Systematic Review and Meta-Analysis

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Survival of total knee arthroplasty after high tibial osteotomy versus primary total knee arthroplasty

A meta-analysis

Seung-Suk Seo, MD, PhD[a], Kyung-Wook Nha, MD, PhD[b], Tae-Yeong Kim, MD[c], Young-Soo Shin, MD, PhD[c,*]

Abstract

Background: Theoretical considerations suggest that total knee arthroplasty (TKA) is technically more challenging after high tibial osteotomy (HTO), resulting in inferior results compared to primary TKA. However, several studies on this issue have shown contradictory results. The purpose of this meta-analysis to compare survivorship and clinical outcomes between TKA with and without previous HTO.

Methods: We reviewed studies that evaluated pain and function scores, range of motion (ROM), operation time, Insall-Salvati (IS) ratio, complications, and survival rates in patients treated with TKA with previous HTO or with primary TKA with short- to midterm (<10 years) or long-term (>10 years) follow-up.

Results: Fifteen studies were included in the meta-analysis. There were no significant differences between TKA with and without previous HTO in pain score (95% CI: −0.27 to 0.29; $P=.94$), function score (95% CI: −0.08 to 0.24; $P=.32$), operation time (95% CI: −5.43 to 26.85; $P=.19$), IS ratio (95% CI: −0.03 to 0.08; $P=.40$), complication rates (TKA with previous HTO, 62/1717; primary TKA, 610/31386; OR 1.31, 95% CI: 0.97–1.77; $P=.08$), and short- to midterm survival rates (TKA with previous HTO, 1860/2009; primary TKA, 37848/38765; OR 0.55, 95% CI: 0.28–1.10; $P=.09$). Conversely, ROM (95% CI: −7.40 to −1.26; $P=.006$) and long-term survival rates (TKA with previous HTO, 1426/1523; primary TKA, 29810/31201; OR 0.71, 95% CI: 0.57–0.89; $P=.003$) were significantly different between the two groups. In addition, both groups had substantial proportions of knees exhibiting short- to midterm survivorship (92.6% by TKA with previous HTO and 97.6% by primary TKA) and long-term survivorship (93.6% by TKA with previous HTO and 95.5% by primary TKA).

Conclusions: This meta-analysis suggests that a previous HTO affected ROM or survival of TKA in the long-term even though both groups have equivalent clinical outcomes and complications. Thus, orthopedic surgeons should offer useful information regarding the advantages and disadvantages of both procedures to patients, and should provide advice on the generally higher risk of revision after TKA with previous HTO at long-term follow-up when counseling patients.

Abbreviations: CI = confidence interval, HTO = high tibial osteotomy, IS = Insall-Salvati, OR = odds ratio, ROM = range of motion, TKA = total knee arthroplasty.

Keywords: high tibial osteotomy, meta-analysis, survivorship, total knee arthroplasty

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[a] Department of Orthopedic Surgery, Haeundae Bumin Hospital, Busan, [b] Department of Orthopaedic Surgery, Inje University, Ilsan Paik Hospital, Goyang, [c] Department of Orthopedic Surgery, Hallym University School of Medicine, Chuncheon, Republic of Korea.

[*] Correspondence: Young-Soo Shin, Department of Orthopedic Surgery, Chuncheon Sacred Heart Hospital, Hallym University School of Medicine, Chuncheon, 77 Sakju-ro, Chuncheon-si, Gangwon-do, Republic of Korea (24253) (e-mail: sysoo3180@naver.com).

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1. Introduction

High tibial osteotomy (HTO) is appropriate for the treatment of medial knee osteoarthritis (OA) with varus deformity in relatively young, active patients who need excellent pain relief and functional improvement.[1–3] However, arthritic deterioration in patients with HTO may progress on longer follow-up, leading to conversion to total knee arthroplasty (TKA) and an overall failure rate of 24% at 10 years.[4,5] In general, TKA with previous HTO is technically more challenging with exposure and also in relation to bone stock loss and altered joint line, which can lead to inferior results including instability, limb malalignment, and patellar maltracking.[6] Nevertheless, previous studies have reported conflicting results regarding the outcome of TKA with previous HTO compared with primary TKA due to different indications for HTO, different degrees of correction on coronal and sagittal planes, and variable patient populations. Some studies have described poorer results and a larger number of complications,[7–9] whereas others have shown minimal or no difference.[10–12] In addition, there is no general consensus on the approximate longevity of survivorship from midterm to long-term follow-up between these two methods.[9,10,13] To our knowledge, no specific meta-analysis to date has quantified survivorship and clinical outcomes between these two methods including data from a national joint registry. This useful information on quantified survival rates may help orthopedic surgeons and patients reduce concerns about procedure survival and clinical improvement between TKA with and without previous HTO.

Therefore, this meta-analysis was designed to compare survivorship and clinical outcomes between TKA with and without previous HTO. We hypothesized that clinical outcomes would be similar between TKA with and without previous HTO, but that survival rates would be different between TKA with and without previous HTO, and that the survival rate of primary TKA would be higher than that of TKA with previous HTO at long-term follow-up.

2. Materials and methods

2.1. Data and literature sources

Although the present study involved human participants, ethical approval or informed consent from the participants was not required because all the data were based on previously published studies and analyzed anonymously without any potential harm to the participants.

