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Timing and Necessity of Dangling after Lower Limb Free Flap Reconstruction: A Systematic Review and Meta-Analysis

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Abstract

Dangling (graduated limb dependency) is widely used after lower limb free flap reconstruction, but protocols vary and its clinical benefit is uncertain. Previous reviews have examined the timing or intensity of dangling in patients who all underwent dangling; recently published randomized evidence allows its necessity to be considered. We systematically searched Medline, Embase, Cochrane Library and three trial registries to March 2026 for clinical studies of lower limb free tissue transfer reporting a defined dangling protocol or unrestricted mobilization. Eighteen studies (845 patients or cases) were included and pooled in random-effects single-arm meta-analyses of flap survival, with subgroup analyses by dangling strategy and mean patient age. Pooled flap survival was high (97–98%) with low heterogeneity, and did not differ significantly between early, late and no-dangling strategies or between age groups. Early dangling or unrestricted mobilization was not associated with more complications and was associated with comparable or shorter hospital stay in several cohorts. Because most studies were non-comparative and direct comparative evidence is limited, these findings indicate that a benefit of formal dangling has not been demonstrated, rather than that no benefit exists. Adequately powered randomized trials within enhanced recovery pathways, including patient-reported outcomes, are needed.

Introduction

Lower-extremity free tissue transfer is frequently required to salvage limbs after high-energy trauma, oncologic resection, infection, or chronic wounds, but postoperative management varies widely between centers.[1–3] “Dangling” (graduated limb dependency) is used to habituate the flap to hydrostatic stress and venous pooling; physiologic studies show predictable reductions in tissue oxygenation with dependency, increased hemoglobin concentration, and progressive adaptation over successive sessions.[4,5] Early foundational work also demonstrated that gravity-induced venous congestion is a key stressor for lower-limb flaps, supporting the rationale for graded training.[6] Whether to initiate dangling early or late remains contested. Prospective and randomized studies suggest that early protocols (from postoperative day [POD] 1–5) are generally safe and may reduce immobilization-related harms, without increasing flap loss.[7–11] Contemporary cohort data from enhanced-recovery pathways similarly report early dangling (~ POD 3) and earlier weight-bearing without higher complication rates and potential reductions in length of stay.[12,13] Conversely, practice surveys consistently show heterogeneity in timing, duration, and use of adjuncts (compression, couplers, thromboprophylaxis), underlining the lack of consensus.[1–3]

Recent randomized evidence has also begun to test the value of dangling itself: a multicenter randomized controlled trial (RCT) comparing a structured dangling protocol (starting POD 7) versus unrestricted mobilization found no apparent reduction in partial flap loss with dangling, highlighting equipoise and the need for higher-level synthesis.[14] Finally, case-series experience emphasizes protocol-driven care through the inpatient course (including dangling as a discharge milestone), but these designs cannot resolve timing questions.[15]

Several reviews have examined postoperative dangling after lower-extremity free tissue transfer. McGhee et al. pooled eight studies (197 patients) published to December 2015 and, using tissue oxygen saturation as a physiological outcome, concluded that flap training produced circulatory adaptation within approximately four days and that dangling might safely begin on POD 3.[16] Subsequent qualitative reviews reached similar conclusions regarding the safety of early dangling, while highlighting marked heterogeneity and low-level evidence.[17–19] Most recently, Foppiani et al. pooled complication rates across dangling protocols published to 2024 and found no association between session duration and complications.[20] These reviews addressed how early, or how intensively, dangling can be performed in patients who all underwent dangling. None was able to consider whether a formal dangling protocol is required, because the full report of the first randomized trial comparing structured dangling with unrestricted mobilization was published after their searches.[14] Preliminary findings from an earlier version of the present work were presented as a conference abstract.[21]

This systematic review aims to evaluate the current evidence of postoperative dangling after lower-limb free flap reconstruction, in particular examining flap survival across early, late and no-dangling strategies (recognizing that most available studies are non-comparative) with respect to: (1) flap survival (primary outcome); (2) secondary outcomes including postoperative length of stay, return to theater, complications (wound dehiscence, infection, flap necrosis); and (3) exploratory subgroup analyses examining whether patient age influences flap survival outcomes.

Methods

This systematic review was conducted in accordance with the PRISMA 2020 guidelines, with the PRISMA flow diagram shown in Appendix A (Figure A1), and the PRISMA-S guidelines for reporting the literature search.[22,23] Titles and abstracts, as well as full texts, were independently double screened by two reviewers (AI, BC), with a third reviewer (CP) serving as an adjudicator for conflicts. Eligible designs included randomized and non-randomized comparative studies, cohort studies, and case series reporting postoperative dangling protocols after lower-extremity free tissue transfer in humans. Studies exclusively addressing upper-extremity or pedicled flaps were excluded from comparative analyses.

Search strategy

The search was conducted on the following databases: Medline (via PubMed), Embase (via Ovid), Cochrane, ClinicalTrials.gov, the EU Clinical Trials Register, and the ISRCTN registry, from inception to March 2026. No language or date restrictions were applied. The search strategy was peer-reviewed by BC and AI using the Peer Review of Electronic Search Strategies (PRESS) checklist and evaluated against the PRISMA-S guidelines.[22,23] The full search strategies used are shown in the supplementary appendix.

