Question : Are mechanical suction drains effective for dead space management following debridement?

SECTION 1. Background

Surgical management of structural dead space following radical debridement is a fundamental component in mitigating the risk of fracture-related infection (FRI) and establishing a viable pathway toward bone union. When structural dead space is left unmanaged, it rapidly fills with stagnant hematoma, creating an optimal microenvironment for bacterial colonization and biofilm protection.

Historically, conventional closed mechanical suction drains have been empirically utilized to manage this dead space. The clinical rationale underlying their use has been the assumption that evacuating postoperative hematomas minimizes soft-tissue tension, preserves local vascularity, and limits the incidence of wound breakdowns. Similarly, advanced active fluid evacuation strategies, such as negative pressure wound therapy (NPWT), have been widely implemented to eliminate fluid, reduce dead space, and control wound contamination.

Despite these theoretical advantages, significant uncertainties and controversies persist regarding their true efficacy. Conventional drains face severe mechanical limitations; while they effectively clear thin, uncoagulated fluid, they are generally incapable of evacuating the dense, fibrin-rich clot that covers exposed bone and damaged muscle. Furthermore, introducing an indwelling foreign material into a contaminated zone can disrupt local leukocyte migration and lower the microbial threshold required for infection, particularly leading to retrograde contamination when drains remain in situ beyond 48 hours.

Given these biological challenges and the methodological mismatches present in current literature—which predominantly focuses on NPWT rather than simple mechanical drainage—there is a critical need to systematically evaluate the available evidence to guide clinical practice on the use of mechanical suction drains for dead space management following debridement.

SECTION 2. Data Extraction Table

S.no	Author, year of publication, Country	Study Design	Sample Size (add individually for each group if multiple groups compared)	Study population (Inclusion and exclusion criteria)	Groups compared	Results
1	Kim et al. 2019 Republic of Korea	Systematic Review and Meta-analysis	Total N = 1322 tibias.	**Inclusion Criteria:** * Patients with open tibia fractures who underwent NPWT or conventional	**Intervention Group:** Negative pressure wound therapy (NPWT) / vacuum-	**Primary/Secondary Outcomes:** Rates of infection (soft-tissue, osteomyelitis), amputation, nonunion, and flap-related complications. **Complications/Main Findings:** * Soft-tissue infection: NPWT significantly lower (OR 0.48, 95% CI

			Group A (NPWT) n = 747 cases. Group B (Control) n = 575 cases. conventional dressing	dressings for soft-tissue defects. **Exclusion Criteria:** Biomechanical/cadaveric studies, technical notes, letters, expert opinions, reviews, meta-analyses, abstracts, and case reports. * Failed to provide a direct comparison and Required data could not be obtained/calculated. * Duplicate studies on the same patients.	assisted closure. **Control Group:** Conventional wound management / conventional dressings.	0.34–0.68, P < 0.0001) & Nonunion: NPWT significantly lower (OR 0.61, 95% CI 0.39–0.95, P = 0.03). * Flap necrosis: NPWT significantly lower (OR 0.37, 95% CI 0.21–0.63, P = 0.0003) & Flap revision: NPWT significantly lower (OR 0.44, 95% CI 0.22–0.89, P = 0.02). * **Osteomyelitis AND Amputation: No significant difference** **Follow-up:** Minimum 12 months up to 186 months. **Conclusion:** NPWT showed lower rates of soft-tissue infection, nonunion, flap necrosis, and flap revision compared to conventional dressings, though more high-quality studies are needed for definitive verification.
2	Liu et al., 2018, China	Systematic review and meta-analysis	**Total N:** 909 patients **Group A (NPWT):** n = 526 (213 in RCTs, 313 in cohorts) **Group B (Conventional Dressings):** n = 383 (208 in RCTs,	**Inclusion Criteria:** • Published and unpublished RCTs and cohort studies comparing NPWT and conventional dressings for open fractures. -Skeletally-mature patients with newly-formed open limb fractures. -Interventions using NPWT	**Intervention Group:** Negative pressure wound therapy (NPWT) systems. **Control Group:** Conventional wound dressings (dry or moist, including gauze, silver	**Primary/Secondary Outcomes:** • **Infection Rate:** Significantly lower in the NPWT group in both RCTs (OR 0.17, 95% CI 0.09 to 0.32, P<0.00001) and cohort studies (OR 0.26, 95% CI 0.16 to 0.42, P<0.00001). • **Wound Healing Time:** RCTs showed significantly lower incidence of healing taking >6 weeks for NPWT (OR 0.06, 95% CI 0.02 to 0.17, P<0.00001). • **Wound Coverage Time:** RCTs showed significantly lower incidence of coverage taking >3 weeks for NPWT (OR 0.09, 95% CI 0.03 to 0.22,

			175 in cohorts)	systems (e.g., VAC, VSD, TNP). - Controls using conventional wound dressings (dry or moist). **Exclusion Criteria:** Studies without direct or indirect intergroup comparison. - Duplicate studies on the same patients. **Patient Characteristics:** • Injury Severity: >76.7% of patients in RCTs had Gustilo-Anderson type **III** fractures; 86.5% of patients in cohort studies had type **III** fractures.	ion, alginate, hydrogel, etc.).	P<0.00001). • **Hospital Stay:** RCTs showed significantly lower incidence of stay lasting >1 month for NPWT (OR 0.06, 95% CI 0.02 to 0.17, P<0.00001). • **Flap Surgery Need:** No significant difference in wounds covered with flap surgery (RCT OR 0.64, P=0.45; Cohort OR 1.54, P=0.09). • **Flap Failure:** Slightly significant difference favoring NPWT in cohort studies (OR 0.36, 95% CI 0.14 to 0.93). • **Amputation Rate: Significantly higher in the conventional group (OR 0.15, 95% CI 0.02 to 0.89, P=0.04) based on cohorts.** • **Fracture Union:** Non-union rate was 27.4% in NPWT vs. 34.0% in control; no significant difference (P=0.21). • **Life Quality:** One RCT noted higher SF-36 physical scores in infected NPWT patients. **Authors' Conclusion:** NPWT significantly reduces infection risk and accelerates wound healing in open fractures. Current evidence is insufficient to prove NPWT reduces flap repair needs.
3	Grant-Freemantle et al.,	Systematic Review and	**Total N (Primary Outcome):** 1,095	**Inclusion Criteria:** RCTs, non-randomized control trials, and retrospective observational	**Intervention Group:** Negative Pressure Wound	**Primary Outcome (Deep Infection):** NPWT had significantly decreased rates of deep infection (OR, 0.43; 95% CI, 0.29-0.62; P<0.0001).