Multiple comprehensive databases, including MEDLINE (January 1, 1976 to June 30, 2018), EMBASE (January 1, 1985 to June 30, 2018), and the Cochrane Library (January 1, 1987 to June 30, 2018), were searched for studies that compared pain and function scores, range of motion (ROM), operation time, Insall-Salvati (IS) ratio, complications, and survival rates in patients treated with TKA with previous HTO or primary TKA with short- to midterm (<10 years) or long-term (>10 years) follow-up. There were no restrictions on language. Search terms used in the title, abstract, MeSH, and keywords fields were ('knee' [MeSH] OR 'tibia' [MeSH] OR 'osteotomy' [MeSH]) AND 'total knee arthroplasty' [tiab] OR 'total joint replacement' [tiab] OR 'high tibial osteotomy' [tiab] OR 'proximal tibial osteotomy' [tiab] OR 'opening wedge' [tiab] OR 'closing wedge' [tiab] OR 'HTO' [tiab] OR 'TKA' [tiab] OR 'knee' [tiab]). Following the initial online search, relevant articles and their bibliographies were manually reviewed.

2.2. Study selection

Studies were included in the meta-analysis if they

1. assessed human knees that had undergone TKA with and without previous HTO;
2. had an evidence level of 1 (high quality randomized trial or prospective study) or 2 (lesser quality randomized controlled trial or prospective comparative study) or 3 (case control study or retrospective comparative study);
3. reported retrospective or prospective comparisons of surgical outcomes between groups with either TKA with previous HTO or primary TKA in studies published after 2000, in order to avoid out-of-date prostheses models;
4. included basic data on at least one of the following seven parameters: postoperative pain and function scores, ROM, operation time, IS ratio, complications, and survival rates;
5. reported the number of subjects in each group (TKA with previous HTO and primary TKA) and the means and standard deviations for the seven parameters, and
6. used adequate statistical methods to compare parameters between groups.

Postoperative scores on knee outcome scales included the Western Ontario McMaster Universities Arthritis Index (WOMAC), American Knee Society Score (AKSS), Knee Society Score (KSS), Oxford Knee Score (OKS), and Hospital for Special Surgery (HSS). A postoperative complication was defined as an adverse treatment event recorded by the author of the study. Studies were excluded if they

1. included missing or inadequate outcome data, such as standard deviation or range of values;
2. included case series, expert opinions, reviews, commentaries, or editorials;
3. included abstract only;
4. included animal in vivo and human in vitro.

2.3. Data extraction

Two reviewers independently recorded data from each study using a predefined data extraction form and resolved any differences by discussion. Recorded variables included those associated with surgical outcomes such as postoperative pain, functional outcome, ROM, operation time, IS ratio, complications, and survival rates for patients with either TKA with previous HTO or primary TKA. Sample size and the means and standard deviations of surgical outcomes in each group were also recorded. If these variables were not included in the articles, the standardized mean difference was calculated from the *P*-value and sample size.

2.4. Methodological quality assessment

Two reviewers independently assessed the methodological quality of the studies. For the Newcastle-Ottawa Scale, as recommended by the Cochrane Non-Randomized Studies Methods Working Group, we assessed studies based on three criteria—selection of the study groups, comparability of the groups, and ascertainment of either the exposure or the outcome of interest for case-control and cohort studies. Studies of high quality were defined as those with scores higher than 6 points. Two reviewers resolved all differences by discussion, and their decisions were subsequently reviewed by a third investigator.

2.5. Statistical analysis

The main outcomes of the meta-analysis were the proportion of cases that developed complications, survival rates, and the weighted mean difference (WMD) in ROM, operation time, and IS ratio. However, standardized mean difference (SMD) was calculated for overall functional outcome and postoperative pain as several different measurement tools, including WOMAC, AKSS, KSS, OKS, and HSS, were used for the same outcome. For all comparisons, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for binary outcomes, while SMDs or WMDs and 95% CIs were calculated for continuous outcomes depending on the similarity of the used scales. Heterogeneity was determined by estimating the proportion of between-study inconsistencies due to actual differences between studies, rather than differences due to random error or chance. A $I^2 < 40\%$ indicated that there was no significant heterogeneity, so a fixed effect model was used to calculate the pooled effect size.