Study Inclusion/Exclusion Criteria

Clinical studies that investigated the effects of dangling on flap success following lower limb free flap surgery were included. Letters to the editor, narrative studies, in vitro, and animal or cadaveric studies were excluded.

Included articles had the following characteristics:

1. Studies involving patients undergoing lower limb free flap reconstruction.
2. Case series, cohort studies, or randomized controlled trials.
3. Studies reporting a defined postoperative dangling protocol (early or late dangling) or unrestricted mobilization without formal dangling.
4. Outcome measures related to flap success, flap loss, and complications.

Excluded articles had the following characteristics:

1. Articles not reporting original research (e.g., narrative review articles).
2. Conference abstracts that have not been published as full-text publications.
3. Duplicate publications (i.e., articles that have been previously published as full-text publications).
4. Studies conducted using non-human (animal) data.

Study selection and Data extraction

Study selection by title and abstract screening was performed independently by two reviewers (AI, BC); any disagreements or discrepancies were resolved through discussion with a third reviewer (CP).

Data were extracted on study design, number of patients, average age of patients, dangling protocol, follow-up, and outcomes. The primary evaluation criterion was flap success.

Statistical Analysis

We used descriptive and quantitative methods to synthesize the results of this systematic review. Mean age was extracted when reported.

Because most included studies did not report comparative effect measures, pooled analyses focused on single-arm flap survival proportions rather than head-to-head comparisons between dangling protocols. Subgroup comparisons therefore represent between-study comparisons and are susceptible to confounding by differences in patient populations, flap types and co-interventions; they should not be interpreted as estimates of the effect of dangling itself. Where a study contributed more than one arm, arms were entered into the relevant subgroups separately, so subgroups are not fully independent.

Accordingly, a single-arm meta-analysis of flap survival proportions was performed. Flap survival proportions were pooled using random-effects models to account for between-study variability. Fixed-effects estimates were calculated for comparison. The random-effects model was used as the primary estimate to account for between-study variability. Statistical heterogeneity was assessed using the Cochran Q test and the I^2 statistic. A p-value < 0.05 for the Q statistic was considered indicative of significant heterogeneity. Sensitivity analyses were performed using Baujat plots to assess the contribution of individual studies to overall heterogeneity and pooled effect estimates.[24]

Prespecified subgroup analyses were conducted to explore potential sources of clinical heterogeneity. These included subgroup analyses according to:

1. Timing of the dangling protocol (early dangling, late dangling, or no dangling), and
2. Mean age of the study population (< 45 years vs ≥ 45 years).

The age threshold of 45 years was chosen to approximate the median age across included cohorts. In both subgroup analyses, pooled flap survival estimates were calculated using random-effects models.

Results were visualized using forest plots. Statistical significance was set at $\alpha = 0.05$. All analyses were performed using R software (version 4.3.2).

Meta-analyses were performed using the meta and metafor packages in R.

Quality Assessment

Study quality was appraised independently by three reviewers (BC, AI, and CP). The risk of bias was evaluated using the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) (Table 1)[12,13] and the Revised Cochrane Risk of Bias Tool for Randomized Trials (RoB-2) (Table 2).[7,9,14] Single-arm cohort studies, case series, physiologic studies, and survey/protocol reports were not formally assessed using these tools because they did not estimate comparative intervention effects and were included solely for narrative or mechanistic context.

Table 1
Risk of bias of studies included in this review using the ROBINS-I tool

Study	D1 Confounding	D2 Classification of interventions	D3 Selection of participants	D4 Missing data	D5 Measurement of outcome	D6 Selection of reported result	Overall ROBINS-I V2
Al-Khalil 2023[12]	Serious	Low	Moderate	Low	Moderate	Serious	Serious
Su 2025[13]	Serious	Low	Moderate	Low	Moderate	Serious	Serious

Table 2
Risk of bias for studies included in this review using ROB-2 tool

Trial (Ref)	D1 Bias from randomization process	D2 Bias due to deviations from intended interventions	D3 Bias due to missing outcome data	D4 Bias in measurement of outcome	D5 Bias in selection of reported result	Overall RoB-2
Jokuszies 2013 (POD 3 vs POD 7; wrap+dangle)[9]	Some concerns (sequence/concealment incompletely described)	Low (protocolized inpatient care)	Low	Some concerns (non-blinded team; outcomes largely objective)	Some concerns (no prereg protocol detail)	Some concerns
Neubert 2016 (early aggressive vs late; microdialysis RCT)[7]	Some concerns	Low	Low	Low	Some concerns	Some concerns
Krijgh 2025 (dangling vs no-dangling)[14]	Low (multicenter randomization)	Low	Low	Low	Low	Low

