, risk bias was negligible in all the 6 studies.

DISCUSSION

Main findings of this meta-analysis are: 1) in the overall analysis, the short tapered stem did not reduce the incidence of thigh pain, 2) in the subgroup analysis of the retrospective studies, the short tapered stem reduced the risk of thigh pain compared to the standard-length tapered stem, and 3) in the subgroup analysis of RCTs, there was no difference in the risk of thigh pain between the two stem designs.

Currently, cementless stems are in wide use due to excellent long-term results.[7,8] Nevertheless, stress-shielding and thigh pain are remaining concerns of cementless stems.[10,11] Thigh pain is a source of dissatisfaction of the patient and sometimes it is persistent and disabling. The

Studies	Short tapered stem		Standard tapered stem		RR	95% CI	Weight (fixed)	Weight (random)
	Events	Total	Events	Total				
Won et al. [11]	9	56	6	44	1.18	(0.45–3.06)	26.8%	23.4%
Hirao et al. [33]	0	29	0	29			0.0%	0.0%
Lim et al. [10]	23	77	18	74	1.23	(0.72–2.08)	73.2%	76.6%
Koyano et al. [34]	0	41	0	41			0.0%	0.0%
Fixed effect model		**203**		**188**	**1.21**	**(0.76–1.93)**	**100.0%**	
Random effects model					**1.22**	**(0.77–1.93)**		**100.0%**

Heterogeneity: I^2 = 0%, τ^2 = 0.0, P = 0.940

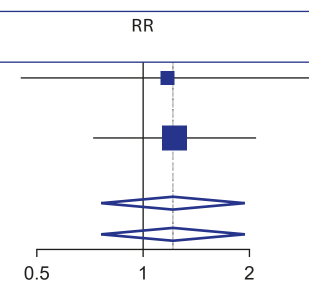

Fig. 3. A forest plot of a comparative meta-analysis between short tapered stem and standard tapered stem in randomized controlled studies.
RR = risk ratio, CI = confidence interval.

Studies	Short tapered stem		Standard tapered stem		RR	95% CI	Weight (fixed)	Weight (random)
	Events	Total	Events	Total				
Del Piccolo et al. [21]	0	24	6	66	0.21	(0.01–3.57)	35.8%	50.2%
Yu et al. [22]	0	55	6	58	0.08	(0.00–1.41)	64.2%	49.8%
Fixed effect model		**79**		**124**	**0.13**	**(0.02–0.90)**	**100.0%**	
Random effects model					**0.13**	**(0.02–0.98)**		**100.0%**

Heterogeneity: I^2 = 0%, τ^2 = 0.0, P = 0.640

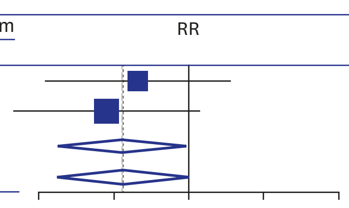

Fig. 4. A forest plot of a comparative meta-analysis between short tapered stem and standard tapered stem in retrospective studeis.
RR = risk ratio, CI = confidence interval.

etiology of thigh pain after cementless hip arthroplasty is unrevealed, yet, but it seems to be multifactorial. Bone-prosthesis micromotion, stress concentration at the tip of the stem, periosteal irritation, or a mismatch of Young's modulus of elasticity between the prosthetic stem and the femur have been suggested as possible causes.[36,37]

Short cementless stems provide more physiologic loading to the proximal femur than conventional stems and have been expected to preserve bone stock of the proximal femur and reduce the rate of thigh pain.[13] However, we found no substantial difference between short- and standard tapered stem designs in the rate of thigh pain.

One interesting finding of our review is that the short stems had a lower incidence of thigh pain compared to the standard length stem in retrospective studies, but the risk was not different between the two stem designs in RTCs. The difference could be explained by two reasons. First, the differences in the structural rigidity of various stem designs might have affected the incidence of thigh pain. Stress transfer from stem to femur might be a cause of pain based on the concept of a mismatch in structural rigidity between stem and femoral bone.[36] The structural rigidity of stem is determined by its geometry, size, and implant material (modulus of elasticity).[36] The stress at the stem tip-anterior femoral cortex interface was higher in cobalt-chromium stems than in the titanium alloy stems.[14] Thus, the titanium alloy stems had a lower incidence of thigh pain compared to the cobalt-chromium stems.[38] It is ideal to compare two stem designs with identical proximal geometry but different lengths for the detection of difference in the thigh pain incidence according to the stem length.[19,20] The stems compared in retrospective studies were from different manufacturers and had various shapes. However, in RTCs, the manufacturer was the same in each study and compared stem designs had similar proximal geometries. Second, reporting bias in the data collection of thigh pain might have affected the evaluation of thigh pain. In retrospective studies, there was no description on the definition of thigh pain.[21,33] In addition, it is possible that these retrospective studies lacked in the differentiation of thigh pains due to other etiologies. However, in RTCs, the diagnostic criteria of thigh pain were pre-defined and the development of thigh pain was prospectively assessed in serial follow-up evaluations.

There are several limitations in our study. First, the diagnostic criteria of thigh pain might be different in each study. Radiating pain on lateral thigh due to spinal problems might have been counted as stem-related thigh pain. There is no unified definition or diagnostic criteria of thigh pain, yet. Brown et al.[36] defined thigh pain as the pain that occurs in well-fixed femoral components after primary cementless hip arthroplasty, and pains due to other origins should be differentiated.[20] Second, bone quality of the proximal femur was not counted. Engh et al.[37] reported that the incidence of thigh pain was higher in patients with poor bone quality than in those with good bone quality. Moreland and Bernstein[39] also reported that patients with preoperative osteopenia had high incidence of thigh pain and argued that it was caused by the difference of elastic modulus between stem and proximal femur. On the other hand, Burkart et al.[38] and Bourne et al.[40] reported that Dorr's femoral morphology was not associated with thigh pain.[14] Third, patient factors were not adjusted. Several studies have reported an association between thigh pain and age. Amendola et al.[17] and Nam et al.[41] reported that younger patients experienced thigh pain more frequently than older patients, because young patients had high activity and more demand after hip arthroplasty. However, we included only comparative studies, and the mean ages between the two stem design groups were similar or same in the involved studies. Thus, we thought the

https://doi.org/10.3346/jkms.2022.37.e41

effect of patient factor was negligible. Fourth, we analyzed only type 4 short-tapered stems and our results might not be generalized to other short stem designs.

In conclusion, we found no substantial difference in the incidence of thigh pain between short tapered stem and standard-length tapered stem in hip arthroplasty. The design of cementless stems should be more developed to reduce this annoying complication.

ACKNOWLEDGMENTS

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this study by any of the authors.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Detailed search strategies for each database

Click here to view

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