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Short Title: A meta-analysis of the management of open tibia fracture wounds with negative pressure wound care compared with traditional wound dressing

RESEARCH ARTICLE

A meta-analysis of the management of open tibia fracture wounds with negative pressure wound care compared with traditional wound dressing

Mohamed S. Imam[1*], Lujain Shbeir[2], Manar Alzahrani[2], Kadi Yahya Alanazi[3], Sana Manzari[4], Norah Ayidh Jabbar Alghamdi[5], Meaad Hossain Alqorashi[6], Lojain Saeed Mohammed Alqahtani[7], Lina Ahmed Alzahrani[7], Nouf Saleh Ahmed Badawod[7], Khawla Lafe Fahad Alobaywi[8], Mohammed Gamal[9], Mohammed A. Amin[10], Marina E. Boules[10], Mohamed E. A. Abdelrahim[10]
[1]Department of Clinical Pharmacy, National Cancer Institute, Cairo University, Fom El Khalig Square, Cairo, Egypt
[2]College of Pharmacy, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia
[3]College of Pharmacy, Northern Border University, Rafha, Saudi Arabia
[4]College of Medicine, Alfaisal University, Riyadh, Saudi Arabia
[5]College of Pharmacy, AlBaha University, AlBaha, Saudi Arabia
[6]College of Pharmacy, Taif University, Taif, Saudi Arabia
[7]College of Pharmacy, King Saud University, Riyadh, Saudi Arabia
[8]College of Pharmacy, Hafr Al Batin University, Hafr Al-Batin, Saudi Arabia
[9]Department of Pharmaceutical Analytical Chemistry, Faculty of Pharmacy, Beni-Suef University, Beni-Suef, Egypt
[10]Department of Clinical Pharmacy, Faculty of Pharmacy, Beni-Suef University, Beni-Suef, Egypt

***Corresponding author:** Mohamed S. Imam, Department of Clinical Pharmacy, National Cancer Institute, Cairo University, Fom El Khalig Square, Kasr Al-Aini Street, Cairo, Egypt
E-mail: imammohamed311@gmail.com

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Abstract

Background and Objectives: The drive of the meta-analysis was to appraise and compare the consequence of Negative Pressure Wound Treatment (NPWT) in the management of open tibia fracture wounds compared with Conventional Wound Dressing (CWD).

Methods: The outcomes identified in this meta-analysis were thoroughly examined, and the Odds Ratio (OR) and Mean Difference (MD) were calculated with 95% Confidence Intervals (CIs). These models can be dichotomous, contentious, or based on random or fixed effects. The existing meta-analysis encompassed 18 studies from 2003 to 2022, encompassing 3331 subjects with post-operative infection after open tibia fracture wounds.

Results: NPWT had a significantly lower post-operative infection rate (OR, 0.28; 95% CI, 0.19-0.42, p<0.001), wound coverage rate (OR, 0.09; 95% CI, 0.03-0.22, p<0.001), wound healing rate (OR, 0.05; 95% CI, 0.02-0.14, p<0.001), and patient hospital stay rate (OR, 0.06; 95% CI, 0.02-0.17, p<0.001) compared to CWD in open tibia fracture wound subjects. However, no significant difference was found between NPWT and CWD in flap surgery (OR, 1.18; 95% CI, 0.78-1.77, p=0.43), and non-union rate (OR, 1.00; 95% CI, 0.71-1.40, p=0.99) in open tibia fracture wound subjects.

Conclusions: The examined data revealed that NPWT had a significantly lower post-operative infection rate, wound coverage rate, wound healing rate, and patient hospital stay rate however, no significant difference was found in flap surgery, and non-union rate compared to CWD in open tibia fractures wound subjects. Nevertheless, their values should be taken into account as several research only encompassed a minor number of participants and some comparisons involved low number of studies.

Keywords: Negative pressure wound treatment, Open fracture wound, Conventional wound dressing, Post-operative infection

Introduction

Open tibia fractures are severe wounds that young male subjects frequently sustain (Court-Brown et al., 2012). They are now receiving better care than they did in previous years. Nonetheless, infection and its sequelae continue to pose a serious issue, particularly when treating Gustilo type III open tibia fractures, (Matos et al., 2015) where initial wound closure is typically not achievable. Thus, many orthopedic surgeons now prefer to use Negative Pressure Wound Therapy (NPWT). Over the last ten years, the use of NPWT has increased while that of Conventional Wound Dressings (CWD) has decreased (Blum etb al., 2012). Several systematic reviews were conducted to validate the efficacy of NPWT. Though, the cases encompassed in the reviews were not entirely distinct from other types of wounds, e.g. pressure sores, diabetic ulcers, and burns, in terms of their pathogenic mechanism and prognosis (Kanakaris et al., 2007). Even if some data supported the usage of NPWT in the treatment of open tibia fractures, the conclusions for some details regarding a paradoxical consequence in the earlier evaluations would become quite unclear (Schlatterer et al., 2015) as a result, the goal of the existing analysis is to measure the specific benefits and drawbacks of NPWT against traditional wound dressings while treating open tibia fractures.