Results

Study Selection and Characteristics

The search identified 3,007 records after removal of duplicates, of which 18 studies (Table 3) met inclusion criteria (Figure A1), representing 845 reported patients or cases. These included 11 clinical outcome studies (601 patients),[7–14,25–27] five physiologic studies (92 patients),[4–6,28,29] one case report (2 patients),[30] and one survey-based protocol study describing 150 clinical cases.[31]

Table 3
Clinical studies reporting outcomes of dangling or mobilization protocols

Author (Year)	Study design	Study population (n)	Mean age (years)	Postoperative dangling / mobilization protocol	Comparison groups	Flap survival	Complications	Return to Theater	Len Sta
Isenberg et al. 1997[6]	Prospective physiologic study	20	32	Hemodynamic testing in elevated vs dependent positions; no clinical dangling protocol	None	100%	Transient venous congestion on dependency	0	NR
Orseck et al. 2018[8]	Prospective cohort	28	NR	Early ambulation with dependent positioning from POD 1; ~15 min BID	Single-arm	100%	None reported	0	NR
Jokuszies et al. 2013[9]	RCT	31	48	POD 3 vs POD 7; elastic wrapping + dangling 5 min TID, doubling daily to 60 min	Early vs late dangling	100%	1 venous thrombosis before dangling	1	Tot mea 21.6
Neubert et al. 2016[7]	RCT	49	46	POD 3 vs POD 7; wrapping + graded dangling 5→60 min TID over 5 days	Early vs late dangling	100%	None reported	NR	LOS trai vs 2
Yim et al. 2024[11]	Prospective cohort (ERAS)	161	40 (median)	POD 3: 5 min; POD 4: 10 min; 6×/day; progressive mobilization with ERAS pathway	Single-arm	94.60%	9 flap failures	18	Tot me (6– flap (4–
Al-Khalil et al. 2023[12]	Retrospective cohort	32	43	Early (POD 3–4) vs delayed weight-bearing	Early vs delayed weight-bearing	97%	1 flap loss each group	NR	Pos LOS 7.1 (tot 12.1
Su et al. 2025[13]	Retrospective cohort	83	39.3	Early ≤ POD 5 vs late > POD 5; dangling 5→10→15→20 min TID	Early vs late dangling	90.9 vs 90.2%	NR	NR	Pos LOS 18.8 LOS 35.3
Krijgh et al. 2025[14]	Multicenter RCT	75	58	POD 7: dangling 5→10→20→30→45→60 min TID × 6 d vs unrestricted dependency	Dangling vs no dangling	~ 97%	Partial necrosis 5.1% vs 2.8%; no total losses	15	Pos LOS 14 v
Knobloch et al. 2012[25]	Retrospective cohort	75	53	POD 7: elastic wrapping + dangling 3×5 min/day; duration increased thereafter	Single-arm	95%	4 flap losses	NR	NR
Henton et al. 2015[4]	Prospective physiologic study	8	40	POD 5: flap training 5 min/hour dangling; POD 6: 10 min/hour; POD 7: mobilization on crutches following 5 days limb elevation	Elevated vs dependent limb perfusion measurements	100%	1 hematoma; 1 venous compromise	2	7–1
Okochi et al. 2017[30]	Case report	2	62	POD 7: dangling 30 min BID → POD 9–10: 60 min BID → POD 11–12: 90 min BID → POD ≥ 13: unrestricted; active ankle motion from POD 3	None	100%	NR	0	NR
Lindelauf et al. 2023[28]	Prospective physiologic study	10	54	POD 7: dangling protocol with progressive dependency; tissue oximetry measured during dangling	None	100%	NR	0	NR
Miyamoto et al. 2014[26]	Retrospective cohort	13	56.6	POD 1: wheelchair mobilization; dangling within 1 week; early ambulation encouraged depending on wound condition	Single-arm	100%	1 partial flap necrosis	0	LOS (cas exa
Pu LLQ 2017[10]	Retrospective case series	28	44 (range 19–70)	Bed rest POD 1–3; out-of-bed POD 4; dangling protocol started at 1 week (5 min hourly increasing to 15 min hourly); progressive	Single-arm	100%	Hematoma 1; wound dehiscence 1; flap	0	NR

POD = postoperative day; LOS = length of stay; BID = twice daily; TID = three times daily; d = day(s); NR = not reported

Author (Year)	Study design	Study population (n)	Mean age (years)	Postoperative dangling / mobilization protocol	Comparison groups	Flap survival	Complications	Return to Theater	Len Sta
				weight-bearing from week 3			elevation for subsequent orthopedic procedures 3; additional skin grafting 2; flap debulking 2		
O'Neill et al. 2010[31]	Survey study with protocol description	Survey of 11 UK units; protocol based on 150 clinical cases	NR	Dangling started POD 4: 10 min dependent followed by 30 min elevation, 4× AM and 4× PM; mobilization from POD 5	None	98% (protocol series)	3 late flap losses due to DVT	8 (all salvaged)	NR
Seth et al. 2017[27]	Retrospective cohort	26	53.6	Early dangling protocol: POD 2 start 5 min TID; increased by 5 min daily to 20 min TID by POD 5; monitoring with Doppler and tissue oximetry	Single-arm	96.20%	Partial flap loss 1; wound dehiscence 3; venous thrombosis 2	2	Mea 7.9 exc reo
Kolbenschlag et al. 2015[5]	Prospective observational physiologic study	39	53.1	Standardized dangling starting POD 6 after 5 days bed rest; 5 min TID on POD6, increased + 5 min/day to 20 min by POD9; leg dependent with knee flexed 90°	None	100% (no clinical flap failure reported)	NR	NR	NR
Dornseifer et al. 2017[29]	Prospective physiologic study	15	54.4	Early full mobilization using tilt-table upright positioning from POD 3; 5 min/day with perfusion monitoring; interval increased progressively	None	100%	NR	0	NR

