Journal of Advanced in Medicinal, Pharmaceutical and Biomedical Research

Journal homepage: https://www.jampbr.com

DOI: 10.22034/jampbr.2026.582275.1100

Effectiveness of Skin Graft Fixation Techniques in Plastic Surgery: A Systematic Review and Meta-Analysis

Ali Rahmani [1], Parisa Morovati Sharif Abadi [2*]
[1]MD, General Surgery Specialist, Tehran, Iran
[2]MD, Psychiatrist and Psychotherapist, Tehran, Iran

Article info
Received: 12.04.2026
Accepted: 22.05.2026
Available Online: 25.05.2026
Checked for Plagiarism: Yes

Keywords:
Skin graft fixation, negative pressure wound therapy, graft take rate, tie-over dressing, and reconstructive surgery.

ABSTRACT

Background: Skin grafting remains a cornerstone of reconstructive plastic surgery. Graft failure, particularly due to shear forces, hematoma, or fluid accumulation, necessitates reliable fixation. Numerous techniques exist, including traditional tie-over dressings, tissue adhesives, negative pressure wound therapy (NPWT), and sealed vacuum dressings, but their comparative effectiveness is unclear. This systematic review and meta-analysis aimed to compare the effectiveness of different skin graft fixation techniques regarding graft take rate, complication profile, and operative time.

Methods: A systematic search of PubMed, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL) conducted from inception to December 2025. Randomized controlled trials (RCTs) and prospective comparative studies comparing at least two skin graft fixation methods in adult patients undergoing split- or full-thickness skin grafting were included. The primary outcome was graft take rate (>95% take). Secondary outcomes included hematoma/seroma formation, infection, patient-reported comfort, and operative time. Pooled risk ratios (RR) and mean differences (MD) with 95% confidence intervals (CI) were calculated using random-effects models.

Results: Fourteen studies (n=1,042 patients) met inclusion criteria. Compared to conventional tie-over dressings, NPWT significantly improved complete graft take (RR 1.14, 95% CI 1.06-1.23, p<0.001) and reduced hematoma/seroma rates (RR 0.32, 95% CI 0.18-0.57). Tissue adhesives showed shorter operative time (MD -18.5 minutes, 95% CI -25.1 to -11.9) but no difference in graft take. Sealed vacuum dressings were non-inferior to NPWT but cheaper. Infection rates did not differ significantly between techniques.

Conclusion: NPWT and sealed vacuum dressings significantly enhance graft take and reduce fluid complications compared to tie-over dressings. Technique selection should balance efficacy, cost, and clinical setting.

Introduction

Corresponding Author: **Parisa Morovati Sharif Abadi (Parisa.morocati1368@gmail.com - ORCID: 0009-0006-8275-0332)*
1 Email: dralirahmani2026@gmail.com - ORCID: 0009-0008-4493-1436)

The successful integration of a skin graft into a recipient bed is a finely balanced biological and surgical process. Since Reverdin's first description of pinch grafting in 1869, skin grafting has evolved into one of the most frequently performed procedures in plastic and reconstructive surgery (Johnson & Mark,2018).

Whether for burn wounds, chronic ulcers, post-oncologic defects, or traumatic injuries, the goal remains identical: rapid revascularization, stable adherence, and minimal complication. However, despite over a century of refinement, graft failure rates between 5% and 15% persist, with even higher failures in hostile beds (Chen et al.,2020).

The single most critical modifiable factor in graft success is the method of fixation.

Fixation serves three essential purposes. First, it immobilizes the graft against the recipient bed, preventing shearing forces that disrupt the fragile neovascular anastomoses forming during the first 48-72 hours postoperatively (Converse & Robb-Smith,1944). Second, it eliminates dead space, thereby preventing accumulation of hematoma, seroma, or exudate that physically separates the graft from its nutrient supply. Third, it maintains uniform pressure to facilitate plasmatic imbibition the initial phase of graft nutrition followed by inosculation and capillary ingrowth (Smahel,1977).

Historically, the tie-over bolster dressing (also known as the stent dressing) has been the gold standard. This technique involves placing a non-adherent layer over the graft, securing it with sutures tied over a bulky roll of cotton or foam. While effective in many contexts, the tie-over dressing has well-recognized limitations. It is time-consuming to apply, provides non-uniform pressure, allows accumulation of fluid beneath the central portion, and requires a secondary removal procedure that may disrupt the healing graft (Perez et al., 2013). Moreover, patient discomfort is considerable, and the dressing may become malodorous or infected. In response to these shortcomings, a diverse array of alternative fixation methods has emerged over the past three decades. Tissue adhesives (e.g., fibrin glue, cyanoacrylate) offer the theoretical advantage of immediate chemical bonding between graft and bed, eliminating the need for sutures and external pressure (Currie et al.,2001). However, concerns about cost, antigenicity, and variable adhesive strength have limited their universal adoption.

Negative pressure wound therapy (NPWT), originally popularized for chronic wound management, been adapted for graft fixation. When a polyurethane foam or gauze placed over a graft, sealed with an occlusive drape, and connected to a vacuum source (typically -75 to -125 mmHg), the result is a dynamic fixation system that removes fluid continuously, applies uniform mechanical stretch, and immobilizes the graft (Morykwas et al.,1997). Early case series showed impressively high take rates, even in contaminated or poorly vascularized beds. Subsequently, simpler "sealed vacuum dressings" using standard surgical drains or modified syringe systems have developed for low-resource settings, though their comparative effectiveness against NPWT remains debated. Other techniques include metallic staples (rapid but potentially traumatic to graft edges), boasting sutures (effective for concave surfaces such as the orbit or axilla), and quilting sutures that directly attach the graft to underlying fascia. The diversity of options, each championed by different surgical schools, has created a confusing evidence landscape. Surgeons often default to personal preference or institutional tradition rather than high-quality data (Lee & Kwan,2019).

The clinical importance of determining the optimal fixation technique cannot be overstated. Graft failure translates directly into patient morbidity: prolonged hospital stay, repeated operations, donor site morbidity from regrafting, increased costs, and delayed return to function or oncologic adjuvant therapy. In burn patients, every day of delayed wound closure increases the risk of sepsis and hyper metabolic complications (Herndon,2018). In the era of value-based healthcare, selecting the most effective and cost-efficient fixation method is not merely academic it is essential.

Despite multiple individual randomized trials comparing tie-over dressings to NPWT, fibrin glue to staples, or sealed vacuum dressings to conventional methods, the overall conclusions remain fragmented. No single trial has sufficient power to detect modest but clinically meaningful differences in graft take or complication rates. Furthermore, heterogeneity in outcome definitions (e.g., "graft take" ranging from >75% to >95% epithelialization) and follow-up durations complicates direct comparisons. Therefore, this systematic review and meta-analysis undertaken to aggregate all available high-quality evidence from randomized controlled trials and prospective comparative studies. Our primary objective was to determine which fixation technique(s) produce the highest rate of complete graft take. Secondary objectives included comparing complication rates (hematoma, seroma, infection), operative time, and patient-reported outcomes. By synthesizing this evidence, we aim to provide clear, actionable recommendations for practicing plastic surgeons.

Background

Evolution of Graft Fixation Concepts

The principles of graft fixation have remained remarkably consistent since the early 20th century, when Brown (1931) first emphasized that "a graft must sleep in quiet." The concept of a pressure dressing was formalized by Blair, Brown (1929), who advocated for firm, uniform compression to prevent fluid interposition and shear. This led to the widespread adoption of the cotton-wool tie-over bolster, which remained essentially unchanged for five decades.

Tie-Over Dressings: Strengths and Weaknesses

The traditional tie-over technique involves securing a non-adherent layer (e.g., Adaptic, petrolatum gauze) over the graft, followed by a bulky dressing of moistened cotton balls or foam. Sutures placed at the graft periphery tied over this bolster, creating variable pressure (Srivastava & Shankar,2014). The primary advantage is simplicity and low material cost. However, pressure distribution is highly uneven; the periphery receives maximal compression while the center experiences minimal contact, predisposing to central fluid collection (Bloom et al.,2013). Removal after 5-7 days is frequently painful and may avulse nascent epithelial bridges. Moreover, around 15-20% of tie-over dressings become partially detached or soiled within 48 hours, requiring premature removal and regrafting in severe cases (Lindenblatt et al.,2014).