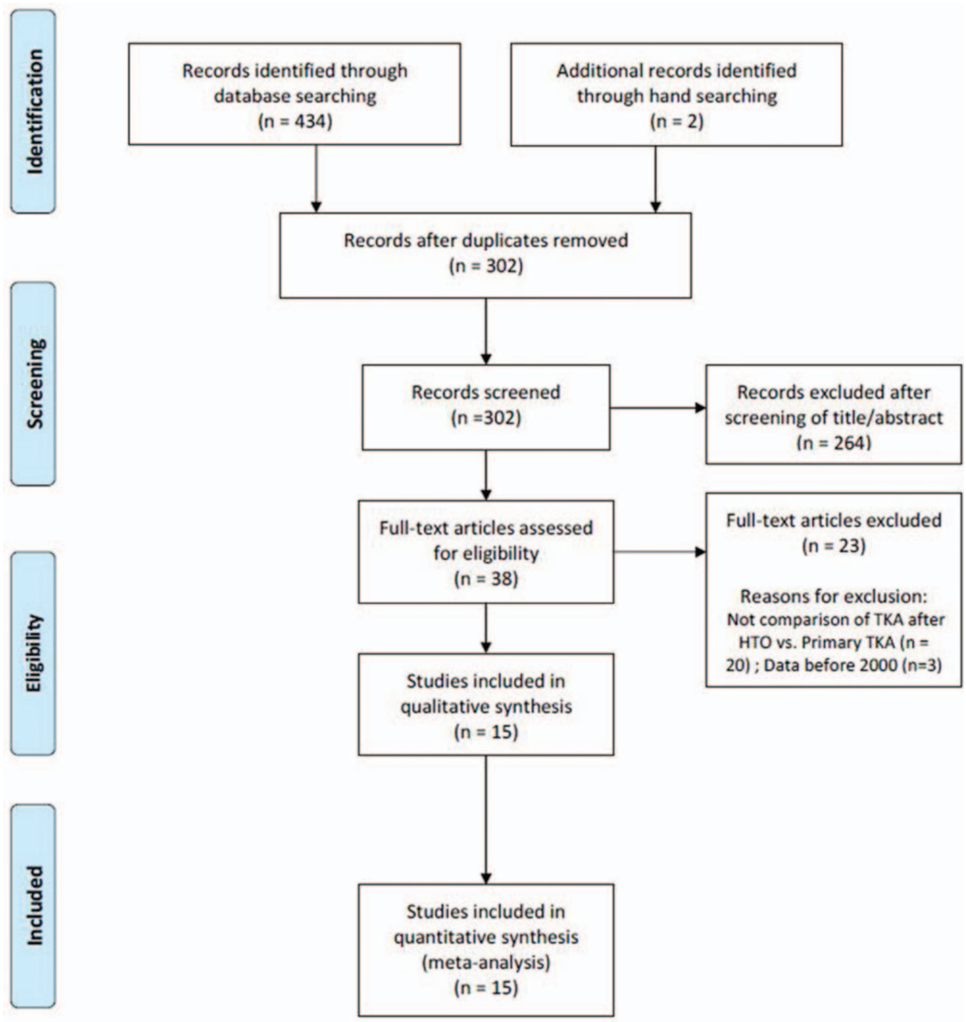

Figure 1. A flow diagram of preferred reporting items for systemic reviews and meta-analyses (PRISMA).

Otherwise, the random effect model was adopted. I^2 statistics with a value of less than 40% represents low heterogeneity and a value of 75% or more indicates high heterogeneity.[14] When statistical heterogeneity was substantial, we conducted meta-regression to identify potential sources of bias such as study type and average length from HTO to TKA. The age and sex of the study subjects were also considered. All statistical analyses were performed with RevMan version 5.3 software and Stata version 14.2. The risks of bias (low, high, or unclear) were independently assessed by two investigators. Publication bias was also assessed using funnel plots. Subgroup analyses based on differences in follow-up period were performed for survival rates to explore a potential source of heterogeneity. As a result, two subgroups were created in each group—short-to midterm (<10 years) and long-term (>10 years) survival rates. Additionally, a sensitivity analysis was performed by excluding one eligible study at a time. Three studies[15–17] with data from a national joint registry were included, and another study[18] with a different surgical technique was included. Pooling of data was feasible for two outcomes of interest—survival rates and ROM.

3. Results

3.1. Study identification, study characteristics, patient populations, quality assessment, and publication bias of the included studies

Details on study identification, inclusion, and exclusion are summarized in Fig. 1. This resulted in 15 studies that were included in the meta-analysis.[7,9–13,15–23] The 15 studies we examined included 3563 subjects with TKA with previous HTO and 71,281 subjects with primary TKA that had clinical outcomes reported, specific clinical scores, ROM, operation time, IS ratio, complications, or survival rates. Five studies (5 PCSs) compared prospectively measured parameters, whereas the other 10 studies compared parameters measured by retrospective chart review. Fourteen studies compared groups according to survival rates, 12 studies compared pain and function scores, 10 compared ROM and complications, and 6 compared operation time and IS ratio (Table 1). The quality of the 15 studies included in the meta-analysis is summarized in Table 1. The non-RCTs (5 PCSs and 10 RCSs) were of high quality (Newcastle-Ottawa Scale

Table 1

Summary of patient characteristics of the included studies.

Study	Year	Study type	Mean age (years): TKA with previous HTO	Mean age (years): Primary TKA	Sample size (M/F): TKA with previous HTO	Sample size (M/F): Primary TKA	Prosthesis properties: TKA with previous HTO	Prosthesis properties: Primary TKA	Follow-up (year): TKA with previous HTO	Follow-up (year): Primary TKA	Average length from osteotomy to arthroplasty (year)	Type of HTO	Quality score	Measured parameters
Amendola et al.[12]	2010	PCS	68.5	71.0	29 (19/5)	29 (NA)	Nexgen LPS	Nexgen LPS	Mean8.1	Mean8.1	Mean8.4	19:closing-wedge 10:opening-wedge	NOS 6	PS, FS, SR
Bae el al[19]	2017	RCS	68.3	68.8	29 (0/29)	29 (0/29)	Press fit condylar, NexGen	Press fit condylar, NexGen	Mean6.2	Mean7.1	Mean12.5	29:closing-wedge	NOS 8	PS, FS, ROM, ISR, CR, SR
Badway et al[15]	2015	RCS	71.0	69.0	1399 (683/716)	31077 (10069/21008)	NA	NA	Mean10.0	Mean10.0	NA	NA	NOS 6	OT, CR, SR
Efe et al[20]	2010	RCS	69.0	73.0	41 (21/20)	41 (17/24)	NexGen LPS	NexGen LPS	Mean 6.8	Mean 7.1	Mean7.2	41:closing-wedge	MJS 6	PS, FS, ROM, OT, ISR, CR, SR
Erak et al[18]	2011	PCS	57.0	69.0	34 (21/13)	1315 (509/806)	NA	NA	Mean3.4	Mean3.4	Mean4.7	34:opening-wedge	NOS 7	PS,FS, ROM,
Haddad et al[10]	2000	RCS	65.0	66.0	50 (16/26)	42 (18/24)	Insall-Burnstein II, Kinemax, Press fit condylar	Insall-Burnstein II, Kinemax, Press fit condylar	Mean 6.2	Mean 6.2	Mean7.3	42:closing-wedge 8:dome	NOS 7	PS, FS, ROM, CR, SR
Haslam et al[9]	2007	RCS	78.0	78.0	51 (20/17)	51 (20/17)	Kinematic, Total Condylar, Kinemax	Kinematic, Total Condylar, 0 Kinemax	Mean12.6	Mean12.6	Mean4.8	51:closing-wedge	NOS 7	PS, ROM, ISR, CR, SR
Karabatsos et al[21]	2002	RCS	64.0	65.0	22 (10/10)	21 (10/10)	Genesis, Tricon Genesis	Genesis, Tricon Genesis	Mean5.2	Mean4.7	Mean8.4	22:closing-wedge	NOS 9	PS, FS, OT, CR, SR
Kazakos et al[22]	2008	RCS	67.2	68.4	38 (8/24)	38 (7/25)	TC-Solution Plus Orthopedics	TC-Solution Plus Orthopedics	Mean4.5	Mean4.3	Mean7.3	38:closing-wedge	NOS 9	PS, FS, ROM, OT, ISR, CR, SR
Meding et al[11]	2000	PCS	66.9	67.4	39 (27/12)	39 (27/12)	Anatomic Graduated Component, Posterior Cruciate Condylar Prosthesis	Anatomic Graduated Component, Posterior Cruciate Condylar Prosthesis	Mean 7.5	Mean6.8	Mean8.7	34:closing-wedge 5:dome	NOS 9	PS, FS, ROM, OT, ISR, CR, SR
Meding et al[13]	2011	PCS	66.9	66.7	39 (27/12)	39 (27/12)	Anatomic Graduated Component, Posterior Cruciate Condylar Prosthesis	Anatomic Graduated Component, Posterior Cruciate Condylar Prosthesis	Mean 16.7	Mean16.6	Mean8.7	39:closing-wedge	NOS 9	PS, FS, ROM, SR
Niinimaki et al[16]	2014	RCS	64.3	64.7	1036 (425/611)	4143 (1694/2449)	NA	NA	Mean6.7	Mean6.2	NA	NA	NOS 6	SR
Parvizi et al[7]	2004	PCS	63.2	67.1	34 (11/23)	34 (11/23)	NA	NA	Mean15.1	Mean 15.4	Mean8.6	NA	NOS 6	PS, FS, ROM, CR, SR
Pearse et al[17]	2012	RCS	68.9	62.4	711 (NA)	34369 (NA)	NA	NA	NA	NA	NA	NA	NOS 6	SR
Van Raaij et al[23]	2007	RCS	60.0	61.0	14 (2/10)	14 (2/10)	Kinemax, Genesis II	Kinemax, Genesis II	Mean3.7	Mean4.0	Mean 4.8	14:closing-wedge	NOS 6	PS, FS, ROM, OT, ISR, CR, SR