POD = postoperative day; LOS = length of stay; BID = twice daily; TID = three times daily; d = day(s); NR = not reported

Dangling Protocol Characteristics

Postoperative dependency regimens varied substantially with respect to initiation day, escalation schedule, duration, and integration with broader rehabilitation pathways. Early protocols generally began between postoperative day (POD) 1–5, whereas late protocols typically began on POD6-7. Most structured protocols started with 5-minute sessions and escalated over several days to 20–60 minutes, most commonly 3 times daily. Several more recent studies incorporated limb dependency within early mobilization or ERAS pathways rather than strict time-based dangling schedules.

Among the 18 included studies, protocol orientation was as follows:

- Early dangling / early dependency: 12 studies, 516 patients[4,6–9,11–13,26,27,29,31]
- Late dangling: 9 studies, 298 patients[5,7,9,10,13,14,25,26,28]
- No formal dangling / unrestricted mobilization: 1 study, 36 patients[14]

Because several comparative studies evaluated more than one protocol arm, these groupings reflect study-level classification rather than mutually exclusive patient-level totals, and patient numbers may overlap across categories.

Flap Survival

Across all included studies, 27 flap losses were identified, corresponding to an overall survival of 96.8%. Pooled estimates demonstrated consistently high flap success (97–98%), with no significant heterogeneity (Q-test p = 0.992; $I^2 \approx 0\%$). Subgroup analyses showed no significant differences in survival between early, late, or no-dangling strategies ($p > 0.05$), nor between age groups. See meta-analysis (Figs. 1–7).

Complications and Return to the Operating Room

Complications were infrequent and inconsistently reported, but pooled descriptive analysis across all studies (n = 845) suggested low event rates:

- Wound dehiscence: 4 cases among studies reporting this outcome
- Partial flap necrosis: uncommon (reported in small numbers; e.g., dangling 5.1% vs non-dangling 2.8% in one RCT, otherwise sporadic)[14]
- Venous thrombosis / vascular compromise: rare and inconsistently reported
- Hematoma: isolated cases only

Across both comparative and non-comparative studies, there was no signal that early dangling or unrestricted mobilization increased complication rates compared with delayed protocols.

Return to theater was reported in 13 studies, with 46 events among 567 patients or cases (8.1%; range 0–20% across studies). Reoperations were primarily for vascular compromise, hematoma evacuation, or planned revision, with no clear association with postoperative protocol.

Where reported, early mobilization or ERAS-based pathways were generally associated with similar or shorter hospital stays. Early dangling shortened stay by about 2 days in two randomized trials[7,9] and postoperative stay by 6.5 days in one cohort,[13] whereas postoperative stay was 8.0 vs 7.1 days with early vs delayed weight-bearing in another cohort[12] and median 14 vs 13 days with dangling vs unrestricted mobilization in one randomized trial.[14]

Meta-analysis

Flap Success Rate

All 18 included studies reported the flap success rates, although each had very different dangling protocols and interventions. Most studies lacked an intervention or control group. Al-Khalil et al. considered two groups of patients with pre and post enhanced protocols.[12] Jokuszies et al. and Su et al. considered two groups of patients with early and late initiation of dangling protocols; however, their definitions of early and late initiations differ.[9,13] Due to the differences in dangling protocols, flap types and the main objectives of the studies, we have decided to combine all the groups to compare the flap success rates among the studies. The forest plot from the single-arm meta-analysis of the flap success rates of the 18 studies is shown in Fig. 1. The fixed effect model produces a pooled estimate of flap success rate of 97% (95% CI: 95%–98%). A random effects model produces a pooled estimate of the flap success rate of 98% (95% CI: 95%–99%). These estimates are not very different indicating that the pooled estimates are not too sensitive to the choice of the model. The heterogeneity among the studies is $I^2 = 0.0\%$ (p-value = 0.992), indicating that the study results are not very heterogeneous.

Figure 2 shows the funnel plot for the above meta-analysis, used to check for publication bias. We observe that only Su et al. has a slightly lower reported flap success rate compared to its standard error.[13] All other studies are within the 95% confidence intervals of the pooled estimates, and we do not suspect any publication bias.