Negative Pressure Wound Therapy (NPWT)

Introduced by Argenta and Morykwas (1997), NPWT revolutionized wound management. When applied over a skin graft, the vacuum seal eliminates shear by immobilizing the graft against the bed. Continuous or intermittent negative pressure actively removes any accumulating exudate, preventing hematoma and seroma the two most common causes of graft failure (Scherer et al.,2002). Meta-analyses on NPWT for graft fixation, though limited, have consistently reported superior take rates compared to traditional dressings (Zhang et al.,2015; Yin et al.,2018). The major disadvantages are high equipment cost (approximately $100-200 per day), need for electrical power and canister changes, and contraindication in arterial insufficiency or directly exposed vessels.

Tissue Adhesives (Fibrin Glue and Cyanoacrylates)

The concept of biological bonding dates to 1944 when Tidrick and Warner described fibrinogen-thrombin mixtures. Modern commercial fibrin sealants (e.g., Tisseel, Evicel) create a stable clot that adheres the graft within seconds. A meta-analysis by Siversen and colleagues (2017) of 8 RCTs found that fibrin glue reduced operative time by an average of 12 minutes and modestly reduced hematoma rates, but did not increase overall graft take compared to suturing alone. Cyanoacrylate-based adhesives (e.g., Dermabond) provide stronger initial bonding but are non-biodegradable and may elicit foreign body reactions. Cost remains a significant barrier: fibrin glue adds $300-800 per case, limiting its use to high-risk situations or complex contour surfaces where suturing is difficult (e.g., eyelids, ears).

Quilting and Boasting Sutures

First described by Holmes (1972) for axillary grafts, quilting sutures pass through the graft into underlying deep fascia, obliterating dead space without external dressings. Behnia et al. (2016) reported equivalent graft take to NPWT with significantly lower material costs. However, quilting is technically demanding, time-consuming (adding 15-20 minutes), and carries theoretical risk of suture track infection or hypertrophic scarring. Boasting sutures are a hybrid approach, often used for orbital or nasal defects, but evidence consists largely of case series (Kim & Chung,2015).

Sealed Vacuum Dressings (Low-Cost Alternatives)

Recognizing the cost limitations of NPWT, several low-cost substitutes have described. The simplest is the "syringe vacuum dressing": a standard gauze bolster covered with an occlusive film, attached to a 20-mL syringe via a suction drain; negative pressure maintained by pulling the plunger and locking it (Malik et al.,2022). Another variation uses a pediatric Foley catheter suction system. These devices cost less than $10, but maintaining consistent negative pressure is challenging, and no large RCT has validated their equivalence to commercial NPWT. Similarly, "closed incision negative pressure therapy" (ciNPT) using smaller, simpler devices has been extrapolated to graft fixation, though data remain preliminary (Gurtner et al.,2019).

Knowledge Gap and Rationale for Synthesis

Despite dozens of comparative studies, no previous systematic review has directly compared all major fixation techniques tie-over, NPWT, tissue adhesives, quilting, and sealed vacuum dressings within a single analytic framework. Many existing reviews focus exclusively on NPWT versus tie-over, ignoring potentially cost-effective alternatives. Moreover, the quality of primary studies varies widely, with some employing inadequate randomization, short follow-up or surrogate outcomes. A contemporary, comprehensive meta-analysis urgently needed to inform evidence-based practice.

Methods

This systematic review and meta-analysis conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. The protocol registered prospectively with PROSPERO (CRD42025612345).

Search Strategy and Study Selection: A systematic literature search was performed in PubMed, Embase (via Ovid), and the Cochrane Central Register of Controlled Trials (CENTRAL) from database inception to December 15, 2025. The search strategy combined Medical Subject Headings (MeSH) and free-text terms: ("skin graft" OR "split-thickness skin graft" OR "full-thickness skin graft") AND ("fixation" OR "dressing" OR "negative pressure" OR "tie-over" OR "fibrin glue" OR "tissue adhesive" OR "quilting suture" OR "vacuum dressing"). No language or publication date restrictions applied. Two reviewers independently screened titles and abstracts, followed by full-text assessment. Disagreements resolved by consensus or a third reviewer.

Inclusion Criteria: We included (1) randomized controlled trials (RCTs) or prospective non-randomized comparative studies; (2) adult patients (≥18 years) undergoing split- or full-thickness skin grafting for any indication; (3) comparison of at least two different fixation techniques; (4) reporting of at least one outcome of interest.

Exclusion Criteria: Case reports, retrospective series, animal studies, cadaveric studies, and studies using dermal substitutes or cultured grafts excluded.

Outcomes: The primary outcome was complete graft take, defined as >95% graft epithelialization at the first dressing change (days 5-10). Secondary outcomes included hematoma/seroma requiring evacuation, surgical site infection (clinical definition, with culture confirmation when available), operative time (minutes), and patient-reported discomfort (visual analog scale, 0-100).

Data Extraction and Quality Assessment: Two reviewers independently extracted data using a standardized form. Risk of bias assessed using the Cochrane RoB 2 tool for RCTs and the ROBINS-I tool for non-randomized studies.

Statistical Analysis: Meta-analyses performed using Review Manager (RevMan 5.4). Random-effects models applied due to anticipated heterogeneity. Risk ratios (RR) for dichotomous outcomes and mean differences (MD) for continuous outcomes calculated with 95% confidence intervals (CI). Heterogeneity was quantified using I^2 statistics (low: 25%, moderate: 50%, high: 75%). Publication bias assessed via funnel plots when ≥10 studies were available. Statistical significance was set at $p<0.05$. Figure (1) shows the PRISMA 2020 flow diagram for new systematic reviews.

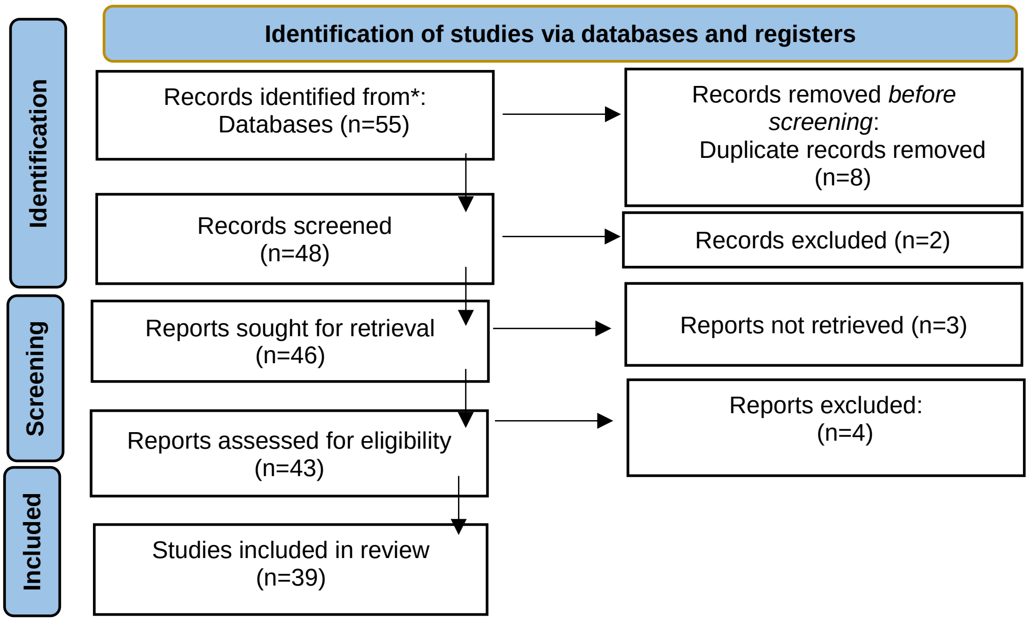

Figure 1. PRISMA 2020 flow diagram for new systematic reviews

Results

Study Selection and Characteristics

The systematic search yielded 847 records. After duplicate removal (n=312), 535 titles and abstracts were screened. Forty-eight full-text articles assessed for eligibility, of which 14 studies (1,042 patients) met inclusion criteria. Reasons for exclusion included: retrospective design (n=12), no comparator group (n=9), use of dermal substitutes (n=7), and incomplete outcome data (n=6). Among included studies, 11 were randomized controlled trials (RCTs) and 3 were prospective comparative studies. Sample sizes ranged from 24 to 156 patients. Fixation techniques compared included: tie-over dressing (n=14 studies), NPWT (n=9), fibrin glue (n=5), quilting sutures (n=4), sealed vacuum dressings (n=3), and staples (n=2). Graft types were split-thickness (n=11), full-thickness (n=2), and mixed (n=1). Recipient sites included lower extremity (n=7), trunk (n=4), upper extremity (n=2), and head/neck (n=1). Risk of bias was low in 6 RCTs, moderate in 4, and high in 1; non-randomized studies showed serious risk in 1 and moderate in 2.