	2020, Ireland	Meta-Analysis	**Group A (NPWT):** n=614 **Group B (CD):** n=481	studies comparing NPWT with CD in the treatment of open fractures at any anatomical site . * Skeletally mature individuals with an open fracture at any anatomical site not amenable to closure at the time of initial debridement . * All NPWT systems applied to an open fracture wound that could not be closed at initial debridement . * All CD considered as controls (if it was the standard dressing of choice in the respective institutions) .**Exclusion Criteria:**	Therapy (NPWT) . **Control Group:** Conventional Dressings (CD).	**Secondary Outcomes:** **Flap Failure:** Statistically significant reduction in NPWT group; NPWT n=241, CD n=115 (OR, 0.37; 95% CI, 0.14-0.96; P=0.04). **Flap Frequency, Fracture nonunion, Amputation, Length of hospital stay has** no statistically significant difference between groups. * **Length of ICU Stay:** Significant reduction favoring CD group; mean difference 2.24 days (2.08 to 2.40; P=0.0001) . **Subgroup Analyses (Deep Infection):** * RCT evidence only: Significant reduction in NPWT (OR, 0.51; 95% CI, 0.32-0.81; $P=0.005$) * Unsealed dressing RCTs: Significant reduction in NPWT (OR, 0.27; 95% CI, 0.11-0.65; P=0.003) * Sealed dressing RCTs: No statistical difference (OR, 0.46; 95% CI, 0.09-2.37; P=0.35) . **Authors' Conclusion:** NPWT results in a decreased likelihood of deep infection and flap failure compared with CD in the management of open

				* Nonobservational study . * Involved procedures and injuries that did not involve an open fracture . * Had less than 10 patients per treatment arm . * Did not report on outcomes listed . .		fractures not directly amenable to early closure.
4	Sagy et al 2019 India	Prospective randomized controlled study	Total N = 100 Group A (VAC)= 50 Group B (Traditional)= 50	**Inclusion Criteria** Fresh compound fractures where primary closure is not possible and require surgical debridement .and absence of relevant medical comorbidities (e.g., diabetes mellitus,	**Intervention Group (VAC):** * Foam band dressing under sub-atmospheric pressure and dressings changed every 3 to 4 days . **Control Group (Traditional):** * Daily dressing	**Primary & Secondary Outcomes:** ***** Time to Granulation Tissue Appearance: VAC 4.0 ± 1.19 days vs. Traditional 9.12 ± 1.42 days ($p < 0.05$) . * Time to 100% Granulation Tissue: VAC 13.00 ± 1.94 days vs. Traditional 22.04 ± 2.09 days ($p < 0.05$) . * Reduction in Wound Surface Area: VAC 3.9% per day vs. Traditional 1.6% per day ($p < 0.05$) .

				obesity) that might affect wound healing **.Exclusion Criteria:** * Hemophilia or haemoglobinopathies * History of diabetes mellitus . * Pathological fractures with untreated osteomyelitis. * Old compound fractures with infected wounds .	changes using a sequential combination of Hydrogen peroxide, Normal saline, and Povidone Iodine .	* Time for Permanent Wound Coverage: VAC 14.88 days vs. Traditional 25.00 days ($p < 0.05$) . * Duration of Hospital Stay: VAC 22.04 ± 2.099 days vs. Traditional 36.00 ± 1.82 days ($p < 0.05$) . Reoperations (Definitive Coverage): * Split skin grafting (SSG): 88 patients (45 VAC, 43 Traditional) . * Secondary suturing: 10 patients (3 VAC, 7 Traditional) . * Flap coverage: 2 patients (2 VAC, 0 Traditional) . Authors' Conclusion: Vacuum assisted dressing is more effective than traditional wound dressing in wound healing of open fractures .
5	Stannard et al., 2009, USA	Prospective randomized study (RCT)	**Total N**: 58 patients (62 fractures) **Group A (NPWT)**: 35 patients (37 fractures) **Group B (Control)**: 23 patients	**Inclusion:** Severe open fracture requiring serial surgical debridements; age > 18 years; willingness to complete protocol and follow-up. Eligible fractures: heavily contaminated Gustilo type **II**, type **III**A (heavily contaminated/s	**Intervention (NPWT):** Vacuum-assisted closure (VAC) system applied to wounds between initial irrigation and debridement (I&D) and subsequent repeat I&Ds (every 36-72 hours) until wound closure.	**Primary Outcome (Deep Infection):** Control: 7 total infections (28%). NPWT: 2 total infections (5.4%). The relative risk ratio is 0.199. Patients treated with NPWT were only one-fifth as likely to have an infection compared with patients randomized to the control group. **Secondary Outcomes:** Mean days to wound closure: Control 3.2 days; NPWT 4.0 days. **Functional Outcome:** SF-36 Physical Component Score (PCS) was

			(25 fractures)	evere soft tissue injury), and all type IIIB or IIIC. **Exclusion Criteria:** Open fractures closed after initial surgery; infected open fractures; incisions that cannot be treated with NPWT; prisoners; pregnant females; unable/unwilling to consent; unable to complete protocol.	**Control:** Standard saline wet to moist fine mesh gauze dressing applied between initial I&D and subsequent repeat I&Ds until wound closure.	significantly higher for NPWT vs Control at 3, 6, and 9 months post-injury (P=0.013, P=0.049, P=0.005) . **Conclusion:** NPWT represents a promising new therapy that significantly decreases the incidence of deep infection compared to standard dressings.
6	Qian et al. , 2022 , China	Meta-analysis	**Total N: 2780** **Group A (NPWT):** n=1394	**Inclusion Criteria:*** Patients with open fractures of the lower limbs, managed with NPWT or traditional	**Intervention Group:** Negative pressure wound therapy (NPWT) .	**Infection Outcomes:** *** Overall infection rate:** NPWT 9.8% vs Standard 13.3% (MD=0.70, 95% CI: 0.54-0.90, P=0.005)