To check for sensitivity of the studies to the pooled estimate and their contribution to the heterogeneity, we have reported a Baujat plot in Fig. 3, which plots the contribution of individual studies by removing them one at a time and recomputing the pooled estimates and the heterogeneity.[24] We observe that the contribution of Su et al in both pooled estimate and the heterogeneity is high.[13] O'Neill et al. has a slightly higher contribution to overall heterogeneity but little influence on the pooled estimate.[31] Yim et al., Knobloch et al., and Al-Khalil et al. have a slightly larger influence on the pooled estimate but they have very little contribution toward the overall heterogeneity.[11,12,25] However, as the overall heterogeneity is low, none of these studies are highly sensitive to the meta-analysis results.

All studies except Orseck et al. and O'Neill et al. reported the average age of the patients; to investigate whether there were any differences in flap success rates between age groups, we ran a subgroup analysis with two age groups (below and above 45 years).[8,31] From Fig. 4, we see that the pooled random effects estimate of the flap success rate for studies with average age above 45 years is 99%, while that for studies with average age below 45 years is 94%. However, there was no significant subgroup difference ($\chi^2(1) = 2.10,\ p = 0.147$).

Comparison of Dangling Groups

Figure 5 shows the meta-analysis of the flap success rates comparing the studies with early, late or no initiation of the dangling protocols. Jokuszies et al., Miyamoto et al., Neubert et al., and Su et al. consider both early (POD3 or earlier) and late initiation of the dangling protocols.[7,9,13,26] Krijgh et al. compare a late dangling protocol (POD7) against no dangling at all.[14] We observe that the pooled estimate of the flap survival among all early dangling studies is 97% (95% CI: 94%–99%) and the pooled estimate among all late dangling studies is 97% (95% CI: 90%–99%). The heterogeneity in each group is insignificant with $I^2 = 0.0\%$. Overall heterogeneity is also insignificant with $I^2 = 0.0\%$ (p-value = 0.999). Using the random effects model, there is no significant difference in flap survival between dangling subgroups ($\chi^2 = 0.01,\ p = 0.999$).

The funnel plot in Fig. 6 does not show any publication bias, though Su et al. has a slightly low standard error compared to its estimate of flap success.[13]

To check for sensitivity of the studies to the pooled estimate and their contribution to the heterogeneity, we have reported a Baujat plot in Fig. 7, which plots the contribution of individual studies by removing them one at a time and recomputing the pooled estimates and the heterogeneity.[24] We observe that the contribution of Su et al for late dangling protocol, in both pooled estimate and the heterogeneity is high.[13] O'Neill et al. has a slightly higher contribution to overall heterogeneity but little influence on the pooled estimate.[31] Yim et al. has a slightly larger influence on the pooled estimate but very little influence on the overall heterogeneity.[11] However, as the overall heterogeneity is low, none of these studies are highly sensitive to the meta-analysis results.[24]

Discussion

Despite substantial heterogeneity in postoperative rehabilitation protocols, reported flap survival rates were consistently high across all strategies.

Is Dangling Necessary?

The pooled single-arm estimates presented here cannot, by design, establish whether dangling improves flap outcomes. What they show is that consistently high flap survival was achieved across studies using very different postoperative regimens, including those with minimal or no formal dangling. Direct comparative evidence is limited. Two randomized trials from the same center compared dangling initiated on POD 3 with POD 7 and found no difference in flap outcomes.[7,9] One multicenter randomized trial compared structured dangling with unrestricted mobilization and found unrestricted mobilization to be non-inferior with respect to partial flap loss (5.1% vs 2.8%).[14] However, randomization in that trial occurred on POD 7, so its findings apply to dangling after the first postoperative week, and its confidence interval was wide (− 10% to 15%) with 75 participants. A recent retrospective cohort similarly found no difference in flap survival between patients managed with and without a formal inpatient dangling protocol, but a longer hospital stay with the protocol.[32]

Taken together, current comparative evidence has not demonstrated that formal dangling improves flap survival. This should be interpreted as an absence of demonstrated benefit rather than as proof that dangling has no effect; adequately powered comparative studies would be required to exclude a clinically relevant benefit.

Timing of Dependency

Where dependency is incorporated into postoperative management, existing evidence suggests early initiation is safe. Studies initiating dependency between POD3 and POD5 have consistently reported outcomes comparable to delayed protocols beginning on POD7.[7,9,13] Some observational cohorts have reported safe initiation as early as POD1-2, although these findings are based on small series and should be interpreted cautiously.[8,26]

Overall, current data provide no evidence that delaying dependency beyond the first postoperative week improves outcomes.

Duration and Structure of Dangling

When dangling is used, protocols typically involve short, incremental sessions beginning at approximately five minutes and gradually increasing to 30–60 minutes over several days.[7,9] Physiologic monitoring studies demonstrate transient decreases in tissue oxygenation during dependency followed by rapid recovery with limb elevation, with progressive adaptation over successive sessions.[4–6,28]

These findings suggest that brief, graded exposure appears to be physiologically tolerated and may support the use of shorter, more flexible protocols rather than prolonged dependency restrictions.

Heterogeneity of Postoperative Protocols

One of the most striking findings across the literature is the substantial variability in dangling protocols. Some programs incorporate no formal dangling at all,[14] while others use multi-day stepwise dependency schedules.[5,7,9–11,13,14,25,27,30,31] Despite these differences, reported flap survival was consistently high, suggesting that strict adherence to a specific dangling protocol may be less important than careful monitoring, coordinated orthoplastic care, and early functional rehabilitation.

