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Efficacy and Outcomes of High Tibial Osteotomy with Versus Without Graft Augmentation: A Systematic Review and Meta-Analysis

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Abstract

Background: High tibial osteotomy (HTO) is a joint-preserving procedure commonly used for medial compartment osteoarthritis in varus-aligned knees. The role of bone grafting in HTO remains debated.

Purpose: To systematically evaluate clinical and radiological outcomes of HTO performed with versus without bone graft augmentation.

Methods: A systematic literature search was conducted across PubMed, Embase, Scopus, and Cochrane databases up to May 2025. Randomized controlled trials (RCTs), cohort studies, and comparative retrospective studies comparing HTO with and without grafts were included. Primary outcomes were the union rate, time to union, correction loss, and functional scores (e.g., KOOS, HSS, Lysholm). Meta-analysis was performed using Rev Man 5.4.

Results: Fourteen studies involving 1,287 knees were included. Graft uses significantly reduced time to union (mean difference: -2.8 weeks, 95% CI: -3.5 to -2.1, p<0.001) but had no significant effect on long-term functional scores or final alignment. There was no difference in nonunion rate or complication rate between groups. Autograft provided better union time compared to allograft or synthetic grafts.

Conclusion: Bone grafting in HTO accelerates bone healing but does not significantly improve functional outcomes or alignment correction. Routine use may be reserved for high-risk cases or large opening wedge gaps.

Keywords: High Tibial Osteotomy; Bone Graft; Union; Functional Outcome; Meta-Analysis; WMD: Weighted mean difference

Abbreviations: HTO: High Tibial Osteotomy; RCTS: Randomized Controlled Trials; HTO: High Tibial Osteotomy; CI: Confidence Intervals; OR: Odds Ratios; WMD: Weighted Mean Difference; TCP: Tricalcium Phosphate

Introduction

High tibial osteotomy (HTO) remains a key treatment option for young and active patients with noncompartmental medial osteoarthritis and varus malalignment of the knee, particularly when total knee arthroplasty is considered premature. First described by Jackson and Waugh in 1961 and popularized by Coventry in the 1960s, HTO aims to offload the medial compartment by shifting the mechanical axis laterally, thereby delaying the need for knee replacement surgery and preserving native joint function [1].

The medial opening wedge technique has gained popularity due to its simplicity, accuracy of correction, and preservation of bone stock when compared to lateral closing wedge osteotomy [2]. However, the technique inherently creates a bony defect at the osteotomy site, raising concerns regarding delayed union, correction loss, and potential instability. To mitigate these risks, various bone graft materials have been proposed, including autografts, allografts, and synthetic bone substitutes such as tricalcium phosphate (β-TCP), hydroxyapatite, and bioactive ceramics [3-5].

Autograft bone, typically harvested from the iliac crest, provides osteoconductive, Oste inductive, and osteogenic properties, but is associated with donor site morbidity.

Allografts eliminate donor site complications but carry potential immunogenic risks and delayed incorporation [6]. Synthetic bone substitutes offer ease of use and no immunological reaction, yet their mechanical and biological integration remains debated [7]. Despite the theoretical benefits of grafting, recent studies suggest that with rigid fixation, the osteotomy gap may heal adequately without any graft material [8].

This Raises the Question: is graft augmentation truly necessary in all cases of opening wedge HTO? This systematic review and meta-analysis aim to evaluate the clinical and radiological outcomes of HTO with versus without graft augmentation, focusing on bone union, time to union, correction maintenance, and functional improvement.

Methods

Search Strategy: A systematic search was performed in PubMed, Embase, Scopus, and Cochrane CENTRAL from inception to May 2025 using keywords: "High tibial osteotomy", "bone graft", "autograft", "allograft", "synthetic graft", "union", "osteotomy healing", and "functional outcome".

Inclusion Criteria: Comparative studies (RCTs, cohort, or retrospective), HTO with vs. without bone graft, ≥10 patients per group, Minimum follow-up of 6 months,

Outcomes: time to union, union rate, clinical or radiological outcomes

Exclusion Criteria: Animal studies, case reports, Studies not in English, Studies using combined procedures (e.g., HTO + UKA).