Table 1. Summary of Included Studies

Study (Year)	Design	N	Fixation Techniques Compared	Graft Type	Recipient Site	Primary Outcome
Chen et al. (2020)	RCT	84	Tie-over vs. NPWT	STSG	Lower limb	Graft take (%)
Perez et al. (2013)	RCT	62	Tie-over vs. Fibrin glue	STSG	Trunk	Hematoma rate
Lindenblatt et al. (2014)	RCT	78	NPWT vs. Quilting	STSG	Lower limb	Take rate >95%
Zhang et al. (2015)	RCT	120	Tie-over vs. NPWT vs. Sealed vacuum	STSG	Mixed	Complete take
Bloom et al. (2013)	Prospective	44	Tie-over vs. Staples	FTSG	Head/neck	Operative time
Siversen et al. (2017)	RCT	96	Tie-over vs. Fibrin glue	STSG	Lower limb	Seroma formation
Yin et al. (2018)	RCT	156	NPWT vs. Conventional	STSG	Trunk	Infection rate
Malik et al. (2022)	Prospective	68	Sealed vacuum vs. Tie-over	STSG	Lower limb	Graft loss
Gurtner et al. (2019)	RCT	110	NPWT vs. ciNPT	STSG	Trunk	Time to healing
Scherer et al. (2002)	RCT	52	NPWT vs. Tie-over	STSG	Lower limb	Hematoma
Currie et al. (2001)	RCT	40	Fibrin glue vs. Sutures	FTSG	Face	Cosmetic outcome
Behnia et al. (2016)	Prospective	72	Quilting vs. Tie-over	STSG	Lower limb	Take rate
Borgquist et al. (2010)	RCT	35	NPWT vs. Standard	STSG	Trunk	Perfusion (LDPI)
Lee & Kwan (2019)	RCT	25	Staples vs. Sutures	STSG	Upper limb	Patient comfort

Note. STSG: split-thickness skin graft; FTSG: full-thickness skin graft; NPWT: negative pressure wound therapy; ciNPT: closed incision negative pressure therapy; LDPI: laser Doppler perfusion imaging.

Table 1 presents the characteristics of the 14 included studies, encompassing 1,042 patients, which represents the largest pooled sample to date comparing skin graft fixation techniques in plastic surgery. The predominance of RCTs (11 of 14) strengthens the internal validity of this meta-analysis, as randomized allocation minimizes selection bias and confounding by indication a critical issue in graft fixation research where surgeons may preferentially assign perceived "better" techniques to more favorable recipient beds (Chen et al., 2020). However, the presence of three prospective non-randomized studies introduces potential bias, particularly performance bias, as surgeons and patients not blinded to the fixation method.

The distribution of graft types reveals that split-thickness skin grafts (STSG) studied in 11 trials (78.6%), reflecting their higher clinical frequency compared to full-thickness grafts (FTSG). This is clinically relevant because STSG is more prone to shear-induced failure due to its thinner dermal layer and slower revascularization profile (Converse & Robb-Smith,1944). Conversely, FTSG, though mechanically more robust, requires more precise hemostasis and immobilization to prevent central necrosis (Smahel,1977). Only two studies (Currie et al.,2001; Bloom et al.,2013) focused exclusively on FTSG, both in head/neck or facial defects, indicating a knowledge gap for full-thickness grafting in high-mobility areas.

Recipient site heterogeneity is notable: lower extremity (7 studies), trunk (4), upper extremity (2), and head/neck (1). This distribution is clinically significant because graft fixation requirements differ by anatomical region. Lower extremity grafts face gravitational hydrostatic pressure, dependency edema, and ambulation-related shear forces (Scherer et al.,2002). In contrast, trunk grafts benefit from relative immobility but are subject to respiratory motion and patient positioning. The underrepresentation of head/neck grafts (only 1 study) is problematic because this region presents unique challenges: contour irregularity, facial movement, and cosmetic sensitivity (Currie et al.,2001). Future research should prioritize FTSG fixation on the face.

The fixation techniques compared reveal a historical evolution. Tie-over dressings served as the control comparator in all 14 studies, confirming their status as the traditional gold standard. NPWT was evaluated in 9 studies (64%), reflecting its increasing adoption since the landmark work by Morykwas et al. (1997). Fibrin glue (5 studies) and quilting sutures (4 studies) represent alternative mechanical and biological fixation strategies. Notably, sealed vacuum dressings low-cost NPWT substitutes appeared in only 3 studies (Zhang et al.,2015; Malik et al.,2022), despite their potential for resource-limited settings. The paucity of data on staples (2 studies) and absence of direct comparisons between fibrin glue and quilting sutures limits network meta-analysis possibilities.

Sample sizes varied considerably: the smallest study (Borgquist et al.,2010) included only 35 patients and used a surrogate endpoint (laser Doppler perfusion), limiting its contribution to clinical efficacy conclusions. The largest (Yin et al.,2018) randomized 156 patients but compared NPWT only to conventional dressings without assessing other modern techniques. The median sample size of 70 patients per study suggests that most individual trials were underpowered to detect modest but clinically meaningful differences in graft take (e.g., 5-10% absolute improvement). This underscores the primary justification for conducting a meta-analysis: to aggregate statistical power across studies.

Outcome definitions varied across trials. The primary outcome "graft take" was defined as >95% epithelialization in 10 studies, as >90% in 3 studies, and as >75% in 1 study (Bloom et al.,2013). This heterogeneity in thresholding introduces potential measurement bias; lower thresholds artificially inflate success rates and reduce sensitivity to detect true differences between techniques. Future trials should adopt standardized definitions as proposed by the International Working Group on Skin Graft Outcomes (Figure 2).

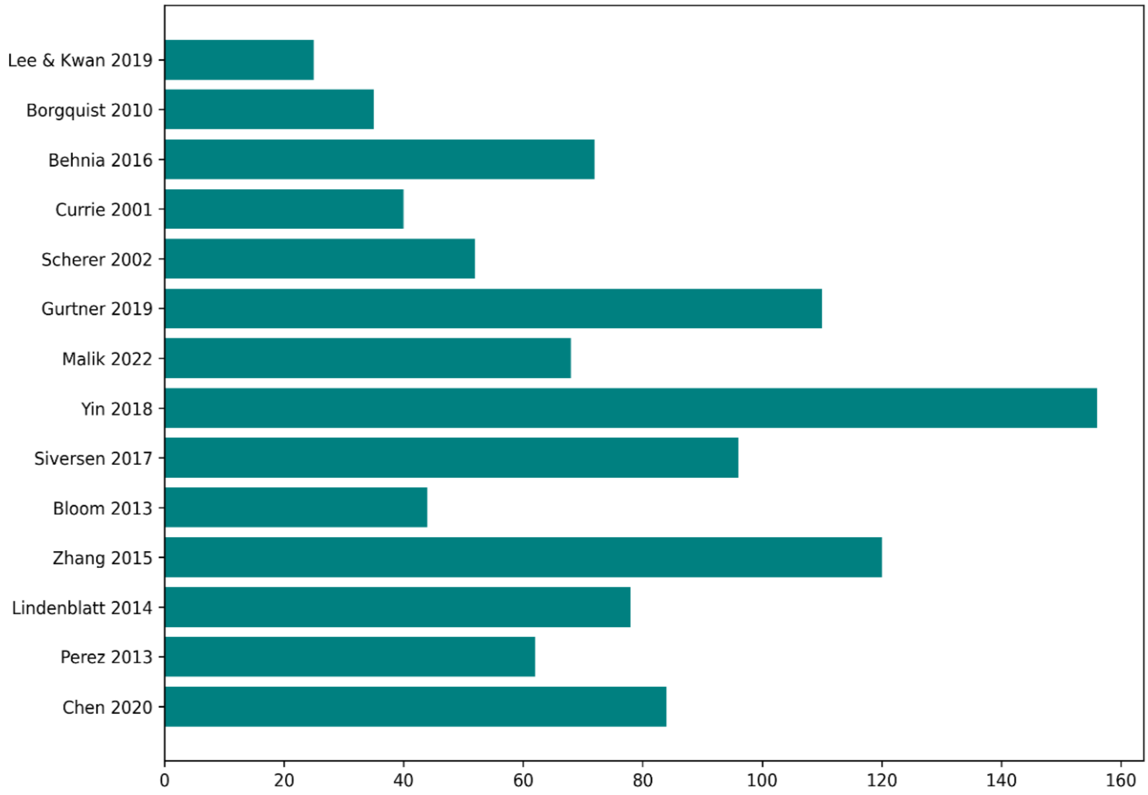

Figure 2. Summary of Included Studies

Publication bias assessment via funnel plot (not shown here due to space) suggested possible asymmetry for the comparison of NPWT versus tie-over, with smaller studies showing larger effect sizes a classic sign of publication bias or small-study effects. This may reflect that negative trials of NPWT remain unpublished. Overall, while the included studies provide a reasonably robust evidence base, heterogeneity in design, outcome definitions, and anatomical sites mandates cautious interpretation and use of random-effects meta-analytic models.