Exploratory Age Subgroup Analysis

An exploratory subgroup analysis evaluated whether mean patient age influenced flap survival estimates across studies. Although pooled survival appeared numerically higher in studies with older mean patient populations, no statistically significant difference was identified between age groups.

This analysis was performed to explore whether patient demographic differences might partially explain variability between study cohorts; however, the findings should be interpreted cautiously given the study-level nature of the analysis and limited number of included studies.

Limitations

Several limitations should be acknowledged. First, many included studies were observational or single-arm cohorts, limiting the ability to infer causal relationships between dependency protocols and outcomes. Second, postoperative protocols varied widely in timing, duration, and integration with broader rehabilitation pathways, introducing clinical heterogeneity. Third, the pooled flap-survival analysis included physiologic studies, a case report and a survey-based protocol series, which report few clinically relevant events and may inflate pooled survival estimates. Fourth, the limited number of studies contributing to quantitative synthesis restricts the precision of subgroup analyses and limits interpretation of publication bias. Fifth, because pooled analyses were based on single-arm proportions, comparisons between dangling strategies were between-study comparisons and are vulnerable to confounding; they cannot estimate the effect of dangling itself. Sixth, the two randomized trials comparing early and late dangling were conducted at the same institution with similar protocols, and may include overlapping patients, which could overweight their findings. Seventh, certainty of evidence was not formally graded. Finally, comparative cohorts published close to or after the final search were not included in the quantitative synthesis, although their findings are consistent with ours.[32,33]

Clinical Implications

Within the limits of the available evidence, prolonged dangling protocols have not been shown to improve flap survival. Two approaches are consistent with current, largely low-level evidence:

1. Unrestricted mobilization without formal dangling, supported by a single randomized trial in which unrestricted mobilization began on POD 7.[14]
2. Early, brief dangling protocols beginning around POD3-5, for centers that prefer a structured dependency schedule.[7,9,11,12]

Both approaches have been associated with high flap survival while facilitating earlier mobilization and potentially shorter hospital stays.

Research Priorities

Future studies should include adequately powered multicenter randomized trials comparing early mobilization with and without formal dangling within standardized ERAS frameworks. Standardized outcome reporting, including partial flap necrosis, return to the operating room, infection, venous thromboembolism, time to mobilization and length of stay, would improve comparability across studies, and trials should also incorporate patient-reported outcome measures, patient satisfaction and longer-term functional outcomes, which are rarely reported in the current literature. The psychological burden of prolonged postoperative bed rest in this population also remains understudied.[34] Finally, work linking physiologic perfusion monitoring with clinically meaningful outcomes may help clarify how flaps adapt to dependency.

Conclusion

Consistently high flap survival has been reported after lower-extremity free tissue transfer across a wide range of dangling practices, including early dangling and unrestricted mobilization. Available comparative evidence, which is limited, has not demonstrated that formal dangling protocols improve flap survival, while earlier mobilization has been associated with comparable or shorter hospital stay. Adequately powered randomized trials within standardized enhanced recovery pathways, including patient-reported outcomes, are needed to determine whether and when formal dangling is required.

Declarations

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions: study conception and design; literature search and screening (BC, AI); adjudication (CP); data extraction; risk-of-bias assessment (BC, AI, CP); statistical analysis; drafting and critical revision; approval of the final manuscript (all authors).

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Figures

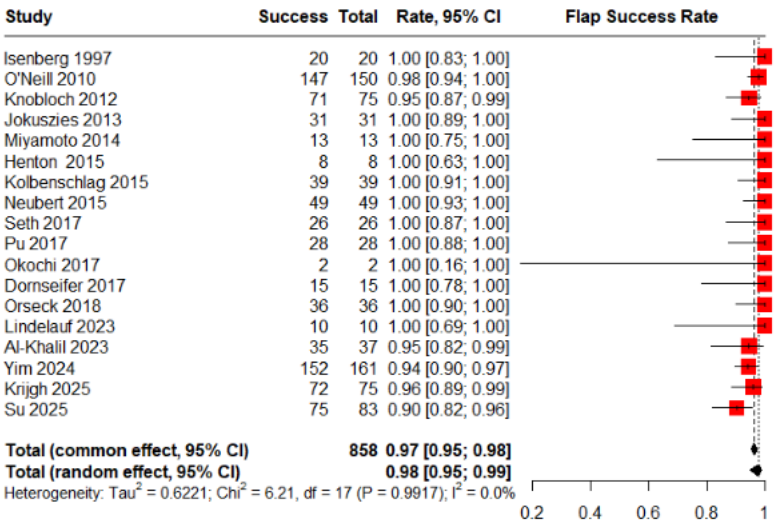


Figure 1

Forest plot of the meta-analysis for flap success rates using fixed and random effects models.