			Group B (Standard): n=1386	gauze dressings . Studies reporting overall infection rate, deep infection rate, acute wound infection rate, time for wound healing, DRI, culture positive rate, hospital stay length, or complications .**Exclusion Criteria:*** Non-RCTs . * Repeated studies involving the same patients . * Studies reporting only cost-effectiveness . * Patients treated with other management . * >20% loss to follow-up .	**Control Group:** Standard treatment (traditional sterile gauze dressings).	*** Acute wound infection:** NPWT 7.5% vs Standard 16.8% (MD=0.35, 95% CI: 0.16-0.77, P=0.009) . *** Deep infection rate:** NPWT 9.1% vs Standard 11.4% (MD=0.76, P=0.05, no significant difference) . *** Positive culture rate:** NPWT 12.6% vs Standard 37.8% (MD=0.19, P=0.0001) . **Wound Healing Outcomes:** *** Time for wound ready for closure:** Significantly shorter in NPWT . Wound overage done less than 3 weeks is Higher in NPWT (MD=24.00, P<0.00001) . *** Time for complete wound healing: No significant difference (P=0.12) .** **Hospital Stay:**stay < 1 month: Significantly higher in NPWT group (OR=24.00, P<0.00001) . **Functional Outcomes:** Disability Rating Index (DRI): NPWT improved DRI at 3 months (MD=0.49, P=0.0003) and 6 months (MD=0.41, P=0.01) . ***** EQ-5D: No significant difference (P=0.99) . **Complications & Reoperations:**

						*** Amputation: No significant difference .** *** Bone nonunion: No significant difference .** **Authors' Conclusion:** NPWT could be a choice over traditional gauze dressings in managing open wound fractures of the lower limbs, significantly reducing acute wound infection rate, total infection rate, and hospital stay.
7	Joethy et al., 2013, Singapore.	Retrospective Cohort	Total N: 69 **Group A NPWT (2008-2009)** n=51. Median age 40 yrs. pre-existing morbidities 6 (12%); average defect size 192 cm². **Group B occlusive (2003-2004)** n=18 Median age 38 yrs. pre-existing	**Inclusion Criteria:** **-** Patients who underwent free flap reconstruction for Gustilo type IIIB traumatic lower third defects of only tibia fractures. **Exclusion Criteria:-** Patients with other or additional fractures.	**Intervention Group:** 2008-2009 cohort: All patients underwent negative-pressure wound therapy (NPWT). NPWT was applied at 125 mmHg in continuous mode. **Control Group:** 2003-2004 cohort: Wounds were dressed with	**Primary Outcomes (Infection):** Clinical flap infection was seen in 5 (10%) patients in the NPWT group vs. 6 (33%) patients in the occlusive dressing group - Infection Incidence was statistically significant (p=0.0288)**.** **Secondary Outcomes (Flap Failure): -** Flap failure (partial or total) occurred in 3 (6%) patients in the NPWT group vs. 2 (11%) in the occlusive group and their difference was not statistically significant**.** **Operative Outcomes:** Average time to flap surgery was 10.8 days (range 1-60) for NPWT vs. 16.8 days (range 1-62) for occlusive dressing. Median duration of free flap surgery was 5 hrs 35 mins (NPWT) vs. 5 hrs 55 mins (occlusive). **Authors' Conclusion:** Patients in the 2008-2009 cohort (NPWT) had better outcomes, and the use of NPWT significantly reduced the rate of

			morbidities- 2 (11%); average defect size 166 cm².		an occlusive dressing.	infection in patients with lower third tibial open fractures.
8	Rezzadeh et al., 2015, USA	Retrospective Cohort	**Total N**: 32 **Acute (<7 d)**: 8 (NPWT n=2, Wet to Dry Dressing(WDD) n=6). **Subacute (7–42 d)**: 16 (NPWT n=8, WDD n=8). **Chronic (>42 d)**: 8 (NPWT n=2, WDD n=6)	**Inclusion:** Patients presenting to the level 1 trauma center over a 5-year period with Gustilo grade IIIB or IIIC open tibial fractures who received free-flap extremity reconstruction. Mean age of 37.65 years. The cohort consisted of 29 males and 3 females.	Negative Pressure Wound Therapy (NPWT) vs. Wet-to-Dry Dressing (WDD).Across three timing cohorts: Acute (<6 days), Subacute (7–42 days), and Chronic (≥42 days).	**Primary/Secondary Outcomes**: The authors assessed flap-specific complications (failure, revision) and other postoperative complications (surgical site infection [SSI], osteomyelitis, hematoma, bony nonunion). **Acute Cohort Complications**: WDD had significantly higher rates of SSI (50% vs 0%, P=0.007) and flap revisions (33.3% vs 0%, P=0.05) compared to NPWT. WDD also exhibited 16.7% rates for osteomyelitis, hematoma, and nonunion, compared to 0% in NPWT. **Subacute Cohort Complications:** WDD demonstrated significantly higher rates of flap failure (25% vs 0%, P=0.05) and osteomyelitis (37.5% vs 0%, P=0.02) compared to NPWT. **Chronic Cohort Complications:** WDD was associated with significantly higher osteomyelitis (33.3% vs 0%, P=0.04) and nonunion (66.7% vs 0%, P=0.002) than NPWT. **Conclusion:** NPWT safely bridges complex open lower extremity wounds to definitive coverage, reducing both flap and non-flap complication rates across all surgical timeframes compared to conventional open wound care.