CCK = constrained condylar knee, CR = complication rate, F = female, FS = function score, HTO = high tibial osteotomy, ISR = Insall-Salvati ratio, M = male, NA = not available, NOS = Newcastle-Ottawa Scale; PS = pain score, OT = operation time, PCS = prospective comparative study, RCS = retrospective comparative study, RHK = rotating hinge knee, ROM = range of motion, SR = survival rate, TKA = total knee arthroplasty.

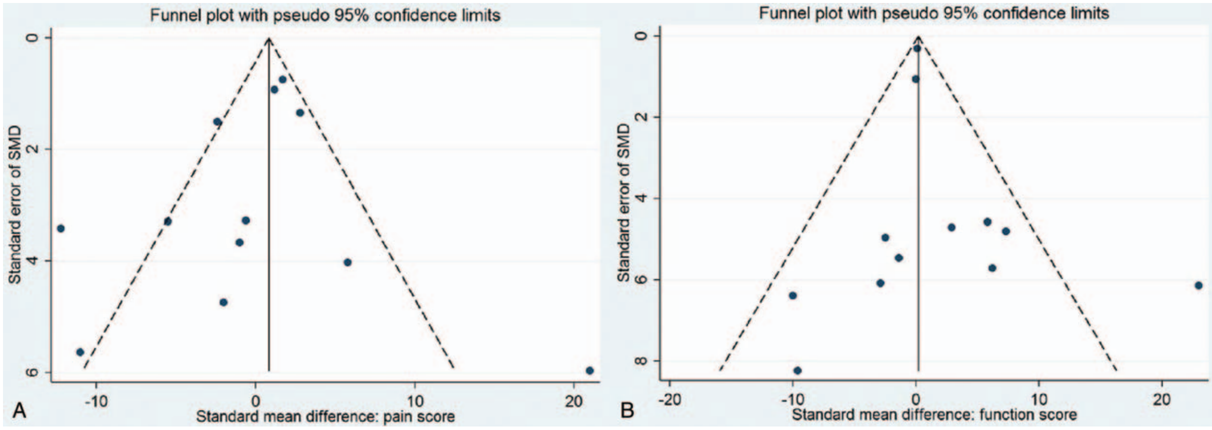

Figure 2. Funnel plot showing asymmetric data on (A) pain score between patients with TKA after HTO and primary TKA, suggesting some publication bias among included studies. However, funnel plot relatively symmetric data on (B) function score between patients with TKA after HTO and primary TKA, suggesting lack of publication biases.

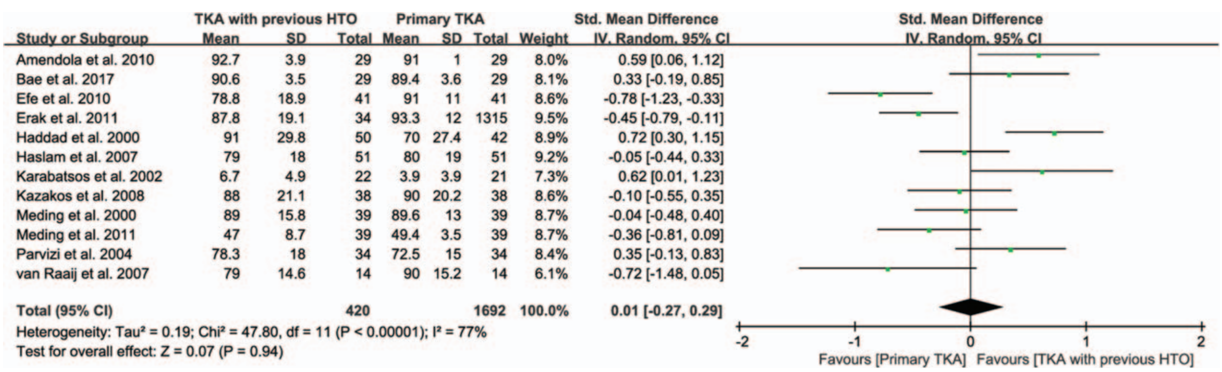

Figure 3. Results of aggregate analysis for comparison of pain scores between patients with TKA after HTO and primary TKA.