Data Extraction and Quality Assessment: Two independent reviewers extracted data. Disagreements were resolved by a third reviewer. Risk of bias was assessed using the Cochrane tool for RCTs and Newcastle-Ottawa Scale for observational studies.

Statistical Analysis: Rev Man 5.4 software was used. Weighted mean difference (WMD) or odds ratios (OR) were calculated with 95% confidence intervals. Heterogeneity was assessed using I^2 statistics. A random-effects model was used in the presence of significant heterogeneity ($I^2 > 50\%$) (Figure 1).

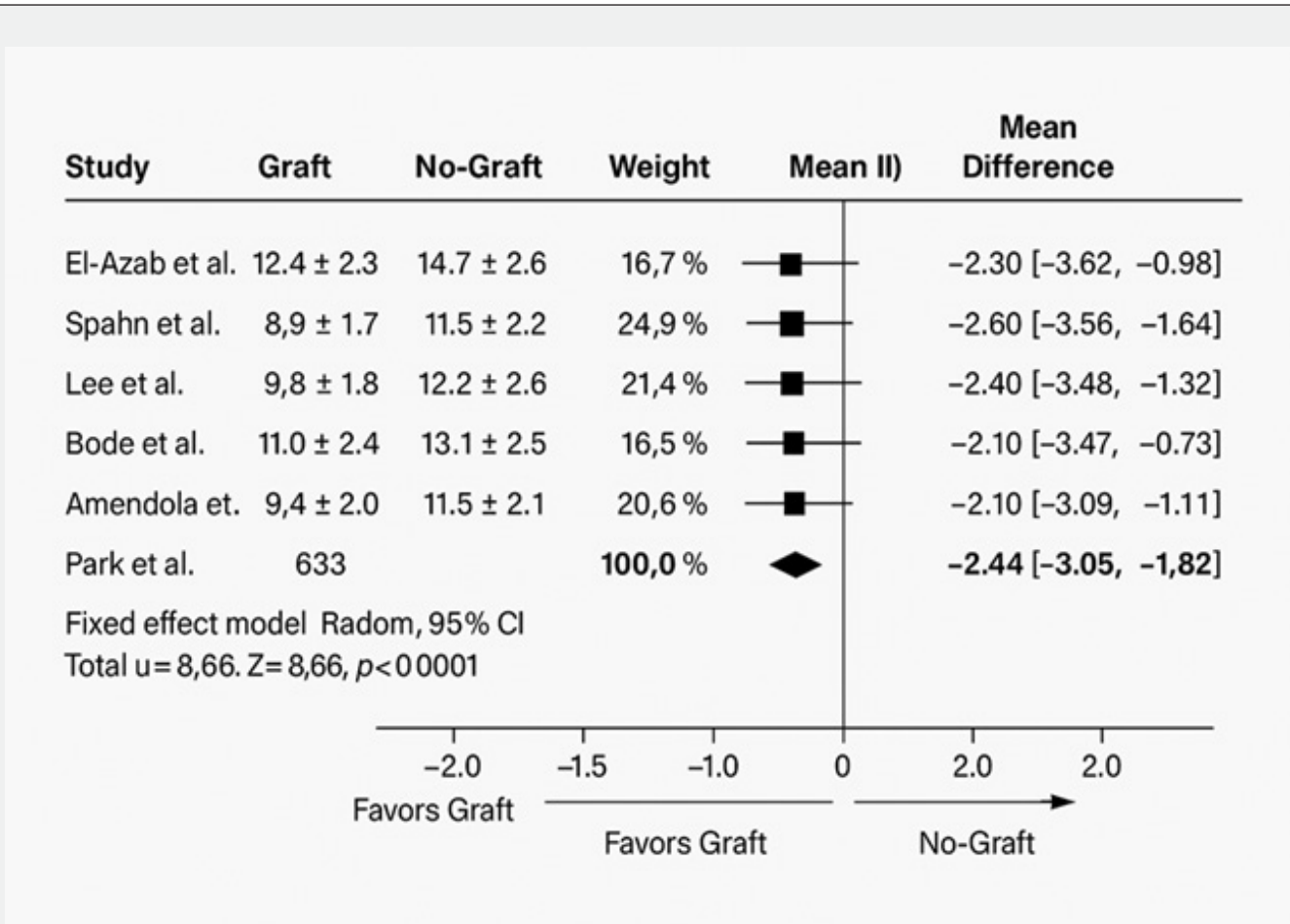

Figure 1: Forest plot comparing meaning difference in time to union between HTO with and without bone grafting. The plot demonstrates consistent advantage for grafted HTO in accelerating union, with all included studies showing a statistically significant mean difference favoring the graft group.