9	Blum et al., 2012, Australia	Retrospective Cohort	**Total N: 220 patients** (229 fractures) **Group A (NPWT): 159 patients - 74%**(166 fractures) **Group B (Conventional): 61 patients - 57%**(63 fractures)	**Inclusion Criteria:** Patients who sustained an open tibial fracture Gustilo type I, II, IIIA, IIIB, and IIIC which underwent delayed soft tissue coverage between January 2002 and December 2007- Treated exclusively with either NPWT or conventional dressings for the period between initial debridement to the definitive wound closure. **Exclusion Criteria:** Immediate soft tissue closure which were Managed with both NPWT and conventional dressings at different times. - Extremities that underwent amputation & Patients who died during the first hospital admission.	**Intervention Group:** Negative Pressure Wound Therapy (NPWT) with reticulated open cell foam (VAC device). **Control Group:** - Conventional dressings like betadine soaked gauze, saline soaked wet-to-dry dressings, and paraffin gauze.	**Primary Outcome:**Deep infection rate: NPWT 8.4% vs Conventional 20.6% **Secondary Outcomes: Superficial infection: NPWT 6.6% vs. Conventional 1.6%.** **-** Nonunion,ICU stay and Length of stay was higher in the Conventional group. **Statistical Significance:** The deep infection rate difference was statistically significant (P = 0.011). Multivariate analysis found NPWT reduced deep infection risk by 78% (OR: 0.22, 95% CI: 0.09-0.55; P = 0.001). **Authors' Final Conclusion:** NPWT substantially decreases deep infection when used in the soft tissue management of open tibial fractures.

10	Costa et al., 2018, UK	Pragmatic, Multicentre Randomised Controlled Trial (RCT)	**Total N:** 460 **Group A (NPWT):** n = 226 **Group B (Standard):** n = 234	**Inclusion Criteria:** - Aged ≥ 16 years who had sustained Open fracture of the lower limb assessed as Gustilo and Anderson (G&A) grade 2 or 3 - Presented/transferred to a trial hospital within 72 hours of injury, Mostly tibia fractures (82.1%). **Exclusion Criteria:** **-** Contraindications to anaesthesia (unfit for surgery). - patients who were unable to adhere to trial	**Intervention Group:** Negative-pressure wound therapy (NPWT) (n=226) consisting of 'open-cell' solid foam/gauze with an adherent sealed dressing connected to a vacuum pump. **Control Group:** Standard wound management (n=234) consisting of a non-adhesive layer applied directly to the wound and covered by a sealed dressing or bandage (no negative pressure).	**Primary Outcome (12 Months):** **-** Disability Rating Index (DRI) score: NPWT mean = 45.5 (SD 28.0); Standard mean = 42.4 (SD 24.2). **-** Mean difference: -3.9 points (95% CI -8.9 to 1.2) in favour of standard dressings; p=0.132 (Not statistically significant). **Secondary Outcomes:** **-** Deep Surgical Site Infection (SSI): Overall 7.6% . NPWT = 7.1% ; Standard = 8.1%. Odds Ratio 1.18 (95% CI 0.59 to 2.37);p=0.638. - HRQoL (EQ-5D utility at 12 months): NPWT = 0.55 (SD 0.33); Standard = 0.56 (SD 0.32). Mean difference 0.01 (95% CI -0.06 to 0.07); p=0.823. - Complications / Reoperations: No evidence of difference in the rate of wound complications or other systemic complications at any point in the 12 months. - Cost-effectiveness: NPWT did not reduce costs **Authors' Final Conclusion: Contrary to existing literature and current clinical guidelines, NPWT dressings do not provide a clinical or an economic benefit for patients with an open fracture of the lower limb compared to standard dressings.**

				procedures or complete questionnaires (e.g., permanent cognitive impairment).		
11	Costa et al., 2018, UK	Pragmatic, Multicentre Randomised Controlled Trial (RCT)	**Total N:** 460 **Group A (NPWT):** n = 226 **Group B (Standard):** n = 234	**Inclusion Criteria:** - Aged ≥ 16 years who had sustained Open fracture of the lower limb assessed as Gustilo and Anderson (G&A) grade 2 or 3 - Presented/transferred to a trial hospital within 72 hours of injury, Mostly tibia fractures (82.1%). **Exclusion Criteria:**	**Intervention Group:** Negative-pressure wound therapy (NPWT) (n=226) consisting of 'open-cell' solid foam/gauze with an adherent sealed dressing connected to a vacuum pump. **Control Group:** Standard wound management (n=234) consisting of a non-adhesive layer applied directly to the wound and	**Primary Outcome (12 Months):** **-Disability Rating Index (DRI): Mean 45.5 in NPWT vs 42.4 in Standard.** - Mean difference: -3.9 (95% CI, -8.9 to 1.2); P=0.13. **Secondary Outcomes & Complications: - Deep surgical site infections at 30 days:** 16 (7.1%) in NPWT vs 19 (8.1%) in Standard (Difference 1.0% [95% CI, -4.2% to 6.3%], P=0.64. **-EuroQol 5-dimensions (EQ-5D-3L):** NPWT 0.55 vs Standard 0.56 (Difference 0.01 [95% CI, -0.06 to 0.07], P=0.82). **-SF-12 Physical Component Score:** NPWT 32.2 vs Standard 32.7 (Difference 0.4 [95% CI, -3.0 to 3.8], P=0.82) . **Conclusion:** **NPWT compared with standard wound dressing did not improve self-rated disability at 12 months .These findings do not support this treatment for severe open fractures.**

				- Contraindications to anaesthesia (unfit for surgery). - patients who were unable to adhere to trial procedures or complete questionnaires (e.g., permanent cognitive impairment).	covered by a sealed dressing or bandage (no negative pressure).	
12	Dedmond et al., 2007, USA	Retrospective consecutive series	**Total N = 50 fractures in 49 patients .** Group IIIA (n=24) Group IIIB (n=24) Group IIIC (n=2)	**Inclusion Criteria:** Pressure wound therapy (NPWT) between Jan 1, 1996, and Dec 31, 2004, at a level 1 trauma center for type 42 fractures. **Exclusion Criteria:** Type 41 or 43 fractures; Gustilo and Anderson grade/type 1 or 2 open fractures. nonreconstructible injuries	No internal control group (single-arm cohort). Compared observationally to historical controls from published literature.	**Primary Outcomes (Infection):** Overall infection rate for all type III fractures was 30% ; requiring surgery for deep infection: 20% . Infection rates by grade: IIIA = 12.5%, IIIB = 45.8%, IIIC = 50% . **Secondary/Functional Outcomes:** 48% required secondary surgical intervention to facilitate fracture healing. 10% required late amputation. Reoperation rate after definitive coverage was 62%. **Flap Coverage:** 17 fractures (7 IIIA, 10 IIIB) ultimately required free tissue transfer or rotational muscle flap.**Follow-up:** Average 19.6 months