> 6). Inter-rater reliabilities (*k* values) for all items of the Newcastle-Ottawa Scale ranged from 0.72 to 0.85, suggesting at least more than substantial agreement between the two investigators. In general, publication bias did not need to be assessed if fewer than 10 studies were included. Therefore, we only evaluated the publication bias of pain and function scores. Funnel plots showed that the mean differences in pain score between patients with TKA with previous HTO and primary TKA were asymmetric (Fig. 2a), indicating some publication bias among the included studies. However, the mean differences in function score between patients with TKA with previous HTO and primary TKA were asymmetric (Fig. 2b), suggesting a lack of publication bias among the included studies.

3.2. Clinical outcomes, ROM, operation time, and IS ratio

Of the 15 studies, 12 compared pain between patients with TKA with previous HTO (n=420) and those with primary TKA (n=1692). The pooled data showed that the standardized mean pain was −0.01 points (95% CI: −0.27 to 0.29 points; $P=.94$; $I^2=77\%$, Fig. 3), with no significant difference between groups. Twelve studies reported function and included 1080 subjects treated with TKA with previous HTO and 36,010 subjects treated with primary TKA. The pooled data showed that the standardized mean function was 0.08 points (95% CI: −0.08 to 0.24 points; $P=.32$; $I^2=48\%$, Fig. 4), with no significant difference between groups. Nine studies compared ROM between patients with TKA with previous HTO (n=369) and primary TKA (n=1642). The pooled data showed that mean ROM was −4.33° lower at TKA with previous HTO than primary TKA and was significantly different between groups (95% CI: −7.40 to −1.26°; $P=.006$; $I^2=43\%$, Fig. 5). Based on the results of sensitivity analysis, a statistical difference could not be shown compared with those of the original analysis, concluding that the findings are robust to decisions made in their collection process (Table 2). Six studies reported operation time and included 1553 subjects treated with TKA with previous HTO and 31,230 subjects treated with primary TKA. The pooled data showed that the mean operation time was 10.71 min (95% CI: −5.43 to 26.85 min; $P=.19$; $I^2=98\%$, Fig. 6), with no significant difference between groups. Six studies compared IS ratio between patients with TKA with previous HTO (n=212) and those with primary TKA (n=212). The pooled data showed that the mean IS ratio was 0.02 (95% CI: −0.03 to 0.08; $P=.40$; $I^2=0\%$, Fig. 7), with no significant difference between groups.

3.3. Complications and survival rates

Of the 15 studies, 10 presented data on the proportion of subjects who developed complications, with no significant difference

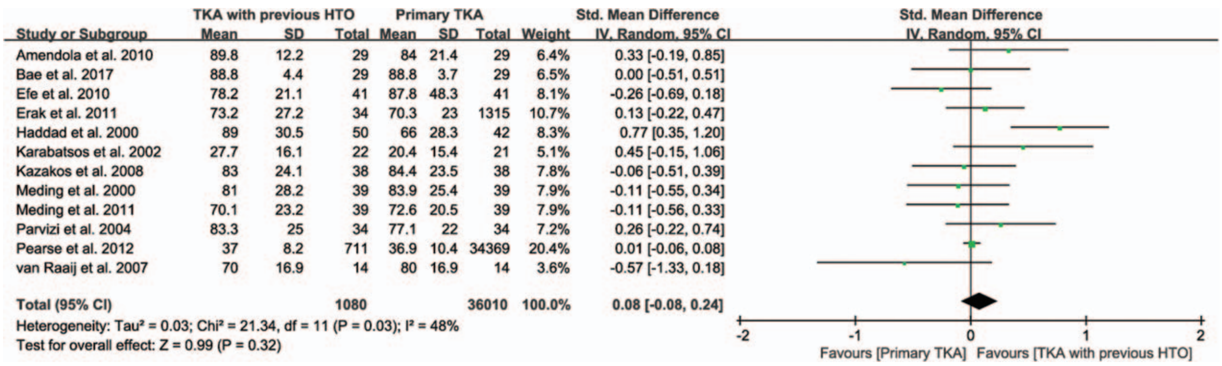

Figure 4. Results of aggregate analysis for comparison of function scores between patients with TKA after HTO and primary TKA.

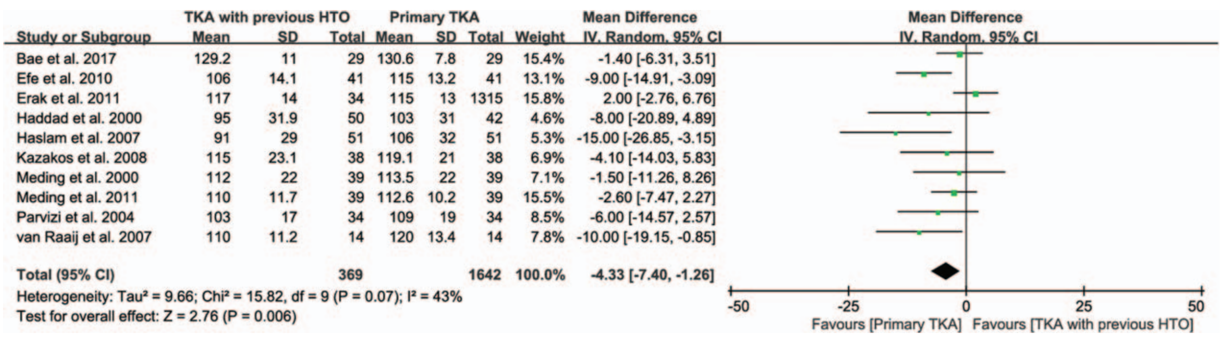

Figure 5. Results of aggregate analysis for comparison of postoperative range of motion (ROM) between patients with TKA after HTO and primary TKA.