Materials and Methods

Examination design

The epidemiological report included the meta-analyses, which were subsequently reviewed according to a predetermined procedure. A multitude of databases, Incorporating PubMed, OVID, the Cochrane Central Register of Controlled Trials, Google Scholar, the Cochrane Library, and Embase, these databases were accessed for data collection and analysis (Liberati et al., 2009). A comparative evaluation of the effectiveness of NPWT in managing open tibia fracture wounds versus CWD was conducted using the aforementioned databases.

Consolidation of data

Comparing NPWT to CWD in the context of wound issues at the surgical site in patients with open tibia fractures revealed multiple clinical outcomes. Post-operative infection rate, flap surgery, and non-union rate in patients with open tibia fractures wound were the key enclosure parameter outcomes in these results. Language barriers were not accounted for in either the research inclusion or the participant screening process. There were no restrictions on the number of participants recruited in the studies. Since editorials, letters, and reviews did not include interventions, they were excluded from our synthesis. The complete examination identification process is illustrated in fig. 1.

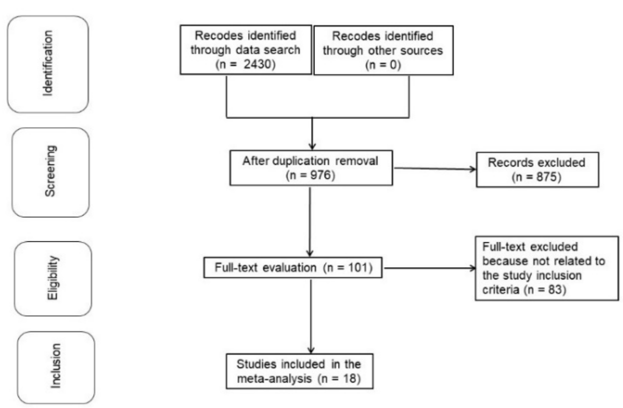

Figure 1. Schematic diagram of the examination procedure.

Eligibility of included studies

The consequence of NPWT, either helpful or harmful, on the clinical outcomes of open tibia fractures wounds is being explored. The sensitivity analysis encompassed only those publications that examined the effects of interventions on the incidence of open tibia fracture wound surgeries. Sensitivity and subclass analyses were performed by comparing the various subtypes with the interventional groups.

Enclosure and exclusion criteria

Enclosure criteria: To be included in the meta-analysis, studies needed to compare the impact of NPWT on surgical site wound complications in patients with open tibia fractures. For statistical analysis, the outcomes had to be clearly reported in the results.

Exclusion criteria: Studies with a non-comparative design were excluded from the analysis. Additionally, letters, books, reviews, and book chapters were also excluded from the current assessment.

Study identification

Based on the PICOS principle, a protocol of search techniques was developed and stated as follows: P (Population) encompassed subjects who had undergone open tibia fractures wounds; I ("intervention" or "exposure") was NPWT; C (Comparison) was NPWT versus CWD. O (Outcome) which were post-operative infection rate, flap surgery, and non-union rate; S (Examination Design): There were no limitations placed on the intended test.

Using the keywords and associated terms listed in tab. 1, we conducted a comprehensive search through relevant databases up to April 2022. All studies included in a reference management program, covering titles, abstracts, and those not linking treatment type to clinical outcomes, were reviewed. Additionally, two authors evaluated the papers to identify pertinent studies.

Table 1. Database search strategy for inclusion of examinations.

Database	Search Strategy
Google Scholar	#1 "open tibia fractures wound" OR "negative pressure wound treatment"
	#2 "conventional wound dressing" OR "post-operative infection"
	#3 #1 AND #2
Embase	#1 'open tibia fractures wound' /exp OR 'negative pressure wound treatment'
	#2 'conventional wound dressing'/exp OR 'post-operative infection'/
	#3 #1 AND #2
Cochrane Library	#1 (open tibia fractures wound):ti,ab,kw (negative pressure wound treatment):ti,ab,kw (Word variations have been searched)
	#2 (conventional wound dressing):ti,ab,kw OR (post-operative infection):ti,ab,kw (Word variations have been searched)
	#3 #1 AND #2
PubMed	#1 "open tibia fractures wound"[MeSH] OR "negative pressure wound treatment"[All Fields]
	#2 "conventional wound dressing"[MeSH Terms] OR "post-operative infection"[All Fields]
	#3 #1 AND #2
OVID	#1 "open tibia fractures wound"[All Fields] OR "negative pressure wound treatment" [All Fields]
	#2 "conventional wound dressing"[All fields] OR "post-operative infection"[All Fields]
	#3 #1 AND #2

Study screening

To condense the data, the following standards were applied: analysis and individual traits presented in a standard format; last name of the first author; publication date and year; country where the study was conducted; gender; characteristics of recruited subjects; sample size; qualitative and quantitative evaluation techniques; demographic data; and clinical and therapeutic attributes. Two anonymous reviewers assessed the bias probability in each test and evaluated the quality of the methods used in the studies selected for further analysis. Each examination's methodology was independently assessed by two reviewers.