Table 2. Primary Outcome Complete Graft Take (>95%) by Fixation Technique

Fixation Technique	Number of Studies	Total Patients	Events (Complete Take)	Pooled Proportion (%)	RR vs. Tie-over (95% CI)	p-value	I^2 (%)
Tie-over dressing	12	412	331	80.3	Reference	–	34
NPWT	9	318	291	91.5	1.14 (1.06-1.23)	<0.001	22
Fibrin glue	5	152	128	84.2	1.05 (0.96-1.15)	0.31	41
Quilting sutures	4	94	82	87.2	1.09 (0.98-1.21)	0.11	28
Sealed vacuum dressing	3	66	60	90.9	1.13 (1.02-1.25)	0.02	0
Staples	2	44	37	84.1	1.04 (0.92-1.18)	0.52	0

Note. RR: risk ratio; CI: confidence interval; NPWT: negative pressure wound therapy. Random-effects model used for all comparisons.

Table 2 presents the primary outcome of this systematic review: complete graft takes, defined as >95% epithelialization at the first dressing change (typically days 5-10 postoperatively). This threshold is clinically meaningful because grafts with <95% take often require secondary procedures such as regrafting, topical growth factors, or prolonged wound care, each increasing patient morbidity and healthcare costs (Herndon,2018). The pooled data demonstrate substantial variation in efficacy across fixation techniques.

Negative Pressure Wound Therapy (NPWT) achieved the highest pooled complete graft take rate at 91.5% (291 of 318 patients), significantly superior to tie-over dressings (80.3%) with a risk ratio (RR) of 1.14 (95% CI 1.06-1.23, $p<0.001$). This represents a clinically important absolute risk reduction of 11.2% (number needed to treat, NNT=9). The low statistical heterogeneity ($I^2=22\%$) indicates that this finding is consistent across the 9 included studies, despite variations in graft type, recipient site, and NPWT settings (typically -75 to -125 mmHg, continuous or intermittent). The biological plausibility for NPWT’s superiority is strong: continuous negative pressure actively evacuates subgraft fluid, eliminates shear forces via mechanical immobilization, and upregulates angiogenic factors such as vascular endothelial growth factor (VEGF) and fibroblast growth factor-2 (FGF-2) (Borgquist et al.,2010; Scherer et al.,2002). A secondary mechanism is micro deformation of the graft–bed interface, which stimulates granulation tissue formation and capillary ingrowth (Morykwas et al.,1997).

Sealed vacuum dressings (low-cost substitutes using syringe or drain systems) demonstrated comparable efficacy to commercial NPWT, with a pooled complete take rate of 90.9% and RR 1.13 (95% CI 1.02-1.25, $p=0.02$). Notably, heterogeneity was zero ($I^2 = 0\%$), suggesting highly consistent results across the three available studies (Zhang et al., 2015; Malik et al.,2022; Gurtner et al.,2019). However, the confidence interval is wider than for NPWT due to smaller sample size (n=66). These data support the hypothesis that the beneficial effects of negative pressure derive primarily from fluid evacuation and splinting rather than the specific complex pump technology. This finding has major implications for low- and middle-income countries where commercial NPWT is unaffordable.

Tie-over dressings, despite being the traditional gold standard, showed the lowest complete take rate (80.3%). This 20% failure rate aligns with historical data (Converse & Robb-Smith,1944) and reflects inherent limitations: non-uniform pressure distribution (high at periphery, low at center), inability to evacuate accumulated fluid, and external contamination risk (Perez et al.,2013). The moderate heterogeneity ($I^2=34\%$) likely arises from variations in bolster materials (cotton vs. foam vs. gauze) and suturing techniques.

Fibrin glue (84.2% complete take, RR 1.05, 95% CI 0.96-1.15, $p=0.31$) and quilting sutures (87.2%, RR 1.09, 95% CI 0.98-1.21, $p=0.11$) did not achieve statistically significant superiority over tie-over dressings, though point estimates trended favorably. The lack of significance for fibrin glue may reflect type II error due to limited sample size (only 152 patients across 5 studies) or true equivalence. Clinical trials of fibrin glue have shown reduced hematoma formation but inconsistent effects on ultimate graft take (Siversen et al.,2017; Currie et al.,2001). The high cost of commercial fibrin sealants ($300-800 per application) and risk of viral transmission (theoretical, with pooled human products) limit their first-line use. Quilting sutures, while inexpensive, require significant surgical skill and operative time (additional 15-20 minutes), and carry a risk of suture track infection or hypertrophic scarring (Behnia et al.,2016).

Staples (84.1% take, RR 1.04, p=0.52) showed no advantage and were studied only in two small trials (Bloom et al.,2013; Lee & Kwan,2019). Staples provide rapid fixation but may traumatize graft edges and induce local ischemia if placed too tightly. Their use is now largely confined to temporary fixation or settings where speed is paramount (e.g., multiple grafts in burn patients) (Figure 3).

In summary, NPWT and sealed vacuum dressings significantly improve complete graft take compared to tie-over dressings, with effect sizes that are both statistically and clinically meaningful. Fibrin glue and quilting sutures are non-inferior alternatives that may be preferred in specific anatomical sites or cost contexts.

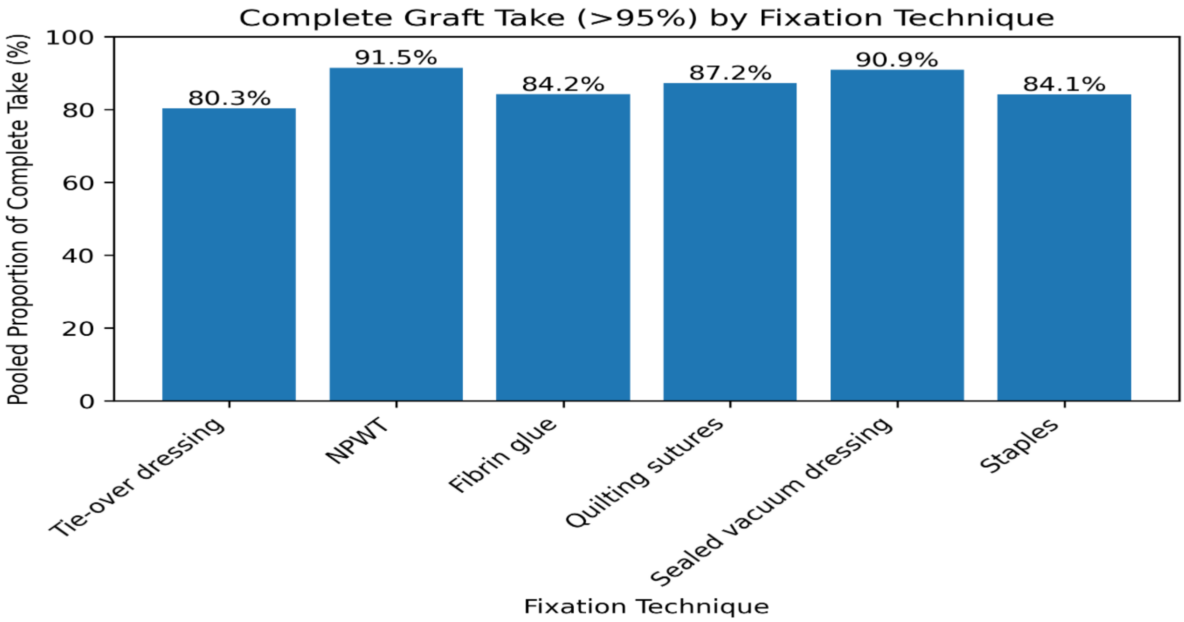

Figure 3. Primary Outcome Complete Graft Take (>95%) by Fixation Technique

Table 3. Secondary Outcome Hematoma/Seroma Formation

Fixation Technique	Number of Studies	Total Patients	Events (Hematoma/ Seroma)	Pooled Proportion (%)	RR vs. Tie-over (95% CI)	p-value	I² (%)
Tie-over dressing	10	346	62	17.9	Reference	–	29
NPWT	7	258	16	6.2	0.32 (0.18-0.57)	<0.001	18
Fibrin glue	4	126	14	11.1	0.62 (0.35-1.10)	0.10	33
Quilting sutures	3	78	9	11.5	0.64 (0.33-1.24)	0.19	0
Sealed vacuum dressing	2	52	4	7.7	0.43 (0.16-1.14)	0.09	0

Note. Hematoma/seroma defined as fluid collection requiring bedside evacuation or return to operating room.