Table 2

Sensitivity analysis.

Study	Parameter	Before exclusion	After exclusion	Statistical significance
Badway et al[15]	SR	OR = 0.53, 95% CI = 0.35,0.83, Z = 2.83, P = .005	OR = 0.48, 95% CI = 0.27,0.86, Z = 2.49, P = .01	No difference
Niinimaki et al[16]	SR	OR = 0.53, 95% CI = 0.35,0.83, Z = 2.83, P = .005	OR = 0.50, 95% CI = 0.27,0.92, Z = 2.22, P = .03	No difference
Pearse et al[17]	SR	OR = 0.53, 95% CI = 0.35, 0.83, Z = 2.83, P = .005	OR = 0.70, 95% CI = 0.60,0.83, Z = 4.26, P < .0001	No difference
Erak et al[18]	ROM	MD = −4.33, 95% CI = −7.40, −1.26, Z = 2.76, P = .006	MD = −5.14, 95% CI = −7.86, −2.42, Z = 3.71, P = .0002	No difference

CI = confidence interval, OR = odd ratio, ROM = range of motion, SR = survival rate.

between groups (TKA with previous HTO, 62/1717; primary TKA, 610/31386; OR 1.31, 95% CI: 0.97–1.77; P = .08; I^2 = 4%, Fig. 8). Fourteen compared the survival rates between groups (TKA with previous HTO, 3286/3532; primary TKA, 67,658/69,966; OR 0.53, 95% CI: 0.35–0.83; P = .005; I^2 = 72%, Fig. 9). Ten studies were assigned to the short- and midterm (<10 years) subgroup and four studies to the long-term (>10 years) subgroup. For the short- and midterm (<10 years) subgroup, the primary TKA group had a higher survival rate than the TKA with previous HTO group, but this difference was not significant (TKA with previous HTO, 1860/2009; primary TKA, 37,848/38,765; OR 0.55, 95% CI: 0.28–1.10; P = .09; I^2 = 79%, Fig. 9). For the long-term (>10 years) subgroup, the primary TKA group had a higher survival rate than the TKA with previous HTO group, and this difference was significant (TKA with previous HTO, 1426/1523; primary TKA, 29,810/31,201; OR 0.71, 95% CI: 0.57–0.89; P = .003; I^2 = 0%, Fig. 9). In addition, both groups had substantial proportions of knees exhibiting short- to midterm survivorship (92.6% by the TKA with previous HTO and 97.6% by the primary TKA) and long-term survivorship (93.6% by the TKA with previous HTO and 95.5% by the primary TKA). Based on the results of sensitivity analysis, a statistical difference could not be shown compared with those of the original analysis, concluding that the findings are robust to decisions made in their collection process (Table 2).

3.4. Meta-regression analysis

The results of the meta-regression analysis are summarized in Table 3. For survival rates of the TKA with previous HTO group, we identified study type (P = .045) as a source of heterogeneity. However, we did not identify the source of heterogeneity for

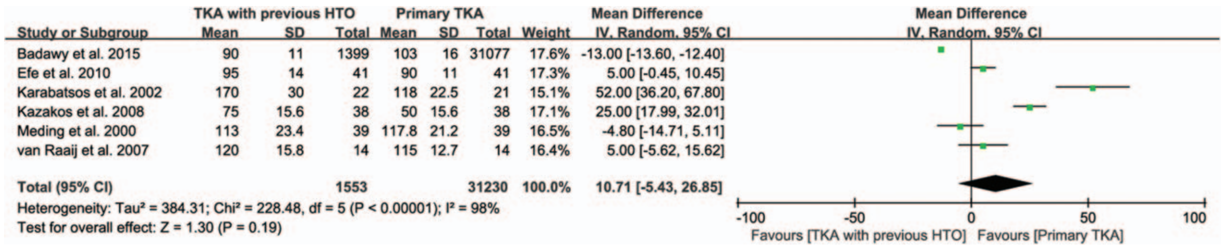

Figure 6. Results of aggregate analysis for comparison of operation time between patients with TKA after HTO and primary TKA.

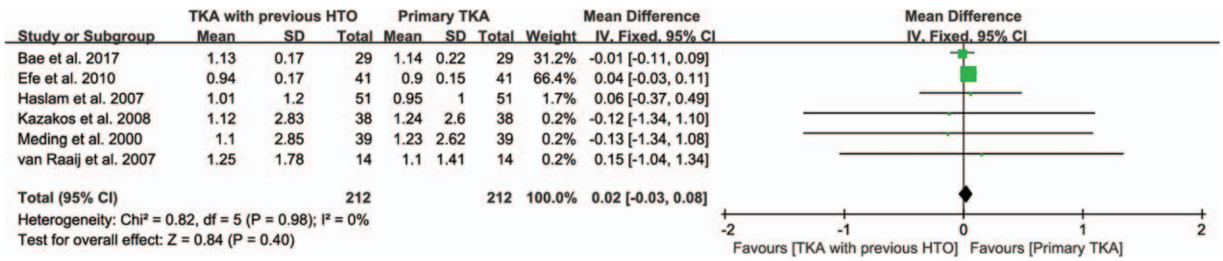

Figure 7. Results of aggregate analysis for comparison of Insall-Salvati ratio between patients with TKA after HTO and primary TKA.