Statistical evaluation

In the current meta-analysis, with a 95% Confidence Interval (CI), the Odds Ratio (OR) and Mean Difference (MD) were calculated using either dichotomous or continuous random- or fixed-effect models. The I2 index, ranging from 0 to 100, was calculated and expressed as a percentage. The higher the I2 values, the greater the heterogeneity, whereas an I2 value of zero indicates no heterogeneity. An I2 value of 50% or higher indicated the use of the random effect, while I2 values below 50% suggested the application of the fixed effect (Sheikhbahaei et al., 2016). The initial investigation results, as previously mentioned, were categorized under the subcategory analysis. Publication bias was assessed using Begg's and Egger's tests for quantitative analysis, and it was considered present at $p>0.05$. Two-tail analysis was used to compute the p-values. Graphs and statistical analysis were generated using review manager 5.4.

Results

In the meta-analysis, nine studies published between 2003 and 2022 were included, after evaluating 2,430 applicable studies that met the inclusion criteria (Blum et al., 2012; Kortesis et al., 2003; Labler et al., 2004; Stannard et al., 2009; Jayakumar et al., 2013; Gupta et al., 2013; Joethy et al., 2013; Rezzadeh et al., 2015; Krtička et al., 2016; Arti et al., 2016; Virani et al., 2016; Sibin et al., 2017; Tahir et al., 2020; Costa et al., 2020; Panchal et al., 2020; Mueller et al., 2021; Khonglah et al., 2021; Kumaar et al., 2022). A summary of the findings from this meta-analysis is presented in tab. 2, encompassing a total of 3,331 subjects with post-operative infections following open tibia fractures.

Table 2. Characteristics of studies.

Study	Country	Total	NPWT	CWDs
Kortesis et al., 2003	USA	101	54	47
Labler et al., 2004	Switzerland	24	13	11
Stannard et al., 2009	UK	58	35	23
Blum et al., 2012	Australia	229	166	63
Jayakumar et al., 2013	India	40	20	20
Gupta et al., 2013	India	30	14	16
Joethy et al., 2013	Singapore	69	51	18
Rezzadeh et al., 2015	USA	32	12	20
Krtička et al., 2016	Czech Republic	41	21	20
Arti et al., 2016	Iran	90	45	45
Virani et al., 2016	India	93	43	50
Sibin et al., 2017	India	30	15	15
Tahir et al., 2020	Pakistan	420	206	214
Costa et al., 2020	UK	1547	784	763
Panchal et al., 2020	India	95	50	45
Mueller et al., 2021	USA	274	118	156
Khonglah et al., 2021	India	30	15	15
Kumaar et al., 2022	India	128	64	64

Total	**3331**	**1726**	**1605**

NPWT had a significantly lower post-operative infection rate (OR, 0.28; 95% CI, 0.19-0.42, p<0.001) with moderate heterogeneity (I2=53%), wound coverage rate (OR, 0.09; 95% CI, 0.03-0.22, p<0.001) with low heterogeneity (I2=37%), wound healing rate (OR, 0.05; 95% CI, 0.02-0.14, p<0.001) with no heterogeneity (I2=16%), and patient hospital stay rate (OR, 0.06; 95% CI, 0.02-0.17, p<0.001) with no heterogeneity (I2=0%) compared to CWD in open tibia fractures wound subjects, as revealed in fig. 2-5.