				requiring amputation before soft-tissue coverage attempt ; patients younger than 18 years ; amputations not classified as "late" .		**Conclusion:** Infection and nonunion rates with NPWT are similar to historical controls, but NPWT may beneficially decrease the need for free tissue transfer or rotational muscle flap coverage.
13	Hou et al., 2011, USA/China	Retrospective Cohort	**- Total N = 32** Patients were divided into two groups according to the interval time from injury to definitive coverage. Group 1- Interval <= 7 days (n=10) Group 2- Interval > 7 days (n=22)	**Inclusion Criteria:** - Adult patients presenting with a Gustilo grade IIIB open tibial fracture who underwent initial treatment of the associated soft tissue wound with VAC therapy. **Exclusion Criteria:** - Gustilo type I, II, IIIA, and IIIC open fractures. - Comminuted fracture deemed nonreconstructable resulting in immediate amputation before soft tissue management. **-** Patients transferred to other hospitals	Patients were divided into two groups according to the interval time from injury to definitive coverage. - Group 1: Interval <= 7 days (n=10). - Group 2: Interval > 7 days (n=22).	**Primary/Secondary outcomes:** **-** Infection, amputation, nonunion, and ISS. **Follow-up duration:** Mean 2.4 years +/- 0.2 years (range 1-6 years). **Complications:** **-** 11 patients (34%) developed acute or chronic infections. - 9 patients (28%) underwent below knee amputation. - 8 of 25 remaining patients (32%) developed nonunion. - 4 of 27 flap coverage cases (14.8%) developed partial flap necrosis. **Reoperations:** Patients required a mean of 3.3 +/- 0.1 debridements (range 1-7) before definitive intervention. **Statistical significance:** The rate of infection was significantly increased in patients with an interval > 7 days (p=0.011). - Differences in amputation (p=0.263), nonunion (p>0.99), and ISS (p=0.925) were not statistically significant.

				before definitive coverage. **-** Mean age 45.9 years +/- 3.2 years.		**Authors' Conclusion:** **-** VAC therapy may help reduce flap size and need for flap transfer. **- Prolonged usage greater than 7 days should be avoided to reduce higher infection and amputation risks.**
14	Petrou et al., 2019, United Kingdom	Economic evaluation based on a pragmatic, randomized controlled trial	**Total N: 460** **Group A (NPWT):** n = 226 **Group B (Standard):** n = 234	**Inclusion Criteria:** Eligible patients, aged 16 years or over, presenting with a severe, open fracture of the lower limb. **Exclusion Criteria:** Not Reported.	**Intervention group**: Negative-pressure wound therapy (NPWT) applied after the first surgical debridement of the open fracture wound. **Control group**: Standard wound dressing applied after the first surgical debridement, with the type left to the discretion of each surgical team.	**Primary outcome:** The base case analysis produced an incremental cost-effectiveness ratio (ICER) of £267,910 per QALY gained. **Secondary outcome:** NPWT reflected higher costs on average (£678; 95% CI -£1082 to £2438) and marginally higher QALYs (0.002; 95% CI -0.054 to 0.059). **Complications:** Mean hospital readmission rates related to the open fracture wound were similar between trial arms (0.22 vs 0.22 between initial discharge and three months). **Functional outcomes:** Disability Rating Index (DRI) score at 12 months showed a mean of 45.5 in the NPWT group versus 42.4 in the standard dressing group. **Statistical significance: No statistically significant difference** was found in the mean DRI score at 12 months (p=0.132). **The probability that NPWT is cost-effective did not exceed 27%.** **Authors' final conclusion:** NPWT is unlikely to be a cost-effective strategy for improving outcomes in adult patients with severe open fractures of the lower limb.

15	Cook et al., 2018, UK	Narrative review on Pragmatic, Multicentre Randomised Controlled Trial (RCT) done by Costa et al	**Total N:** 460 **Group A (NPWT):** n = 226 **Group B (Standard):** n = 234	**Inclusion Criteria:** - Aged ≥ 16 years who had sustained Open fracture of the lower limb assessed as Gustilo and Anderson (G&A) grade 2 or 3 - Presented/transferred to a trial hospital within 72 hours of injury, Mostly tibia fractures (82.1%). **Exclusion Criteria:** **-** Contraindications to anaesthesia (unfit for surgery). - patients who were unable to adhere to trial procedures or complete questionnaires (e.g., permanent	**Intervention Group:** Negative-pressure wound therapy (NPWT) (n=226) consisting of 'open-cell' solid foam/gauze with an adherent sealed dressing connected to a vacuum pump. **Control Group:** Standard wound management (n=234) consisting of a non-adhesive layer applied directly to the wound and covered by a sealed dressing or bandage (no negative pressure).	**Primary Outcome (12 Months):** **-Disability Rating Index (DRI): Mean 45.5 in NPWT vs 42.4 in Standard.** - Mean difference: -3.9 (95% CI, -8.9 to 1.2); P=0.13. **Secondary Outcomes & Complications:** **- Deep surgical site infections at 30 days:** 16 (7.1%) in NPWT vs 19 (8.1%) in Standard (Difference 1.0% [95% CI, -4.2% to 6.3%], P=0.64. **-EuroQol 5-dimensions (EQ-5D-3L):** NPWT 0.55 vs Standard 0.56 (Difference 0.01 [95% CI, -0.06 to 0.07], P=0.82). **-SF-12 Physical Component Score:** NPWT 32.2 vs Standard 32.7 (Difference 0.4 [95% CI, -3.0 to 3.8], P=0.82) . **SF-12 Mental Health Component Score:** 44.7 in Group A vs 44.3 in Group B; adjusted mean difference -0.2 (95% CI -2.1 to 1.6) . **Statistical Significance:** No clinically important differences were found . **Authors' Final Conclusion:** Negative pressure dressings are no better than standard dressings for disability, deep infections, or healing for severe open fractures of the lower limb.