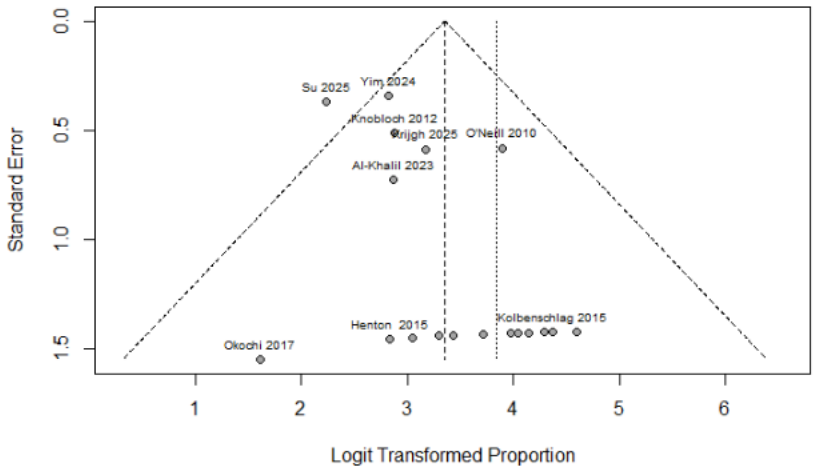


Figure 2

Funnel plot of the meta-analysis for flap success rates using fixed and random effects models. The dotted line is the pooled random effects estimate, and the dashed lines are pooled estimate and 95% C.I. from the fixed effects model.

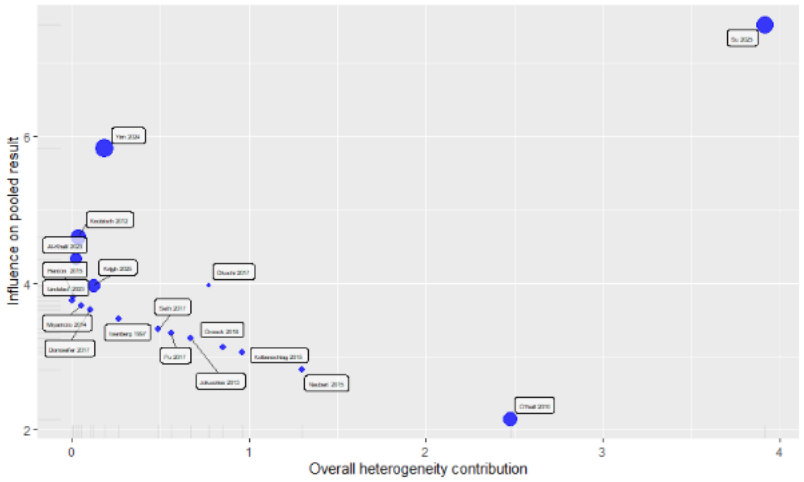


Figure 3

Baujat plot for sensitivity analysis of the included studies in the overall flap-success meta-analysis.

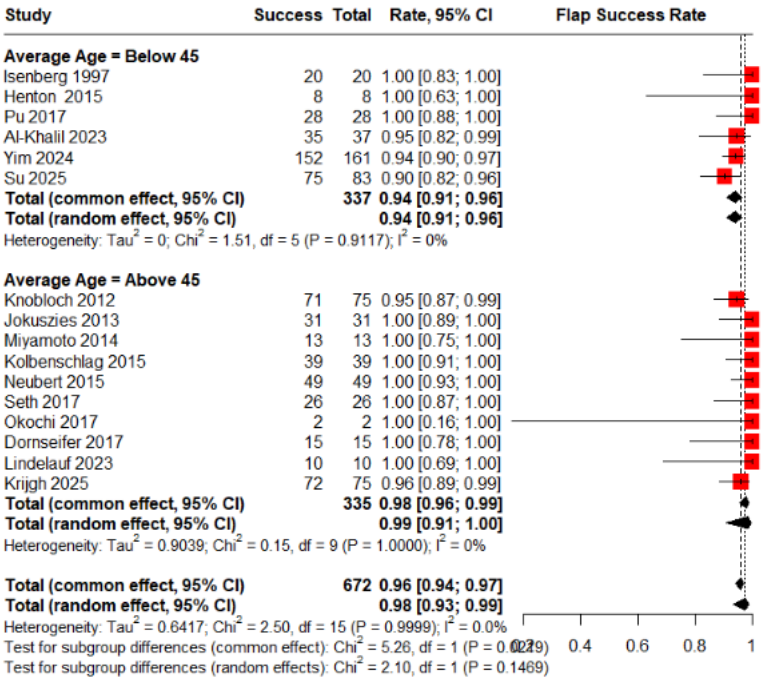


Figure 4

Subgroup analysis of the flap-success rates with reported average age of the patients.