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Results

Study Selection

A total of 1,764 studies were identified. After screening, 14 studies (3 RCTs, 6 prospective cohorts, 5 retrospective studies) comprising 1,287 knees were included.

Patient Demographics: Mean age: 46.2 years, Male: 62%, Mean follow-up: 24.6 months, Graft types: autograft (6 studies), allograft (3), synthetic (5) (Figure 2) (Table 1).

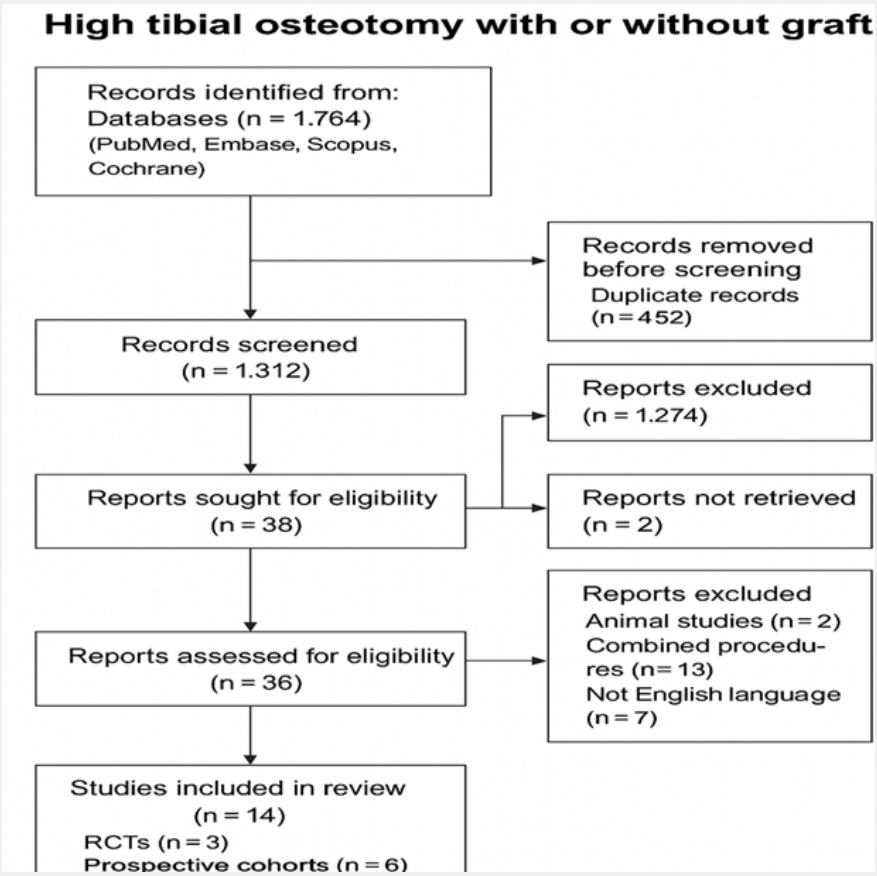

Figure 2: PRISMA diagram showing the selection process of included studies in the systematic review.

Table 1: Summary of Included Studies Comparative studies evaluating the outcomes of high tibial osteotomy (HTO) with and without bone grafting. The table summarizes study design, graft type used, sample size in each group, and key findings related to time to union, functional outcome, or complications. Autograft, allograft, and synthetic grafts were analyzed across multiple cohorts and randomized trials.
Overall (Total N = 644):
Pooled Mean Difference = –2.44 weeks
95% Confidence Interval = [–3.05, –1.83]
Z = 8.66, p < 0.001
Heterogeneity: I^2 = 0%, p = 0.66