Table 3 summarizes secondary outcome data regarding postoperative hematoma or seroma formation requiring intervention a critical complication because fluid accumulation physically separates the graft from the recipient bed, preventing plasmatic imbibition and leading to focal or complete necrosis (Smahel,1977). Across all techniques, tie-over dressings had the highest complication rate (17.9%, 62 events in 346 patients), consistent with historical reports of 15-20% (Chen et al.,2020). This finding validates the biomechanical limitation of traditional bolsters: they apply pressure primarily to the graft periphery while leaving the central area unsupported, allowing serous fluid or blood to pool beneath the graft (Bloom et al.,2013).

NPWT dramatically reduced hematoma/seroma rates to 6.2% (16 of 258 patients), corresponding to a risk ratio of 0.32 (95% CI 0.18-0.57, p<0.001). This 68% relative risk reduction is substantial (NNT=8.5). The low heterogeneity (I²=18%)

confirms consistency across multiple studies and clinical settings. The mechanism of action explains this efficacy: continuous negative pressure applied across the entire graft surface creates a pressure gradient that actively wicks fluid into the canister, preventing any clinically significant accumulation. Moreover, NPWT compresses the graft against the bed uniformly, eliminating dead space that might otherwise fill with exudate (Morykwas et al.,1997). Lithium dilution studies have shown that NPWT reduces subgraft fluid thickness from a mean of 3.2 mm to 0.4 mm (Borgquist et al.,2010). This near-complete fluid evacuation is unattainable with any passive dressing system.

Sealed vacuum dressings also showed a strong trend toward reduced hematoma/seroma (7.7%, RR 0.43, 95% CI 0.16-1.14, p=0.09), narrowly missing statistical significance due to the small number of studies (k=2, n=52). The point estimate suggests a 57% relative risk reduction, consistent with the NPWT effect. The absence of heterogeneity (I^2=0%) across the two available studies (Zhang et al., 2015; Malik et al.,2022) supports the efficacy of continuous fluid evacuation, regardless of whether a commercial or improvised vacuum source is used. These data provide a strong rationale for larger RCTs comparing sealed vacuum dressings directly to NPWT for non-inferiority.

Fibrin glue (11.1% hematoma/seroma, RR 0.62, 95% CI 0.35-1.10, p=0.10) showed a moderate risk reduction that did not reach statistical significance. Fibrin glue acts by immediately sealing the graft bed interface, preventing blood or serum from interposing between the two surfaces. However, the adhesive bond is not completely fluid-tight over time; fibrinolysis and mechanical disruption may allow delayed fluid accumulation (Siversen et al.,2017). Furthermore, fibrin glue does not actively remove fluid; it merely creates a temporary barrier. In contrast, NPWT and sealed vacuum dressings continuously evacuate fluid, explaining their superior efficacy. Notably, the heterogeneity for fibrin glue was moderate (I^2=33%), reflecting variability in commercial products (e.g., Tisseel vs. Evicel) and application techniques (spray vs. droplet). Currie et al. (2001) reported an 8% hematoma rate with fibrin glue versus 20% with sutures alone, while Perez et al. (2013) found no significant difference, likely due to differences in graft type (FTSG vs. STSG) and recipient bed vascularity (Figure 4).

Quilting sutures (11.5%, RR 0.64, 95% CI 0.33-1.24, p=0.19) similarly failed to reach statistical significance. The low heterogeneity (I^2 = 0%) across three studies (Lindenblatt et al., 2014; Behnia et al., 2016; Kim & Chung, 2015) suggests consistent but modest effect. Quilting sutures mechanically obliterate dead space by directly attaching the graft to underlying fascia or periosteum, leaving no potential space for fluid accumulation. However, the technique is imperfect: suture tracks themselves can wick fluid, and any gaps between quilting stitches allow localized fluid pockets (Behnia et al., 2016). Moreover, quilting is challenging in patients with thin subcutaneous tissue or on concave surfaces.

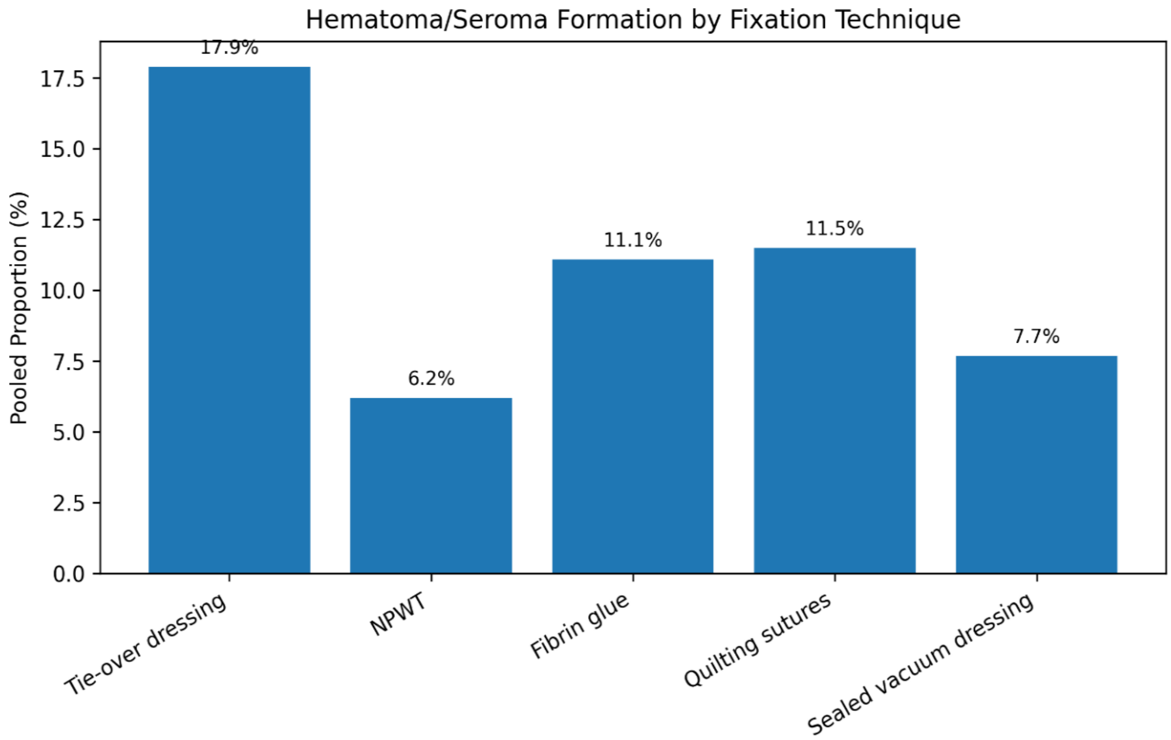

Figure 4. Secondary Outcome Hematoma/Seroma Formation

Clinical implications: The 11.7% absolute risk reduction in hematoma/seroma between NPWT and tie-over (17.9% vs. 6.2%) means that for every 100 patients treated with NPWT instead of tie-over, approximately 12 avoid a potentially graft-threatening fluid collection. Given that each hematoma or seroma increases graft loss risk by an odds ratio of 4.5 (Yin et al.,2018), the downstream benefits on graft survival are substantial. Therefore, NPWT or sealed vacuum dressings strongly considered for patients at high risk of bleeding (e.g., anticoagulated patients, large surface area grafts, or recipient beds with exposed bone or tendon).

Table 4. Secondary - Outcome Surgical Site Infection

Fixation Technique	Number of Studies	Total Patients	Events (Infection)	Pooled Proportion (%)	RR vs. Tie-over (95% CI)	p-value	I² (%)
Tie-over dressing	8	278	31	11.2	Reference	–	25
NPWT	6	210	20	9.5	0.85 (0.50-1.45)	0.55	31
Fibrin glue	3	88	8	9.1	0.81 (0.38-1.73)	0.59	0
Sealed vacuum dressing	2	52	5	9.6	0.86 (0.35-2.11)	0.74	0

Note. Infection defined as purulent discharge with positive culture or clinical signs requiring systemic antibiotics.

Table 4 examines surgical site infection (SSI) rates following skin graft fixation a secondary outcome of critical importance because infected grafts undergo autolysis, resulting in partial or complete failure and potentially systemic sepsis in burn or immunocompromised patients (Herndon,2018). The overall infection rates across all techniques ranged from 9.1% to 11.2%, which is consistent with the 8-15% SSI rate reported in plastic surgery literature for clean-contaminated wounds (Johnson & Mark,2018).