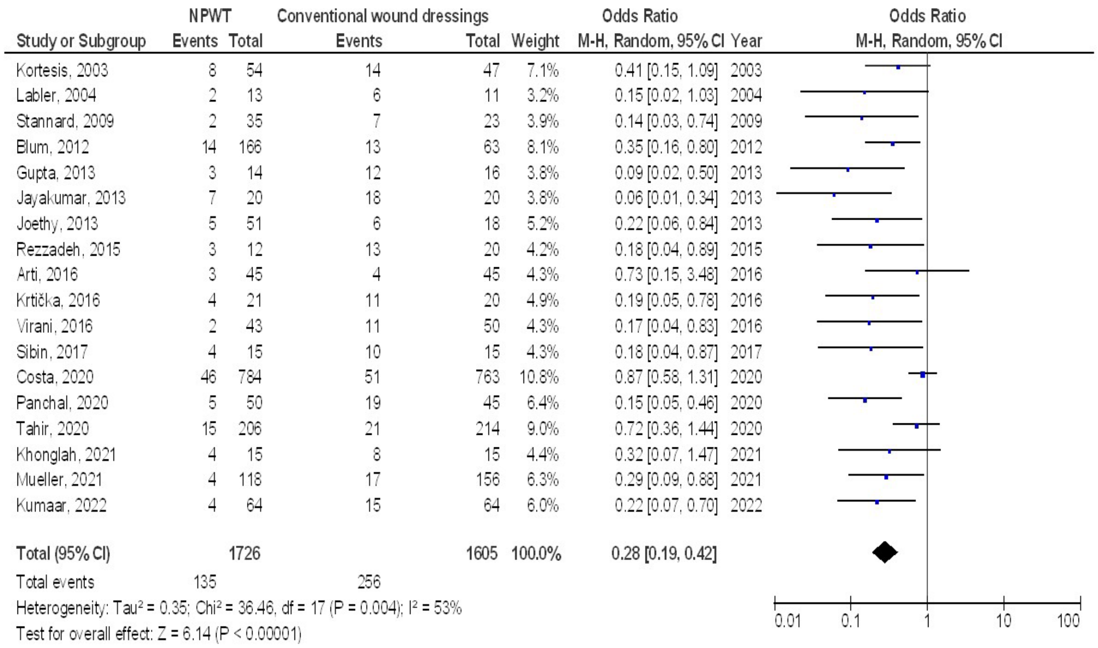

Figure 2. **The effect's forest plot of the NPWT compared to CWD on post-operative infection rate in open tibia fractures wound subjects.**

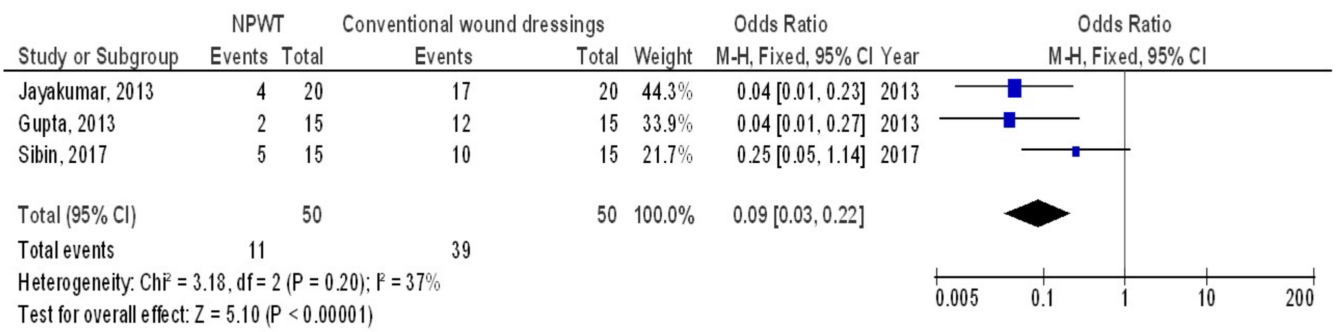

Figure 3. **The effect's forest plot of the NPWT compared to CWD on wound coverage rate in open tibia fractures wound subjects.**

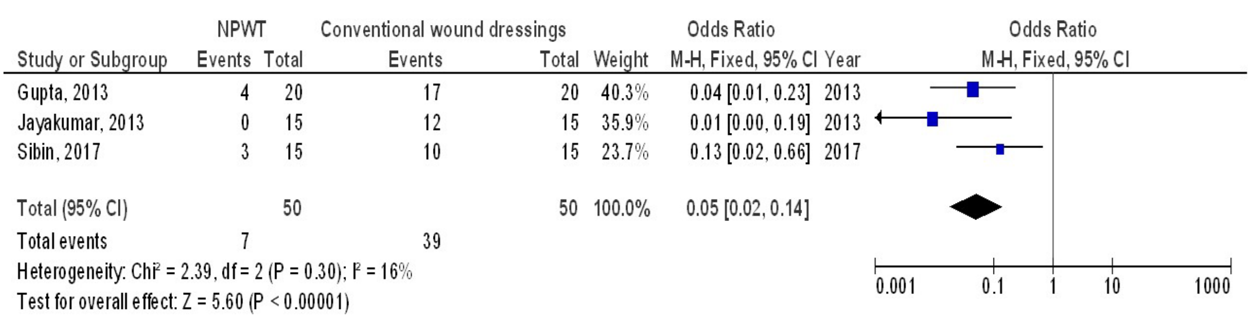

Figure 4. **The effect's forest plot of the NPWT compared to CWD on wound healing rate in open tibia fractures wound subjects.**

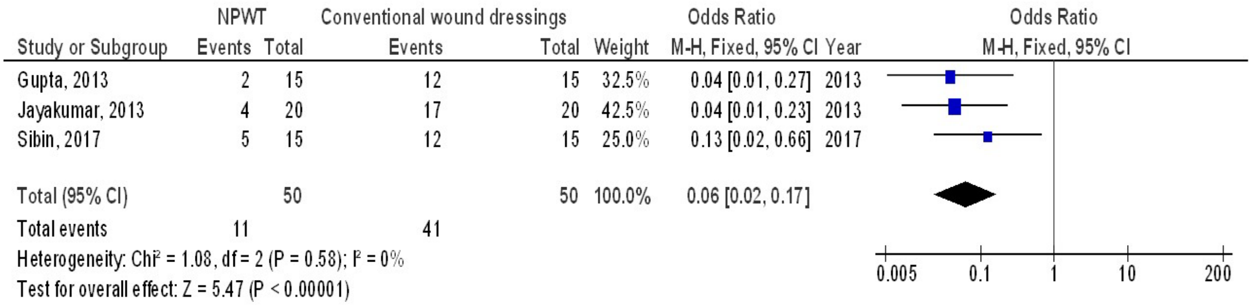

Figure 5. **The effect's forest plot of the NPWT compared to CWD on patient hospital stay rate in open tibia fractures wound subjects.**

However, no significant difference was found between NPWT and CWD in flap surgery (OR, 1.18; 95% CI, 0.78-1.77, p=0.43) with no heterogeneity (I2=0%), and non-union rate (OR, 1.00; 95% CI, 0.71-1.40, p=0.99) with no heterogeneity (I2=0%) in open tibia fractures wound subjects, as revealed in fig. 6 and 7.