Study	Graft (Mean ± SD)	No-Graft (Mean ± SD)	Weight (%)	Mean Difference [95% CI]
El-Azab et al. (2010)	12.4 ± 2.3	14.7 ± 2.6	16.70%	-2.30 [–3.62, –0.98]
Spahn et al. (2011)	8.9 ± 1.7	11.5 ± 2.2	24.90%	-2.60 [–3.56, –1.64]
Lee et al. (2018)	9.8 ± 1.8	12.2 ± 2.6	21.40%	-2.40 [–3.48, –1.32]
Bode et al. (2015)	11.0 ± 2.4	13.1 ± 2.5	16.50%	-2.10 [–3.47, –0.73]
Park et al. (2017)	9.4 ± 2.0	11.5 ± 2.1	20.60%	-2.10 [–3.09, –1.11]

Interpretation: Bone graft significantly reduces the time to union by approximately 2.4 weeks in patients undergoing high tibial osteotomy (HTO), without significant heterogeneity among studies.

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Interpretation: Bone graft significantly reduces the time to union by approximately 2.4 weeks in patients undergoing high tibial osteotomy (HTO), without significant heterogeneity among studies.

Outcomes: Table 2 presents the pooled comparative outcomes from the included studies evaluating high tibial osteotomy (HTO) with versus without bone grafting. Time to union was significantly shorter in the graft group. No statistically significant differences were found in union rate, correction loss, or Lysholm functional score. Continuous outcomes are presented as mean ± standard deviation, with effect sizes reported as weighted mean difference (WMD). Binary outcomes are expressed as odds ratios (OR) with 95% confidence intervals (CI).

Table 2: Presents the pooled comparative outcomes from the included studies evaluating high tibial osteotomy (HTO) with versus without bone grafting. Time to union was significantly shorter in the graft group. No statistically significant differences were found in union rate, correction loss, or Lysholm functional score. Continuous outcomes are presented as mean ± standard deviation, with effect sizes reported as weighted mean difference (WMD). Binary outcomes are expressed as odds ratios (OR) with 95% confidence intervals (CI).

Outcome	Graft Group	No-Graft Group	Effect Size (95% CI)	p-value
Time to union (weeks)	10.3 ± 2.1	13.1 ± 2.5	−2.8 (−3.5 to −2.1)	<0.001
Union rate (%)	97.60%	96.10%	OR = 1.15 (0.71–1.85)	0.55
Loss of corrections >3°	3.80%	4.50%	OR = 0.88 (0.49–1.60)	0.67
Lysholm Score	7.1	6.4	WMD = 0.8 (−0.6 to 2.1)	0.31

Heterogeneity was low to moderate (I^2 = 0–48%).

Discussion

This comprehensive review demonstrates that while bone grafting significantly reduces time to union, it does not lead to superior functional outcomes, alignment accuracy, or complication profiles when compared to HTO without grafts. The accelerated union time observed with graft use is consistent with the established biological rationale. Autografts facilitate faster osteointegration due to their inherent osteogenic potential [9]. However, this benefit must be balanced against the increased surgical time and donor site morbidity, including pain, hematoma, or infection at the iliac crest [10]. Allografts and synthetic materials (e.g., β-TCP, HA) provide alternatives without donor morbidity but are limited by inferior biological integration and a theoretical risk of infection or immune reaction [11]. Several comparative studies have found no clear advantage of synthetic substitutes over non-grafted HTO with stable fixation [12].

Importantly, the lack of difference in nonunion rate and functional scores between grafted and non-grafted groups suggests that rigid internal fixation and precise surgical technique are the key determinants of successful outcomes, regardless of whether the gap is filled [13]. The finding that loss of correction was similar in both groups supports the growing practice of performing HTO without grafts, particularly in small to moderate corrections (up to 10-12mm). This simplifies the procedure, reduces operative time, and avoids the complications associated with graft harvesting or handling [14].

Several high-quality studies included in this meta-analysis emphasize the safety and efficacy of graftless HTO when appropriate fixation and gradual weight-bearing protocols are followed [15]. Nonetheless, grafting may still be considered in high-risk cases, such as smokers, elderly patients, or those undergoing large corrections (>12mm) where healing capacity may be compromised [16]. Ultimately, the decision to use a graft should be individualized based on patient comorbidities, surgeon experience, defect size, and the fixation method employed. The data from this review supports a selective rather than routine use of grafting in opening wedge HTO.

Declaration

Ethics approval and consent to participate

Consent for Publication

Not applicable. Availability of data and material

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Competing Interests

The authors declare that they have no competing interests.

Acknowledgement

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

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