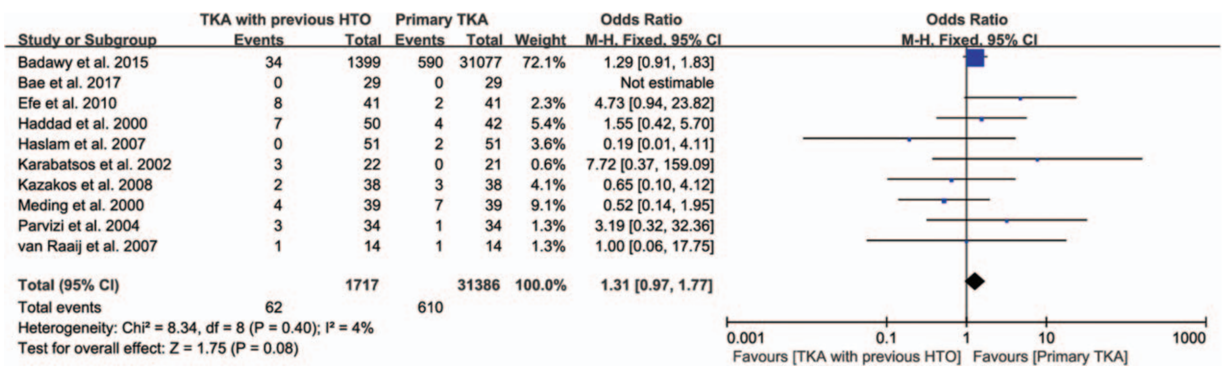

Figure 8. Results of aggregate analysis for comparison of complication rate between patients with TKA after HTO and primary TKA.

survival rates of the primary TKA group. Thus, heterogeneity in survival rates of the TKA with previous HTO group in the included studies was likely caused by study type.

4. Discussion

The most important finding of this meta-analysis was no significant differences for clinical outcomes, operation time, IS ratio, complication rates, and survival rates on short- and midterm follow-up. However, groups with primary TKA showed significantly greater ROM and greater survival rates on long-term follow-up than those with TKA with previous HTO.

TKA with previous HTO is thought to be a technically more demanding procedure than primary TKA. These findings may be attributable to altered anatomy in the proximal part of the tibia and difficulties in exposure requiring modifications of the standard approach, which can lead to suboptimal component positioning, soft-tissue balancing, and limb alignment, and subsequently lower survival rates of TKA with previous HTO.[6,7] However, previous studies have reported contradictory results on whether TKA with previous HTO or primary TKA is superior regarding survivorship. In a recent registry-based, New Zealand study that compared survival rates and functional outcomes between two methods, TKA with previous HTO had a revision rate almost three times higher than that of primary TKA.[17] In contrast, another study investigating the risk of revision between TKA with and without previous HTO using 32,476 TKAs in the Norwegian Arthroplasty Register found that previous HTO did not appear to increase the risk of revision after a secondary procedure with TKA at 15-year follow-up.[15] Our findings from subgroup analysis evaluating the differences in follow-up period suggested that the survival rates of TKA with and without previous HTO were not significantly different at short- and midterm follow-up. Over time, primary TKA showed decreased survival rates, whereas TKA with previous HTO showed slightly increased survival rates, even though both groups had substantial proportions of knees exhibiting short- to midterm survivorship and long-term survivorship. A recent study reported that long-term survival rates between TKA with and without previous HTO were influenced by age and sex even though long-term survival rates are determined by numerous variables including time of follow-up, type of prosthesis implanted, and limb alignment.[7,11,23] These findings suggest that there are worse long-term survival rates of TKA with previous HTO

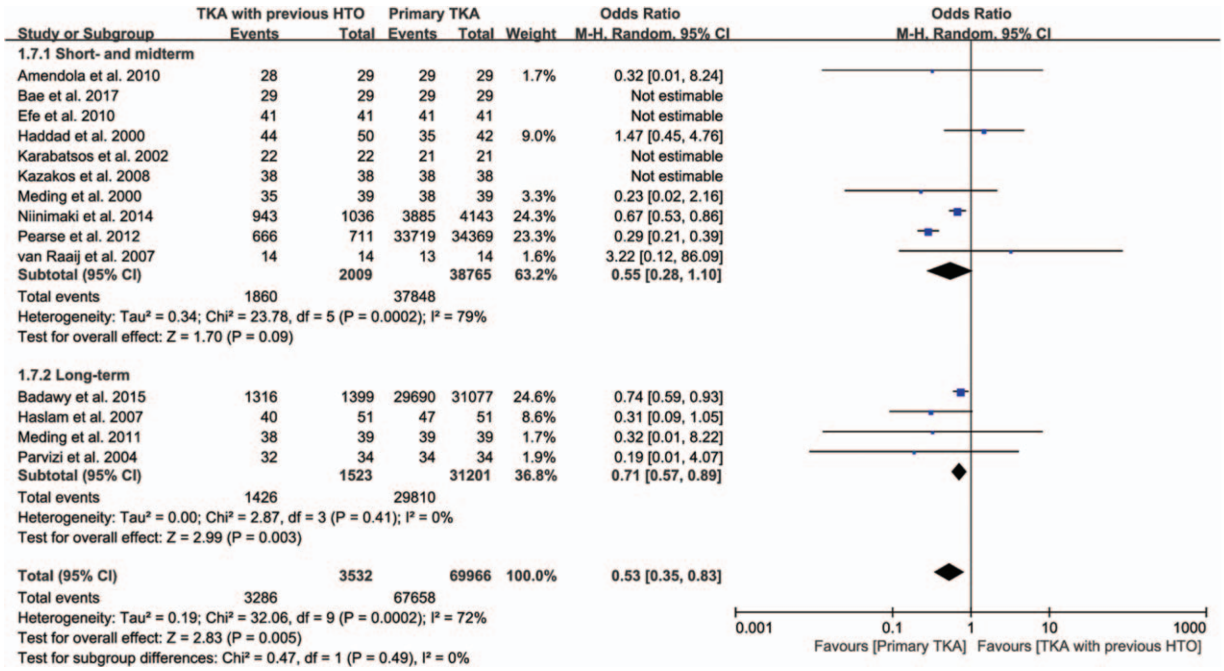

Figure 9. Results of aggregate analysis for comparison of short- to midterm and long-term survival rates between patients with TKA after HTO and primary TKA.