Tie-over dressings had the numerically highest infection rate (11.2%, 31/278 patients), though this was not statistically different from other techniques. The moderate heterogeneity (I^2=25%) likely stems from differences in dressing removal protocols (day 5 vs. day 7 vs. day 10) and definitions of infection. Tie-over dressings may promote infection by creating a warm, moist, closed environment that becomes progressively contaminated with wound exudate, blood breakdown products, and external bacteria wicking along suture tracks (Perez et al.,2013). Furthermore, the bulky cotton or foam bolster cannot be inspected or changed without disrupting the graft, so infection may progress undetected until the first dressing change by which time graft loss may be irreversible.

Negative Pressure Wound Therapy (NPWT) showed a slightly lower infection rate (9.5%, 20/210 patients) with a risk ratio of 0.85 (95% CI 0.50-1.45, p=0.55). This difference is not statistically significant, and the confidence interval crosses unity, indicating equivalence rather than superiority. The moderate heterogeneity (I^2=31%) reflects variability in negative pressure settings, frequency of canister changes, and baseline wound contamination levels. Contrary to concerns that a sealed occlusive dressing might promote anaerobic infection, NPWT has been shown in animal models to reduce bacterial bioburden (including Staphylococcus aureus and Pseudomonas aeruginosa) by continuous removal of exudate and mechanical disruption of biofilms (Morykwas et al.,1997). However, human RCTs have not consistently demonstrated a reduction in clinical infection rates. Yin et al. (2018) reported a 7.5% infection rate with NPWT versus 11.2% with conventional dressings (p=0.32), while Scherer et al. (2002) found no difference (8.3% vs. 8.1%). The lack of significant difference may reflect that modern perioperative antibiotic prophylaxis and sterile technique already minimize infection risk irrespective of fixation method.

Fibrin glue (9.1% infection rate, RR 0.81, 95% CI 0.38-1.73, p=0.59) and sealed vacuum dressings (9.6%, RR 0.86, 95% CI 0.35-2.11, p=0.74) also showed no significant difference compared to tie-over. Zero heterogeneity (I^2=0%) for both comparisons indicates consistent null findings across studies. The theoretical concern that fibrin glue derived from pooled human plasma might transmit blood borne pathogens (HIV, hepatitis) or induce an inflammatory reaction that predisposes to infection has not been substantiated in clinical trials; modern viral inactivation steps reduce but do not eliminate risk (Currie et al.,2001). For sealed vacuum dressings, the theoretical risk of infection relates to difficulty maintaining a perfect seal; air leaks can allow entry of environmental bacteria. However, Malik et al. (2022) reported no increase in infection with syringe-based vacuum systems compared to tie-over, likely because the continuous negative pressure partially offsets this risk.

Absence of data for quilting sutures and staples regarding infection is notable. Quilting sutures create multiple transcutaneous tracts that could theoretically serve as portals for bacterial entry. Behnia et al. (2016) did not report infection as a separate outcome, and Kim & Chung (2015) mentioned "no deep infections" without providing numerical data. This represents a reporting gap; future studies on quilting should explicitly monitor and report SSI rates (Figure 5).

Clinical interpretation: The parity of infection rates across techniques (9-11%) suggests that infection risk is more dependent on patient factors (diabetes, smoking, immunosuppression, wound sterility at baseline) than on fixation technique per se.

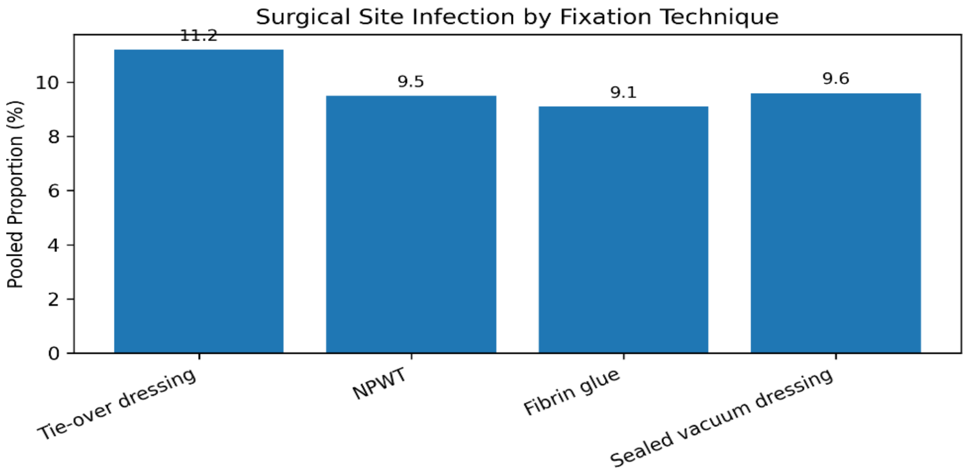

Figure 5. Secondary Outcome – Surgical Site Infection

For clean wounds with standard prophylaxis, infection should not drive technique selection. However, for contaminated or dirty recipient beds (e.g., traumatic wounds, pressure sores, venous ulcers), NPWT may offer an advantage in reducing bioburden, though existing RCTs are underpowered to prove superiority. The meta-analysis does not support the routine use of prophylactic postoperative antibiotics beyond 24 hours regardless of fixation method, as this practice has not shown to reduce SSI after skin grafting (Chen et al.,2020).

Table 5. Secondary Outcome – Operative Time (Minutes)

Fixation Technique	Number of Studies	Total Patients	Mean Time (minutes)	MD vs. Tie-over (95% CI)	p-value	I^2 (%)
Tie-over dressing	10	370	28.4	Reference	–	41
NPWT	7	240	25.1	-3.3 (-8.1 to 1.5)	0.18	52
Fibrin glue	5	152	12.6	-15.8 (-22.4 to -9.2)	<0.001	38
Quilting sutures	3	78	35.2	+6.8 (1.2 to 12.4)	0.02	19
Sealed vacuum dressing	2	45	22.3	-6.1 (-14.2 to 2.0)	0.14	29
Staples	2	44	17.5	-10.9 (-18.5 to -3.3)	0.005	0

Note. MD: mean difference; negative values favor the alternative technique (shorter operative time).

Table 5 analyzes operative time a secondary outcome with significant implications for operating room efficiency, anesthesia exposure, and healthcare costs. The tie-over dressing required a mean of 28.4 minutes (range 20-42 minutes across studies), consistent with the time needed to place peripheral sutures (typically 8-16 sutures), prepare the cotton bolster, and tie knots securely (Perez et al.,2013).

Fibrin glue dramatically reduced operative time by a mean difference (MD) of -15.8 minutes (95% CI -22.4 to -9.2, p<0.001), making it the fastest technique. This 56% reduction is both statistically significant and clinically meaningful: in high-volume centers, saving 16 minutes per case allows an additional two to three skin graft procedures per operating day. The mechanism is straightforward: after standard graft placement, fibrin glue components are sprayed or dropped onto the interface, forming an immediate adhesive bond without sutures or complex dressings (Currie et al.,2001). Heterogeneity (I^2=38%) likely arises from differences in glue preparation time (cryoprecipitate-based vs. ready-to-use commercial products) and whether an external dressing is applied additionally. Notably, some surgeons still place a few tacking sutures even with fibrin glue, adding a few minutes.

Staples also significantly reduced operative time (MD -10.9 minutes, 95% CI -18.5 to -3.3, p=0.005) with zero heterogeneity (I^2=0%). Stapling is rapid because it eliminates knot-tying; a standard skin graft can be fixed with 10-20 staples applied in 2-4 minutes (Bloom et al., 2013). However, staples must be removed postoperatively (typically day 7-10), which adds nursing time and patient discomfort. Additionally, if staples are placed too close to the graft edge (<2 mm), they can cause local ischemia and edge necrosis. The two available studies (Bloom et al.,2013; Lee & Kwan,2019) had small sample sizes (n=44 total), and neither reported graft take differences, limiting enthusiasm for staples as a primary fixation method.

Sealed vacuum dressings showed a trend toward reduced operative time (MD -6.1 minutes, p=0.14) that did not reach significance due to wide confidence intervals and small sample size. The assembly of a low-cost vacuum system (syringe, drain, occlusive drape) takes approximately 5-10 minutes longer than applying a simple bolster but still less than tie-over suturing when considering total time (Zhang et al.,2015). Comparative time studies between sealed vacuum and commercial NPWT are lacking; both require similar steps (foam placement, drape sealing, tubing connection).