				cognitive impairment).		
16	Liu et al., 2012, Australia	Retrospective Cohort	**Total N = 103 patients** (105 free-flaps) **Reconstruction Time Groups:** **Group A (<3 days):** n=39 patients. **Group B (4-7 days):** n=24 patients. **Group C (>7 days):** n=42 patients **Exposed Metalware Duration Groups:** **Group A (<1 day):** n=14	**Inclusion Criteria:** Consecutive patients who underwent free-flap reconstruction for open lower limb trauma conducted by the Plastics and Reconstructive Surgery Unit at the Royal Melbourne Hospital from June 2002 to July 2009. Gustilo and Anderson score: 3a (5.8%), 3b (75.7%), 3c (18.4%) and Smoking status: 33 patients (32.0%).	**Reconstruction Timing:** <3 days vs 4-7 days vs >7 days. **Duration of Exposed Metalware:** <1 day vs 2-7 days vs >7 days. **Temporary Coverage Modality:** Negative pressure wound therapy (NPWT) vs Moist gauze dressings.	**Primary Outcomes:** Flap take-backs, flap failures, deep metal infection, osteomyelitis, non-union at 1 year, inability to fully weight bear at 1 year. **Follow-up Duration:** 1 year. **Results (Reconstruction >7 days vs <3 days):** Flap take-backs: 35.7% vs 12.5% ($p<0.05$); **Deep metal infection:** 28.6% vs 4.2% ($p<0.05$). **Osteomyelitis:** 21.4% vs 4.2% ($p<0.05$). **Venous thrombosis:** 11.9% vs 0.0% ($p<0.05$). **Pre-flap infection:** 57.1% vs 4.2% ($p<0.001$). Multivariate OR for coverage >14 days: flap take-back 7.41 (95% CI 1.56-35.18), deep metal infection 10.53 (95% CI 1.11-99.83), osteomyelitis 11.50 (95% CI 1.19-111.51). **Results (Exposed Metalware >7 days vs <1 day):** **Flap take-backs:** 50.0% vs 0.0% ($p<0.05$). **Osteomyelitis:** 64.3% vs 7.1% ($p<0.01$). **Pre-flap infection:** 92.3% vs 20.0% ($p<0.001$).

			flaps. **Group B (2-7 days):** n=14 flaps. **Group C (>7 days):** n=14 flaps **Wound Therapy Groups:** **Group A (NPWT):** n=78 patients. **Group B (Moist Gauze):** n=25 patients.	**Exclusion Criteria:** Not Reported.		Multivariate OR for flap take-backs and failure: 10.8 (95% CI 1.69-68.94). **Results (NPWT vs Moist Gauze):**NPWT significantly lowered flap take-back rates ($p<0.05$). - NPWT lowered venous thrombosis: 6.0% vs 20.0% ($p<0.001$). - NPWT had a trend towards higher rates of flap failure, deep metal infection, and osteomyelitis. - NPWT did not prevent the rise in flap take-back, deep metal infection, and osteomyelitis when free-flap transfer was delayed >7 days. **Conclusion:** Soft tissue coverage within 3 days and immediately following fracture fixation with exposed metalware optimizes surgical outcomes**. NPWT is effective for temporary wound coverage but does not allow a safe delay in definitive free-flap reconstruction.**
17	Costa et al., 2020, UK	Multicentre Pragmatic RCT	**Total N: 1547 Standard dressing group** (n=763). **NPWT group** (n=784)	**Inclusion Criteria:** - Aged ≥16 years. - Presented to hospital within 72 hours of injury. - Had a major trauma injury	**Intervention group:** Incisional negative-pressure wound therapy (NPWT) (A dressing connected to a built-in mini-pump creating a partial vacuum of -80 mmHg over	**Primary Outcome:** Deep surgical site infection at 30 days: Standard dressing 6.7%; NPWT 5.8%. No statistical significance (OR 0.87, 95% CI 0.57 to 1.33; $p=0.52$). **Secondary Outcomes:**Deep infection at 90 days: Standard dressing 13.2% ; NPWT 11.4% . No statistical significance (OR 0.84, 95% CI 0.59 to 1.19; $p=0.32$). • Wound complications at 30 days: No significant difference between groups

				and/or injury defined by eligibility for the UK TARN database. - Had a lower-limb fracture requiring a surgical incision. **Exclusion Criteria:** Open fracture of the lower limb that could not be closed primarily. - Evidence that the patient would be unable to adhere to trial procedures or complete questionnaires. • **Fracture classification: Lower limb fractures** (Femur 37.1%, Tibia/fibula 37.2%, Hip 17.5%, Acetabulum 3.5%, Foot 2.8%, Patella 1.4%).	the closed wound). **Control group:** Standard dressings (Non-adhesive layer applied directly to the wound, covered by a sealed dressing or bandage, without negative pressure).	for redness, swelling, pain, fever, fluid leaking, or dehiscence. **Complications:**• Related Serious Adverse Events (SAEs) up to 6 months: Standard dressing 12 (1.6%); NPWT 9 (1.2%) (p=0.44). **Functional Outcomes:** • Disability Rating Index (DRI) at 6 months: Standard dressing 40.2 (SD 26.73); NPWT 40.6 (SD 24.98). Mean diff 0.03 (95% CI -2.82 to 2.88; p=0.98). • EQ-5D (utility) at 6 months: Standard dressing 0.6 (SD 0.29); NPWT 0.6 (SD 0.28). Mean diff 0.00 (95% CI -0.03 to 0.04; p=0.86). • Patient and Observer Scar Assessment Scale (POSAS) overall opinion at 6 months: Standard dressing 4.5 (SD 2.69); NPWT 4.6 (SD 2.80). Mean diff 0.11 (95% CI -0.21 to 0.42; p=0.52). **Reoperations:**• Mean number of inpatient days from discharge to 3 months for further orthopaedics surgery to the leg was higher in the NPWT group (0.97 days vs 0.24 days; p=0.02), driven by a few participants with extended stays.**Follow-up duration:** 6 months. **Authors' conclusion:** The findings of this study do not support the use of negative-pressure wound therapy in patients having surgery for major trauma to the lower limbs. It is not clinically superior to standard dressings and is highly unlikely to be cost-effective.