Table 3

Meta-regression analyses of potential sources and difference in survival rate for TKA with or without HTO.

Variable	Coefficient	Standard error	*P* value	95% confidence interval
Survival rate (TKA after HTO)				
Age, mean, year (≤65 or ≥65)	0.007	0.065	.918	−0.174 to 0.188
Men, % (≤48 or ≥48)	0.073	0.046	.189	−0.056 to 0.203
Study type (RCS or Others)	**0.114**	**0.040**	**.045**	**0.004–0.224**
Average length from HTO to TKA (≤6years or ≥6years)	0.161	0.062	.061	−0.012 to 0.333
Survival rate (primary TKA)				
Age, mean, year (≤65 or ≥65)	−0.013	0.028	.647	−0.085 to 0.058
Men, % (≤48 or ≥48)	0.029	0.027	0.321	−0.039 to 0.098
Study type (RCS or others)	−0.001	0.029	0.967	−0.077 to 0.074

Bold value is a significant difference ($P < .05$).
HTO = high tibial osteotomy, RCS = retrospective comparative study, TKA = total knee arthroplasty.

because it involves a highly selected population with unfavorable demographic status including younger patients and higher proportion of male patients. Our study showed that age and sex did not have much impact on survival rates on meta-regression analysis. Rather, the slightly inferior survival rate of TKA with previous HTO at long-term follow-up compared with primary TKA may be explained by less experienced surgeons being likely to have treated TKA with previous HTO even with an understanding of technical challenges including preservation of soft tissue balance, controlled bone resection, restoration of a normal joint line, and correct rotational alignment. Interestingly, TKA with previous HTO had higher survival rates on long-term (93.6%) follow-up than short-to midterm (92.5%) follow-up. Generally, survivorship during TKA decreases with increasing length of follow-up. This discrepancy was likely due to groups in short-to midterm follow-up having more patients with specific problems in terms of asymmetric bone cuts and residual ligament laxity and severe bone defects on the lateral plateau requiring bone grafts or metal augmentation and intramedullary stem compared to groups in long-term follow-up.[24]

Contrary to our hypothesis, the results of the present study showed that TKA with previous HTO was associated with less postoperative ROM than primary TKA. Although it is unclear why there was a significant difference in ROM between TKA with and without previous HTO, we offer some possible reasons. One of the most plausible causes was relatively less patellar resurfacing of patients in the included studies. These patients who did not have patellar resurfacing within TKA with previous HTO were less tolerant of anterior knee pain than patients within primary TKA because of the presence of a low patella caused by shortening of the patellar tendon during osteotomy healing and contracture of the patellar tendon during cast immobilization.[10] This possibility is supported by the results of our study in that there was a trend toward decline in patellar height for TKA with previous HTO compared to primary TKA with respect to IS ratio, but the difference was not significant. This can result in much lower postoperative ROM with TKA with previous HTO than expected. Another possible reason is in the difference of implant design between posterior cruciate-retaining (CR) and posterior stabilized (PS) prosthesis, even though it was not assessed in our study owing to the limited data reported in the original papers. One study evaluating midterm results of 20 patients treated with TKA following failed HTO showed that inferior results of postoperative ROM were more common in the CR prosthesis group than in the PS prosthesis group, and that PS TKA is recommended for use after HTO because of the likelihood of inappropriate tension on the posterior cruciate ligament (PCL) caused by tibia bone loss and relaxation of the PCL.[25,26]

This study has several limitations. All 15 studies were observational, resulting in some inherent heterogeneity due to uncontrolled bias even though the studies had high quality scores. In addition, the heterogeneity of the included studies could also be explained by slight differences in other factors affecting surgical outcomes such as lack of information on surgical technique used for osteotomy, use of a wide variety of fixation devices, and variability in functional and pain scores. Finally, the time interval from HTO to TKA differs between studies, which might affect survival rates after surgery. However, the results of the meta-regression analysis in our study showed that average length from HTO to TKA did not influence survival rates for TKA with previous HTO.

5. Conclusion

This meta-analysis revealed that 92.6% of TKA with previous HTO and 97.6% of primary TKA survive at short- to midterm (<10 years), while 93.6% of TKA with previous HTO and 95.5% of primary TKA survive at long-term (>10 years). In addition, previous HTO affected ROM or survival of TKA in the long-term even though the groups demonstrated equivalent clinical outcomes and complications. Thus, orthopedic surgeons should offer useful information regarding the advantages and disadvantages of both procedures to patients, and should provide advice on the generally higher risk of revision after TKA with previous HTO at long-term follow-up when counseling patients.

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Author contributions

Conceptualization: Seung-Suk Seo, Kyung-Wook Nha, Young-Soo Shin.
Data curation: Seung-Suk Seo, Kyung-Wook Nha, Tae-Yeong Kim, Young-Soo Shin.
Formal analysis: Young-Soo Shin.
Investigation: Seung-Suk Seo, Kyung-Wook Nha, Tae-Yeong Kim, Young-Soo Shin.
Methodology: Young-Soo Shin.
Software: Young-Soo Shin.
Supervision: Young-Soo Shin.
Validation: Young-Soo Shin.
Visualization: Young-Soo Shin.
Writing – original draft: Young-Soo Shin.
Writing – review & editing: Young-Soo Shin.
Young-Soo Shin orcid: 0000-0003-1030-9979.

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