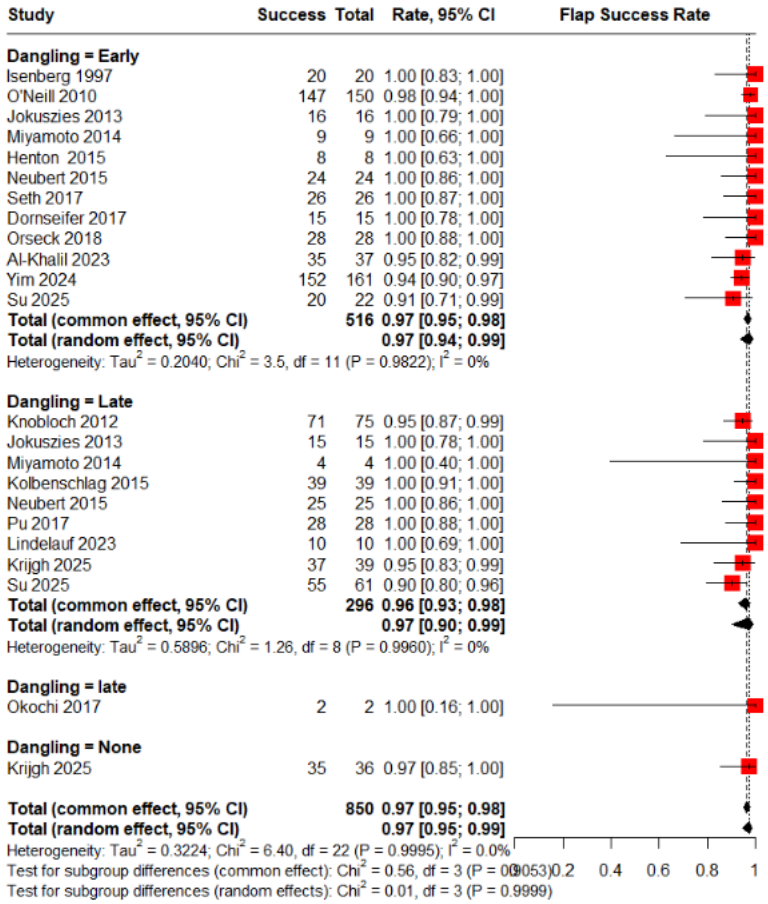


Figure 5

Subgroup analysis of the flap success rates based on initiation of the dangling protocols.

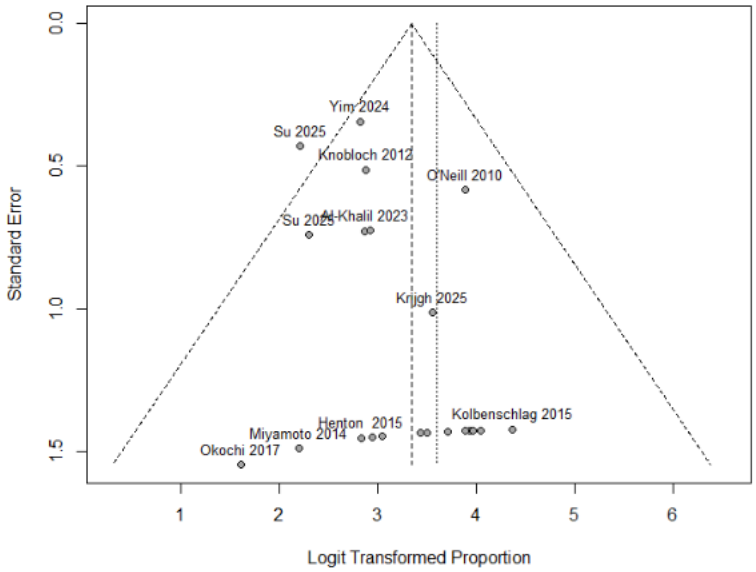


Figure 6

Funnel plot of the flap survival rates considering different dangling procedures as separate studies.

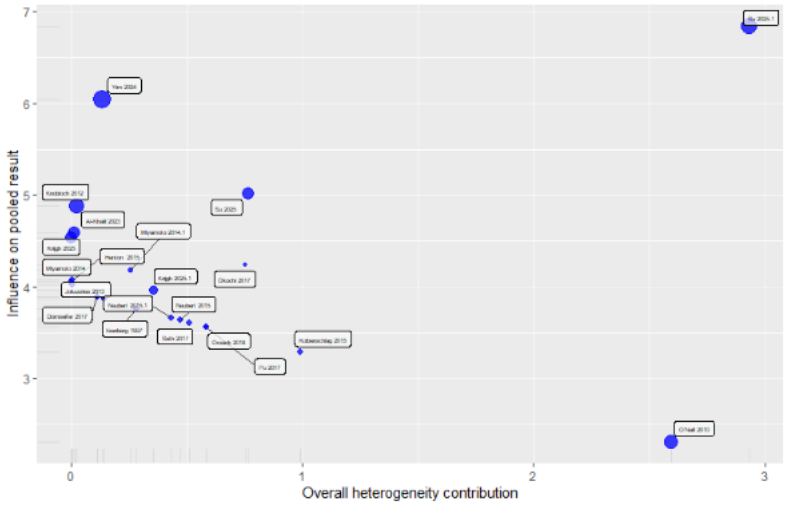


Figure 7

Baujat plot for sensitivity analysis of the included studies in the dangling-strategy subgroup analysis.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- PRISMA2020checklist1.pdf
- Appendix.docx