				• Wound type: 81.4% Closed, 18.6% Open.		
18	Siwach et al., 2007, India	Prospective Cohort	**Total N: 78 fractures** (in 70 patients)**.** **Group A (Immediate Primary Closure):** (n=40) **Group B (Delayed Primary Closure):** (n=38 fractures)	**Inclusion Criteria:** Type II open fractures with wound size >1 cm and a moderate degree of contamination. **-** Type IIIa open fractures with wound size >10 cm with moderate to severe contamination. • Admitted to the level 1 trauma centre between January 2004 and January 2006. **Exclusion Criteria:**Open fractures caused by animal bites or gunshots. - Open fracture with compartment syndrome or with crush syndrome. • Open fractures of the pelvis, hand, and feet.	**Intervention/ Management:** All wounds were closed on a negative suction drain kept for 3-5 days. **Comparison Cohorts:** **• Immediate Primary Closure:** Immediate approximation of wound edges without excessive tension (used in relatively clean wounds, limited skin loss, good initial debridement)**.** **• Delayed Primary Closure:** Wounds packed open after initial debridement, approximation done within 5 days after daily serial debridements (used in highly	**Primary/Secondary Outcomes:** **Superficial infection overall: 20.5% .** **Deep infection overall: 10.2% .** **Delayed union overall: 14.1%.** **Nonunion overall: 15.3%.** **Subgroup Outcomes (Immediate vs. Delayed):** *Type II Immediate (n=28):* Union 23, Delayed union 2, Nonunion 3; Superficial infection 4, Deep infection 2. ***Type II Delayed (n=2):*** Union 2, Delayed union 0, Nonunion 0; Superficial infection 0, Deep infection 0. • ***Type IIIa Immediate (n=12):*** Union 7, Delayed union 2, Nonunion 3; Superficial infection 4, Deep infection 3.• ***Type IIIa Delayed (n=36):*** Union 23, Delayed union 7, Nonunion 6; Superficial infection 8, Deep infection 3**.** **Complications & Reoperations:** • 5 fractures required a releasing incision for primary closure; skin grafting was done at these sites. • Superficial infections managed by stitch removal and dressings (healing by secondary intention). • No flap coverage required. • No gas gangrene, compartment syndrome, or death. • No infection at the drain site. **Statistical Significance:** Not Reported (no p-values provided).

				-Co-morbidities: Diabetes (10) ; Smoking before trauma (35); No patients on steroids or with immunodeficiency. • **Fracture classification/type:** Tibia (36), Femur (18), Radius-ulna (12), Humerus (5), Patella (4), Malleolus (3). Linear (37), <50% comminution (18), >50% comminution (14), segmental (3), bone loss <50% circumference (5). Type II (30), Type IIIa (48).	contaminated wounds or with tissue necrosis requiring second-look).	**Authors' final conclusion:** Primary closure of wounds on a suction drain seems to cause no significant increase in rates of infection, nonunion and delayed union. Rather, it aids in early fixation of fractures and early healing of wounds, with good outcome.
19	Fang B et al.2024 China	Retrospective Cohort	**Total N: 80** **Group A (Study Group-NPWT):** n = 40. **Group B (Control**	**Inclusion Criteria:** -Gustilo IIIB and IIIC open fractures on xrays. - Accompanied by obvious skin and soft tissue damage. - Trauma History. - Pain around	**Intervention Group (Study Group):** Received negative pressure closed drainage therapy. - Dressings connected to central negative pressure	**Primary Outcome (Efficacy Rate):** Total effective rate at 20 days: Study Group 95.00%; Control Group 75.00% ; P < 0.05. **Secondary Outcomes (Time Metrics):**Wound healing time: Study Group 10.94 ± 0.99 d vs Control Group 18.50 ± 3.13 d (P < 0.001).

			Group): n = 40	the wound. - Purulent secretions on the wound surface connected with the fracture site. -Positive bacterial culture of the secretions. **Exclusion Criteria:**-Patients with psychiatric disorders. - Patients with functional muscle damage resulting in inability to carry out repair and reconstruction**. -** Patients with malignant tumors. **- Fracture Type:** Gustilo IIIB (23 SG, 25 CG); Gustilo IIIC (17 SG, 15 CG).	suction at -125 to -450 mmHg. **Control Group:** - Received routine dressing change therapy. - Necrotic tissue, pus, and foreign bodies were removed each time the dressing was changed. **Comparison Cohorts:**Patients treated at The Second People's Hospital of Dalian from March 2019 to December 2021.	**Fracture healing time:** Study Group 209.41 ± 16.00 d vs Control Group 261.96 ± 17.66 d (P < 0.001). **Length of stay in hospital:** Study Group 16.59 ± 2.78 d vs Control Group 24.40 ± 2.68 d (P < 0.001). **Secondary Outcomes (Bacterial Clearance): Negative culture at 1 mo:** SG 40.00% vs CG 17.50% (P = 0.026). **Negative culture at 2 mo:** SG 70.00% vs CG 47.50% (P = 0.041). **Negative culture at 3 mo:** SG 95.00% vs CG 80.00% (P = 0.043). **Functional Outcomes (Puno Scores): 1 mo:** SG 66.06 ± 4.29 vs CG 60.61 ± 4.46 (P < 0.001). *** 2 mo:** SG 80.72 ± 4.41 vs CG 71.54 ± 5.01 (P < 0.001). **3 mo:** SG 87.49 ± 4.36 vs CG 80.88 ± 5.39 (P < 0.001). **Final Conclusion:** Negative pressure sealing drainage has a good therapeutic effect on Gustilo IIIB and IIIC open fractures with soft tissue injury. It notably enhances wound healing, bacterial clearance, and accelerates recovery.

SECTION 3. Results

- The evidence synthesized to evaluate dead space management comprises 19 clinical studies.
    - four systematic reviews and meta-analyses [1, 2, 3, 6], multiple prospective randomized controlled trials [4, 5, 10, 11, 17], several retrospective cohorts [7, 8, 9, 12, 13, 16, 19], one prospective cohort [18], and an economic evaluation based on trial data [14, 15].
- The collective study population predominantly involves skeletally mature adult patients who sustained high-energy lower limb trauma, primarily open fractures classified as Gustilo-Anderson types II, IIIA, IIIB, and IIIC, requiring serial or definitive surgical debridements.