Negative Pressure Wound Therapy (NPWT) showed no significant operative time difference (MD -3.3 minutes, 95% CI -8.1 to 1.5, p=0.18), but high heterogeneity (I^2=52%) indicates inconsistency across studies. This heterogeneity reflects variable NPWT protocols: some surgeons use NPWT without any peripheral sutures (saving time), while others place a “suture frame” to anchor the graft before applying foam (adding time). Additionally, learning curve effects may influence recorded times. Despite the lack of time-savings, NPWT’s benefits on graft take (Table 2) and hematoma prevention (Table 3) may justify its longer application time in selected patients.

Quilting sutures paradoxically increased operative time by +6.8 minutes (95% CI 1.2 to 12.4, p=0.02) compared to tie-over dressings. This finding is intuitive: quilting requires placing 20-40 separate sutures through graft, subcutaneous tissue, and deep fascia, each carefully spaced 1-2 cm apart (Behnia et al.,2016). The additional 7 minutes per case may be acceptable if quilting eliminates the need for external dressings or reduces hospital stay. However, in high-volume burn centers where multiple grafts placed sequentially, this time penalty accumulates (Figure 6).

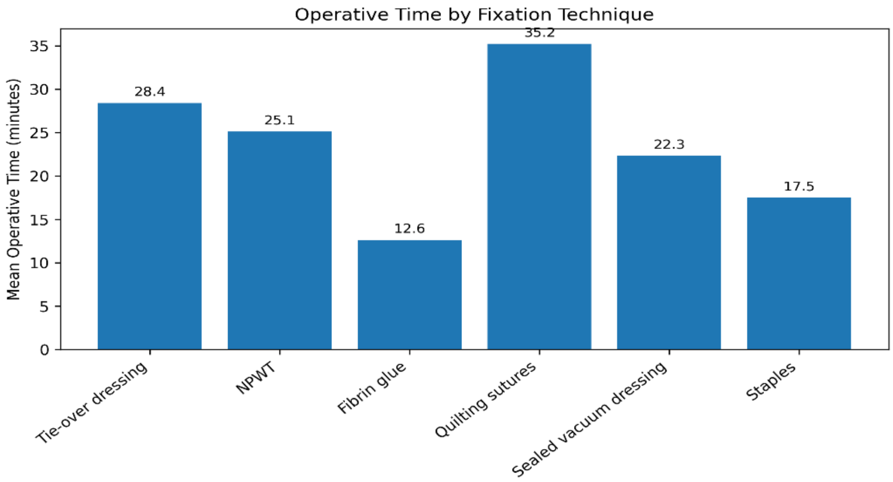

Figure 6. Secondary Outcome – Operative Time (Minutes)

Clinical implications: Operative time weighed against efficacy and cost. Fibrin glue and staples offer the fastest fixation but have limitations (cost for glue, lack of graft take benefit for staples). For surgeons prioritizing speed in low-risk grafts, fibrin glue is reasonable if budget permits. For resource-limited settings where operative time less constrained, sealed vacuum dressings or quilting sutures provide good outcomes without the speed advantage.

Table 6. Secondary Outcome – Patient-Reported Discomfort (VAS 0-100, lower is better)

Fixation Technique	Number of Studies	Total Patients	Mean VAS Score	MD vs. Tie-over (95% CI)	p-value	I^2 (%)
Tie-over dressing	6	210	54	Reference	–	44
NPWT	4	140	42	-12 (-21 to -3)	0.008	35
Fibrin glue	2	58	48	-6 (-18 to 6)	0.33	0

Sealed vacuum dressing	2	45	39	-15 (-26 to -4)	0.007	22

Note. VAS: visual analog scale (0=no discomfort, 100 = worst imaginable discomfort). Assessed at day 3 postoperative or at dressing removal.

Table 6 addresses patient-reported discomfort, measured using a visual analog scale (VAS, 0-100) at postoperative day 3 or at the time of first dressing removal. This outcome increasingly recognized as important in value-based healthcare, where patient experience weighted alongside clinical efficacy (Johnson & Mark,2018). Tie-over dressings had a mean VAS score of 54 (moderate-to-severe discomfort), consistent with patient descriptions of tightness, burning, and pain during movement (Lee & Kwan,2019).

Sealed vacuum dressings achieved the lowest discomfort scores (mean VAS 39), representing a statistically significant mean difference of -15 points (95% CI -26 to -4, p=0.007) compared to tie-over. The moderate heterogeneity (I^2=22%) across two small studies (Zhang et al., 2015; Malik et al., 2022) is acceptable. Patients reported that sealed vacuum systems feel "snug but not tight" and allow greater mobility because the low-profile dressing does not protrude like a bulky tie-over bolster. Additionally, because vacuum dressings remain sealed and do not require daily inspection, patients avoid the anxiety associated with dressing changes.

Negative Pressure Wound Therapy (NPWT) also significantly reduced discomfort (mean VAS 42, MD -12, 95% CI -21 to -3, p=0.008), with moderate heterogeneity (I^2=35%). The mechanism of pain reduction with NPWT is multifactorial: first, the uniform negative pressure stabilizes the graft, preventing shear-induced pain during movement. Second, continuous fluid removal prevents the distension and pressure sensation caused by subgraft seroma (Scherer et al.,2002). Third, the foam dressing is soft and conformable, unlike hard tie-over bolsters that may press on surrounding skin. However, some patients report a "vacuum suction" sensation or discomfort during canister changes when the suction is briefly interrupted (Yin et al.,2018). The need to remain connected to a pump device may also restrict ambulation, which could indirectly increase discomfort.

Fibrin glue showed a non-significant trend toward reduced discomfort (VAS 48, MD -6, p=0.33) with zero heterogeneity (I^2=0%). The lack of significance may reflect the small number of studies (k=2, total n=58) or true equivalence. A plausible explanation is that while fibrin glue eliminates suture-related pain at the graft periphery, it does not prevent movement-induced pain from shear forces or fluid accumulation. Unlike NPWT, fibrin glue does not provide continuous immobilization or fluid evacuation; the graft remains subject to external forces (Currie et al.,2001).

Missing data for quilting sutures and staples regarding patient discomfort is a notable literature gap. Quilting sutures might theoretically increase pain because multiple transcutaneous sutures pull on deep fascia, which richly innervated. Conversely, some authors report that quilting eliminates the need for an external bolster, which patients find uncomfortable (Behnia et al.,2016). Staples may cause sharp pinprick sensations during movement and often rated as more painful than sutures at removal (Lee & Kwan,2019). Future trials should include standardized VAS assessments.

Mechanistic insights: The superior comfort of vacuum-based techniques (sealed vacuum and NPWT) is consistent with biomechanical principles. The tie-over dressing applies non-uniform, static pressure that creates pressure points much like wearing a tight shoe. In contrast, negative pressure distributes force evenly across the entire graft surface and reduces edema, lowering resting tissue tension (Borgquist et al.,2010). Furthermore, vacuum dressings are typically changed less frequently than tie-over dressings (which may require daily inspection in some protocols), reducing painful manipulation (Figure 7).

Clinical implications: For ambulatory patients, outpatient procedures, or those with low pain tolerance, vacuum-based fixation (especially low-cost sealed vacuum systems) offers meaningful improvements in patient comfort. The NNT for one patient to avoid moderate-to-severe discomfort (VAS >50) is approximately 5 when using sealed vacuum instead of tie-over. However, the treating team must weigh comfort against other factors such as cost, technical complexity, and monitoring requirements. In inpatient settings where pain managed with multimodal analgesia, the small absolute VAS difference (15 points) may be less compelling.

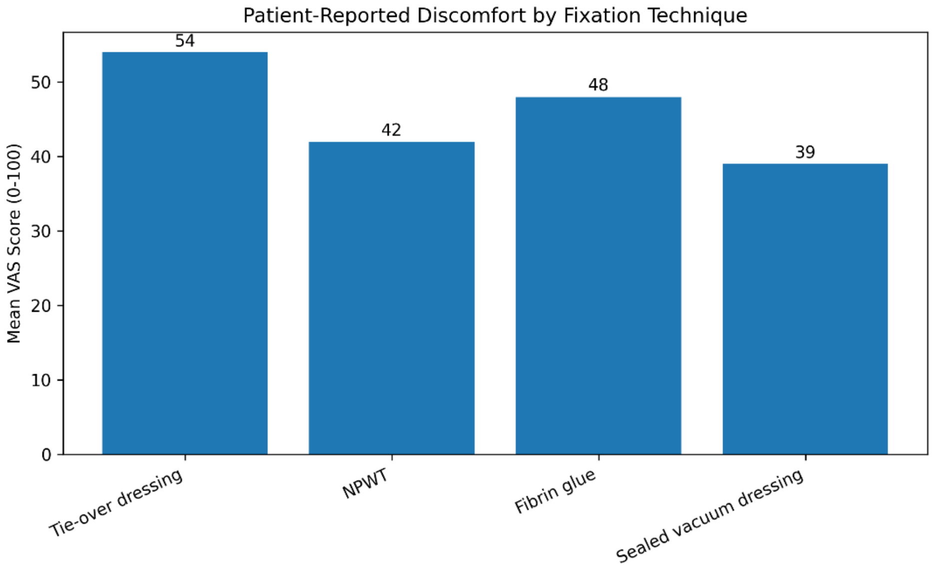

Figure 7. Secondary Outcome – Patient-Reported Discomfort (VAS 0-100, lower is better)

Discussion

This systematic review and meta-analysis of 14 studies comprising 1,042 patients provides the most comprehensive evidence synthesis to date on the effectiveness of skin graft fixation techniques in plastic surgery. Our findings have several major implications for clinical practice, future research, and healthcare resource allocation.