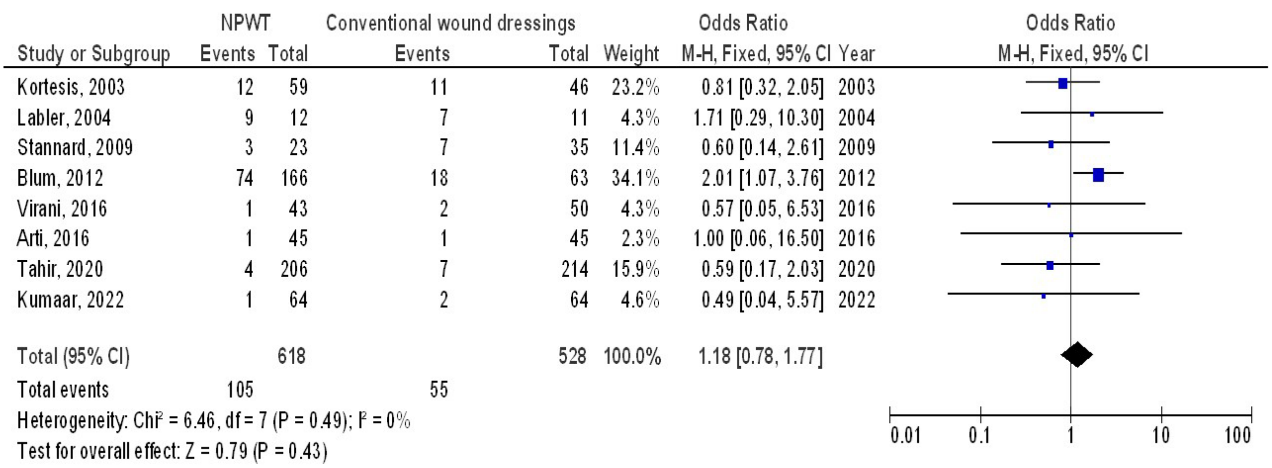

Figure 6. **The effect's forest plot of the NPWT compared to CWD on flap surgery in open tibia fractures wound subjects.**

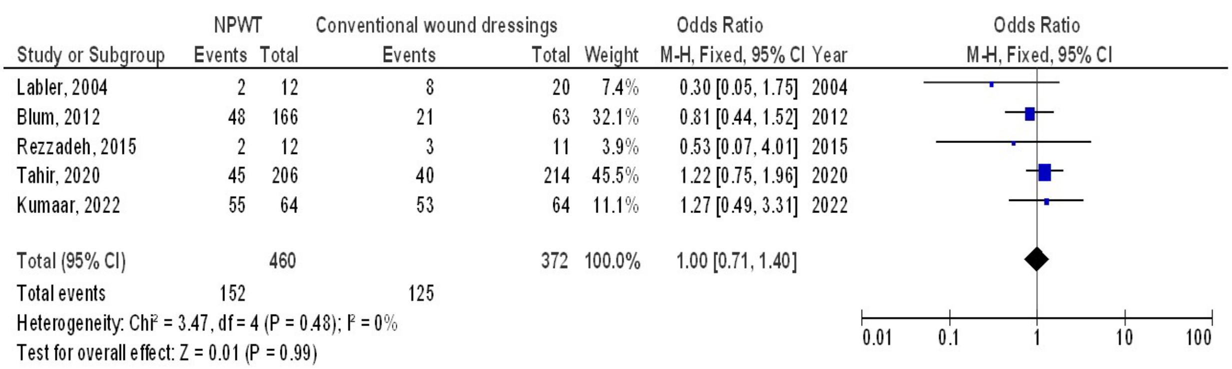

Figure 7. **The effect's forest plot of the NPWT compared to CWD on non-union rate in open tibia fractures wound subjects.**

The visual interpretation of the effect's forest plot and the quantitative Egger regression test revealed no examination bias (p=0.87), as fig. 8-13 demonstrate. It was exposed that the mainstream of relevant exams had low practical quality and were impartial in their selective reporting.