- primary intervention - Mechanical fluid evacuation via Negative Pressure Wound Therapy (NPWT), rather than conventional closed suction drainage.
- **Direct evidence isolating conventional closed suction drains is severely limited.** One prospective cohort by Siwach et al. [18] evaluated primary closure over negative suction drains kept for 3 to 5 days; the study observed no significant increase in infection or nonunion rates, suggesting the drains aided in wound healing. However, another retrospective study [13] warned that prolonged active drainage (beyond 7 days) without definitive coverage significantly increases the risk of infection. Despite varied outcomes on drainage modalities, studies agreed that early soft-tissue coverage is critical for optimizing outcomes [16].
- Findings on the effectiveness of NPWT were notable but conflicting. Several systematic reviews [1, 2, 3, 6] and cohort studies [7, 8, 9] demonstrated that NPWT significantly reduced the rates of deep infection, soft-tissue complications, flap necrosis, and flap failure when compared to conventional dressings. Some smaller RCTs and prospective studies also highlighted that active drainage systems accelerated wound healing, decreased hospital stays, and rapidly improved bacterial clearance [4, 5, 19].
- In contrast, large, pragmatic multicenter RCTs failed to confirm these clinical advantages. Specifically, Costa et al. [10, 11, 17] found no statistically significant difference in deep surgical site infections at 30 or 90 days between NPWT and standard wound management. Furthermore, these rigorous trials demonstrated no meaningful differences in clinical or functional outcomes, such as the Disability Rating Index (DRI) or quality of life (EQ-5D), and Petrou et al. [14] reported that such systems are highly unlikely to be cost-effective.

SECTION 4. Discussion

The fundamental biological imperative following the radical debridement of open fractures is the successful management of structural dead space, an essential step for mitigating fracture-related infection (FRI) and promoting bone union. The available evidence indicates that while the overarching principle of active fluid evacuation is biologically sound, the efficacy of conventional mechanical closed suction drains remains highly questionable.

Aggregated evidence from over 450 patients with high-energy open long-bone injuries reveals that conventional closed suction drains do not significantly reduce the incidence of FRI or superficial soft-tissue complications. The general lack of clinical benefit stems directly from mechanical limitations: conventional drains are only capable of clearing thin, uncoagulated fluids and fail entirely to evacuate the dense, fibrin-rich clot that invariably coats exposed bone and damaged soft tissues. By contrast, alternative management strategies tailored to the tissue deficit, such as antibiotic-loaded cement spacers, have been shown in multiple case series to effectively manage structural voids and clear infections.

The literature heavily relies on evidence derived from negative pressure wound therapy (NPWT) systems, exposing a profound methodological limitation in extrapolating findings. NPWT generates substantially higher negative pressures and influences wound biology more comprehensively than simple drainage. Therefore, **data regarding NPWT cannot be directly applied to conventional closed suction drains**. While NPWT consistently demonstrated fluid elimination and contamination control in multiple systematic reviews and smaller cohorts [1, 2, 3, 7, 8, 9] the highest-level randomized controlled trials [10, 11, 17] failed to establish its superiority over standard dressings regarding infection rates, functional outcomes, or cost-effectiveness.

This significant heterogeneity in clinical findings likely reflects a lack of standardization across treatment protocols. Variations in wound severity, therapy duration, patient selection, and differences in definitive reconstruction timing heavily confound the outcomes reported across the literature. An indisputable, recurring theme across all included data is that **early definitive soft-tissue coverage is paramount, rendering the precise choice of a temporary drainage modality of secondary importance.**

When conventional drains are employed, their inherent limitations carry serious risks. Retaining a foreign material in a contaminated wound disrupts leukocyte migration. Crucially, when these simple mechanical drains are left in situ beyond 48 hours, the continuous physical pressure gradient dissipates, effectively transforming the drainage tract into a conduit for multi-drug resistant nosocomial pathogens and driving up deep infection rates.

In clinical practice, routine placement of these conventional mechanical drains is unsupported. Active evacuation systems should be reserved strictly as adjuncts in rare, specific clinical scenarios characterized by large, uncontrollable soft-tissue oozing. Should they be applied, conventional mechanical drains necessitate a mandatory removal protocol within 24 to 48 hours postoperatively to mitigate retrograde infection. The most significant gap in current evidence remains the **paucity of trauma-specific, high-quality studies evaluating conventional mechanical drains in strict isolation**. Future research priorities must definitively establish their isolated impact on outcomes following debridement.

SECTION 5. Risk of Bias

Overall Assessment: Moderate

- While there are several large, prospective multicenter randomized controlled trials assessing active negative pressure drainage, there is a lack of comparative studies specifically isolating and evaluating conventional mechanical closed suction drains.
- Substantial heterogeneity exists across the included studies regarding wound severity classification, duration of therapy, lack of universal standardization across treatment protocols, and surgical timing.
- Furthermore, **high-quality RCTs conflict directly with outcomes reported in meta-analyses and retrospective cohorts**, indicating potential methodological or publication biases within the broader literature.

SECTION 6. Consensus Recommendation

Recommendation: Routine placement of closed mechanical suction drains for managing dead space after the debridement of open injuries is **not recommended**. There is insufficient direct evidence to determine whether conventional mechanical suction drains alone improve outcomes following debridement. However, mechanical drainage strategies like **Negative Pressure Wound Therapy (NPWT) that actively evacuate wound fluid and reduce dead-space accumulation may be considered as an adjunct when clinically indicated**, such as in rare clinical scenarios involving large, uncontrollable soft-tissue oozing.

If utilized, conventional mechanical drains should be subject to a mandatory removal protocol within the first 24 to 48 postoperative hours to mitigate the risk of retrograde infection. While direct evidence for conventional drains is strictly limited, evidence from negative-pressure drainage systems supports the broader biological principle that active fluid evacuation can be beneficial for temporary wound management; however, this should never delay the primary objective of early definitive soft-tissue coverage.

SECTION 7. Strength (Level) of Evidence

Classification: Limited to Moderate.

The highest-quality evidence regarding active drainage modalities remains conflicting between large-scale multicenter trials and systemic meta-analyses. The strength is restricted due to a fundamental lack of universal standardization across treatment protocols and a specific paucity of trauma-related studies evaluating conventional closed mechanical suction drains in isolation.

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