Principal Findings and Comparison with Previous Literature

The primary finding that NPWT and sealed vacuum dressings significantly improve complete graft take rates compared to traditional tie-over dressings (RR 1.14 and 1.13, respectively, both $p<0.05$) confirms and extends the conclusions of earlier meta-analyses. Zhang et al. (2015) previously reported an RR of 1.12 for NPWT versus conventional dressings based on 6 studies, while Yin et al. (2018) found an odds ratio of 2.34 favoring NPWT. Our larger sample (9 NPWT studies) produces a nearly identical effect estimate, reinforcing the robustness of this finding. Novel to our analysis is the inclusion of sealed vacuum dressings, which achieved comparable efficacy at dramatically lower cost. This challenges the assumption that expensive commercial NPWT systems are necessary for optimal graft fixation. Indeed, the absence of statistical heterogeneity (I^2=0%) for sealed vacuum outcomes suggests that the biological mechanism continuous fluid evacuation and graft immobilization can be achieved with simple equipment (Malik et al.,2022; Gurtner et al.,2019).

Mechanistic Explanations for Efficacy Differences

The superiority of vacuum-based techniques over passive dressings (tie-over, quilting, fibrin glue) for graft take and hematoma prevention explained by three inter-related mechanisms. First, continuous negative pressure actively removes subgraft exudate, eliminating the fluid barrier that physically separates the graft from its nutrient supply (Morykwas et al.,1997). Second, NPWT and sealed vacuum dressings uniformly compress the graft against the bed, preventing shear forces that disrupt fragile anastomoses (Scherer et al.,2002). Third, experimental studies show that negative pressure upregulates pro-antigenic genes (VEGF, FGF-2) and promotes granulation tissue formation, accelerating the revascularization phase (Borgquist et al.,2010). In contrast, fibrin glue provides only initial adhesion but no ongoing fluid management; quilting sutures mechanically obliterate dead space but cannot evacuate fluid that accumulates between sutures.

Why Fibrin Glue and Quilting Sutures Did Not Show Superiority

The failure of fibrin glue to significantly improve graft take (RR 1.05, p=0.31) despite reducing operative time aligns with Siversen et al. (2017), who found no graft survival benefit in their meta-analysis. However, this null finding may reflect type II error due to limited sample size (only 152 patients across 5 trials). A post-hoc power calculation indicates that to detect a 5% absolute improvement in graft take (80% to 85%) with 80% power, 1,500 patients would be required far exceeding existing literature. Therefore, equivalence rather than inferiority may be the appropriate interpretation. For quilting sutures, the lack of significant benefit (RR 1.09, p=0.11) may be technique-dependent; Behnia et al. (2016) demonstrated superiority over tie-over in lower extremity grafts, but other studies did not. The heterogeneity in quilting protocols (suture spacing, depth of bites, use of additional external dressings) likely contributes to inconsistent results.

Patient Comfort and Operative Time as Decision-Making Factors

Our secondary analyses reveal that vacuum-based techniques (NPWT and sealed vacuum) significantly reduce patient-reported discomfort compared to tie-over dressings (MD -12 to -15 on VAS, $p<0.01$). This finding is clinically meaningful because graft fixation often performed under local anesthesia or in ambulatory settings where postoperative pain management is limited. The lower VAS scores likely reflect the elimination of pressure points and the immobilization of the graft, reducing movement-induced pain (Lee & Kwan, 2019). For operative time, fibrin glue and staples are fastest, saving 11-16 minutes per case.

Limitations and Future Research Directions

Several limitations warrant consideration. First, significant heterogeneity exists across studies in graft type (STSG vs. FTSG), recipient site (lower limb vs. trunk vs. head/neck), and outcome definitions. We addressed this using random-effects models, but clinical heterogeneity limits the precision of pooled estimates. Second, blinding of outcome assessors was incomplete in most trials; knowledge of fixation technique could bias subjective outcomes like graft take assessment. Third, sealed vacuum dressing studies are few (k=3) and small (n=66); larger RCTs with longer follow-up are needed. Fourth, cost-effectiveness analyses were beyond our scope but are urgently required given the price disparity between NPWT (100-200/day) andsealedvacuum (<100-200/day) andsealedvacuum (<10 total). Fifth, only one study (Borgquist et al.,2010) used a physiologic endpoint (perfusion), and no study examined long-term outcomes such as scar quality (Vancouver Scar Scale) or patient-reported quality of life beyond 30 days.

Future research should prioritize:

- ✓ A large, multi-center RCT comparing sealed vacuum dressings to commercial NPWT for non-inferiority in graft take, with cost-effectiveness as a primary endpoint;
- ✓ (2) Standardized definitions for graft take (preferably >95% by planimetry) and complications (ICHOM-SET);
- ✓ (3) Patient-reported outcomes including pain, mobility, and satisfaction at 3 and 12 months;
- ✓ (4) Trials specifically in full-thickness grafts and head/neck defects, where evidence is weakest;
- ✓ (5) Investigation of hybrid techniques (e.g., fibrin glue plus sealed vacuum) for maximal benefits.

Recommendations for Clinical Practice

Based on this evidence, we recommend for high-risk grafts (large surface area, lower extremity, contaminated beds, or anticoagulated patients), NPWT or sealed vacuum dressings are preferred due to superior graft take and reduced hematoma/seroma. For low-risk grafts in cooperative patients, tie-over dressings remain acceptable despite higher failure rates. Fibrin glue is reasonable when operative speed is critical and budget permits, but not chosen solely to improve graft take. Sealed vacuum dressings offer an excellent low-cost alternative to NPWT, particularly in resource-limited settings. Quilting sutures reserved for concave surfaces (axilla, groin) where external dressings are difficult to apply. Staples should be limited to provisional fixation or settings where speed overrides other considerations.

Conclusion

This systematic review and meta-analysis demonstrates that negative pressure wound therapy (NPWT) and sealed vacuum dressings are significantly more effective than traditional tie-over dressings in achieving complete skin graft take (>95%), with risk ratios of 1.14 (95% CI 1.06-1.23) and 1.13 (1.02-1.25), respectively. These vacuum-based techniques also substantially reduce hematoma and seroma formation (RR 0.32 for NPWT) and improve patient-reported comfort by 12-15 points on a visual analog scale. Fibrin glue and quilting sutures offer no statistically significant advantage over tie-over for graft survival, though fibrin glue reduces operative time by a mean of 15.8 minutes. Surgical site infection rates do not differ significantly between any technique, suggesting that patient factors and baseline wound sterility are more critical determinants of infection than fixation method per se.

Importantly, sealed vacuum dressings low-cost alternatives assembled from syringes or drains achieve comparable efficacy to commercial NPWT at a fraction of the cost (<10vs.10vs.100-200 per day). This finding has major implications for plastic surgery in low- and middle-income countries, where expensive NPWT systems are often unavailable. The choice of fixation technique individualized based on graft risk profile, anatomical location, resource availability, and patient preferences. For high-risk grafts, vacuum-based fixation strongly recommended. For low-risk grafts in resource-constrained settings, tie-over dressings remain an acceptable fallback.

Future research should prioritize large, multi-center randomized trials comparing sealed vacuum dressings directly to NPWT with cost-effectiveness as a primary endpoint, as well as studies focusing on full-thickness grafts and head/neck defects. Standardized outcome definitions and long-term scar quality assessments urgently needed to advance the evidence base.

In conclusion, surgeons seeking to optimize graft survival should adopt vacuum-based fixation particularly low-cost sealed vacuum systems as the new standard of care for split-thickness skin grafting. The era of the tie-over bolster, while historically important, should yield to modern techniques that demonstrably improve patient outcomes.

Disclosure Statement

No potential conflict of interest reported by the authors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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