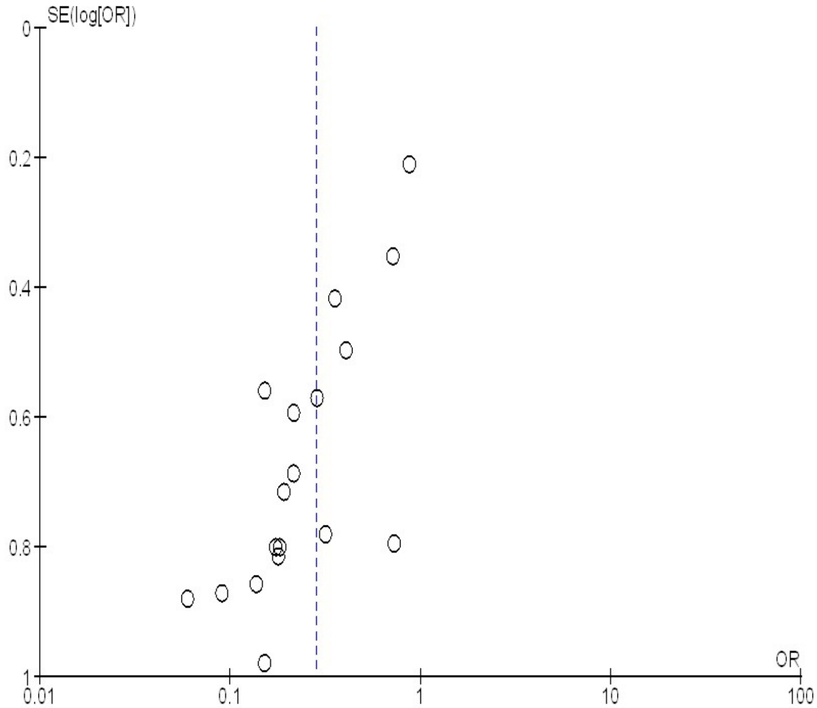

Figure 8. The funnel plot of the NPWT compared to CWD on post-operative infection rate in open tibia fractures wound subjects.

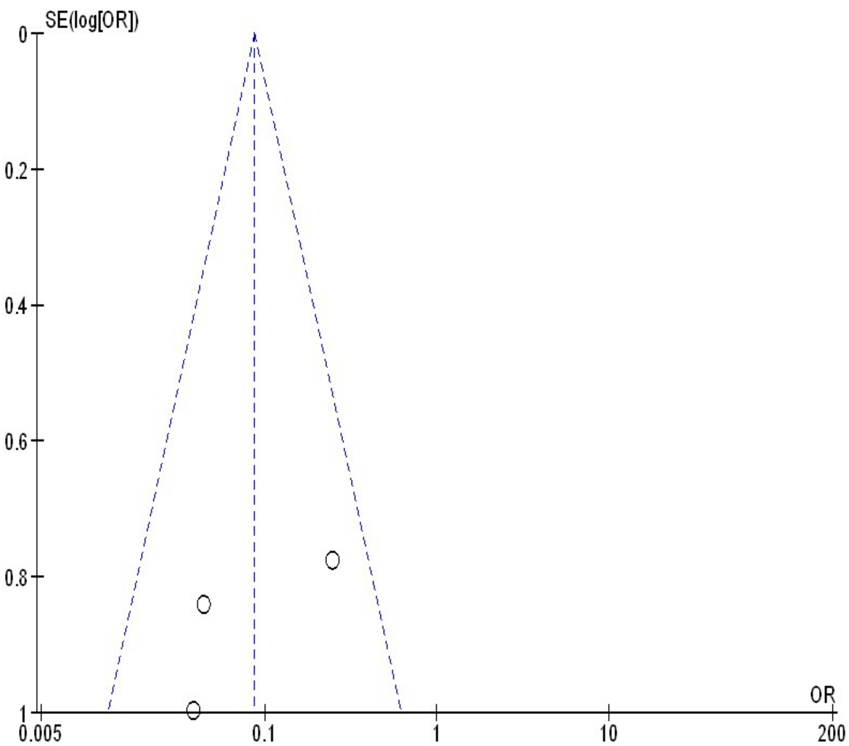

Figure 9. The funnel plot of the NPWT compared to CWD on wound coverage rate in open tibia fractures wound subjects.

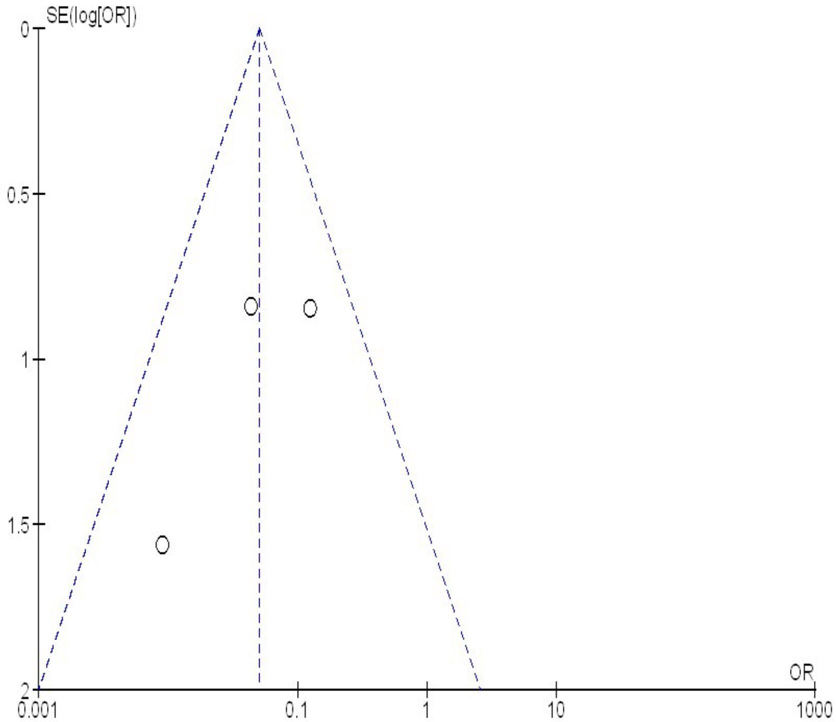

Figure 10. **The funnel plot of the NPWT compared to CWD on wound healing rate in open tibia fractures wound subjects.**

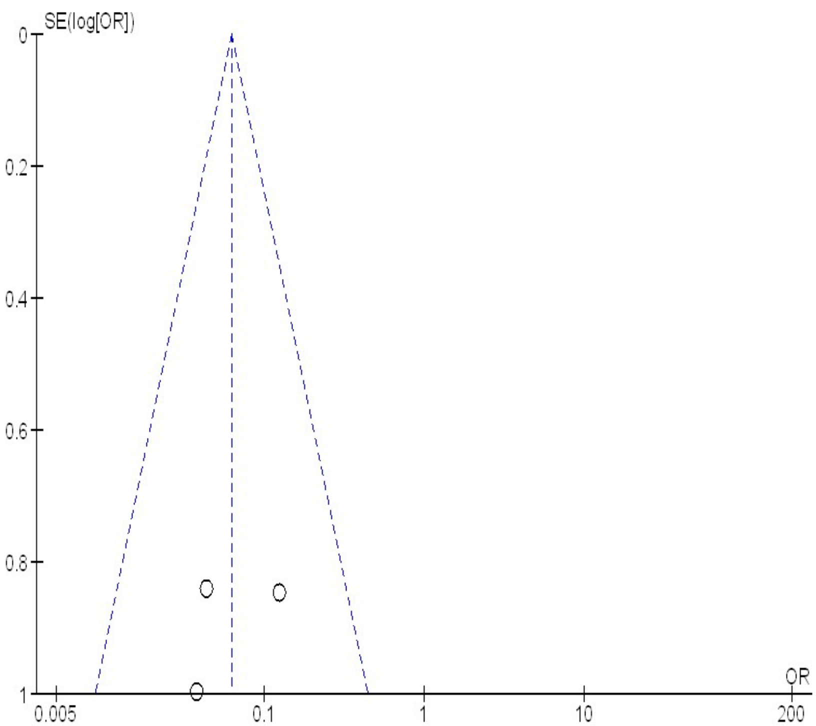

Figure 11. **The funnel plot of the NPWT compared to CWD on patient hospital stay rate in open tibia fractures wound subjects.**

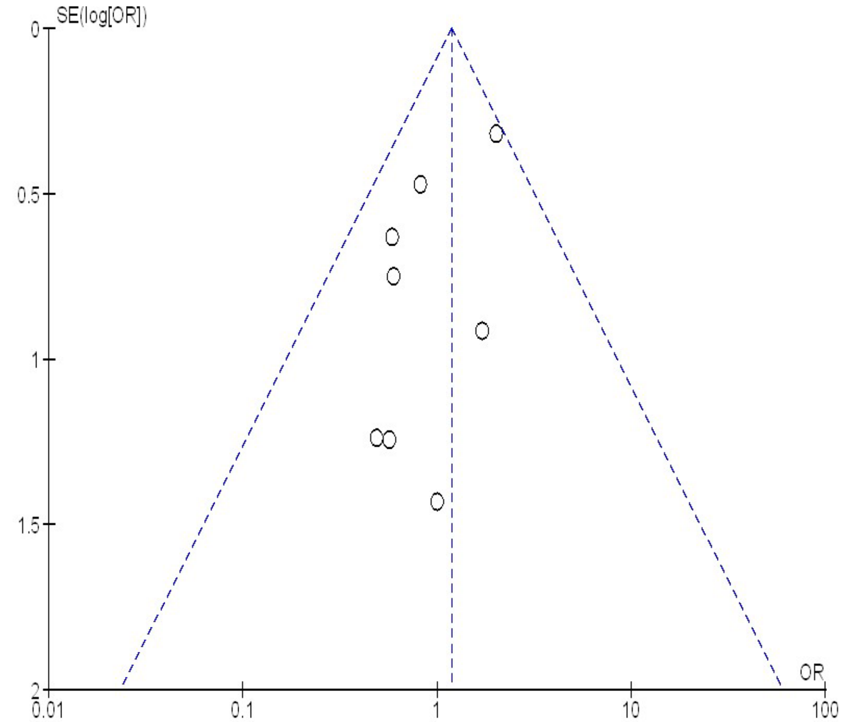

Figure 12. The funnel plot of the NPWT compared to CWD on flap surgery in open tibia fractures wound subjects.

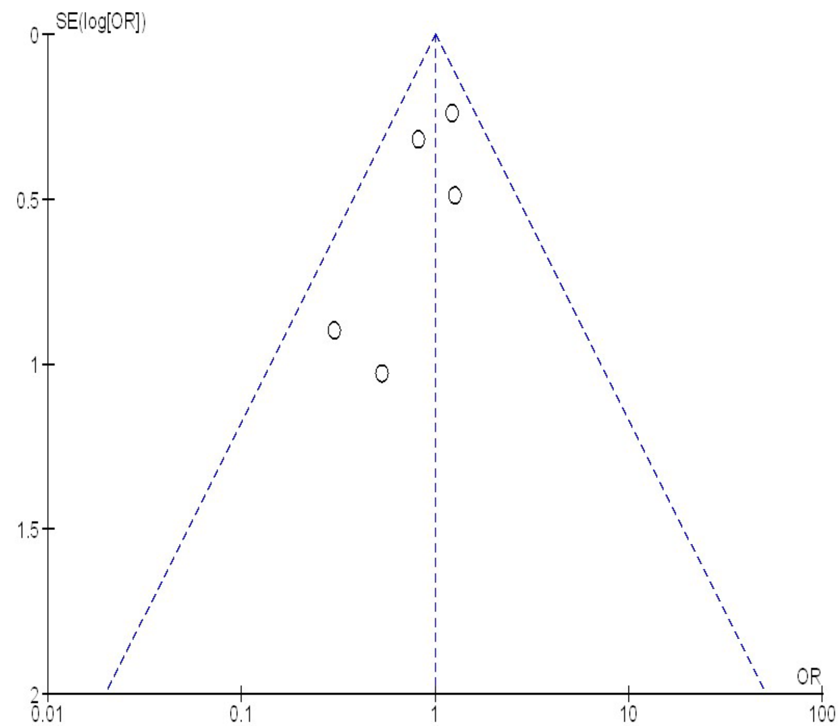

Figure 13. The funnel plot of the NPWT compared to CWD on non-union rate in open tibia fractures wound subjects.

Discussion

For the existing meta-analysis, 18 studies from 2003 to 2022 were encompassed; of these, 3331 people were tested for a post-operative infection after open tibia fractures wound of them 1726 were using NPWT positive and 1605 were using CWD. The sample size was 24–1547 people (Blum et al., 2012; Kortesis et al., 2003; Labler et al., 2004; Stannard et al., 2009; Jayakumar et al., 2013; Gupta et al., 2013; Joethy et al., 2013; Rezzadeh et al., 2015; Krtička et al., 2016; Arti et al., 2016; Virani et al., 2016; Sibin et al., 2017; Tahir et al., 2020; Costa et al., 2020; Panchal et al., 2020; Mueller et al., 2021; Khonglah et al., 2021; Kumaar et al., 2022). The examined data exposed that NPWT had a significantly lower post-operative infection rate, wound coverage rate, wound healing rate, and patient hospital stay rate compared to CWD in open-fracture wound subjects. Nevertheless, no significant difference was found between NPWT and CWD in flap surgery, and non-union rate in open tibia fractures wound subjects. Nevertheless, given that some studies encompassed a minor number of subjects—12<100 subjects out of 18—attention ought to be given to its values and some comparisons involved low number of studies.

The widely mentioned benefit of NPWT, (Gage et al., 2015) which is the clearance of wound bacterial numbers and inflammatory cells that ensue, could have had a role in this outcome (Sinha et al., 2013). According to certain data, NPWT can greatly speed up the healing process of wounds, which is consistent with the findings of earlier research (Hunter et al., 2007). Results from earlier research indicated that the NPWT treatment decreased the occurrence of flap procedures in severe open tibia fracture s for concomitant flap surgeries (Dedmond et al., 2007; Dedmond et al., 2006). However, data from the existing meta-analysis was unable to identify any meaningful intergroup differences in the percentage of free flaps required to treat open tibia fracture s or the rate at which flap surgery is performed. These results contradict the earlier theory (Schlatterer et al., 2015; Schlatterer et al., 2008). This discrepancy could be the result of the small sample size masking insufficient inspection efficiency or the intergroup incomparability wound severity amongst the retrospective studies encompassed in the existing evaluation. Nevertheless, this contradiction can also be caused by the prior research' use of historical control and the enclosure of case series without similar control groups (Dedmond et al., 2007; Dedmond et al., 2006). The coexisting amputation rate is another element that can have an impact on the outcome. It is well-recognized that a decline in the usage of flaps combined with an increase in the risk of amputations is not encouraging. It implies that, even with flaps, there are still more limbs beyond salvation. Nevertheless, the coexisting amputation rate was not mentioned in the prior research when discussing flap rates (Dedmond et al., 2007; Dedmond et al., 2006). The majority of the studies encompassed in this meta-analysis did not encompasses patients who had amputations. Using NPWT may be able to reduce the intricacy of the wound and convert some non-salvageable limbs into ones that can be saved with flaps. This is in line with earlier findings that NPWT can shrink wounds and encourage the formation of granulation tissues (Arti et al., 2016; Sinha et al., 2013; Borgquist et al., 2010). However, due to the small number of relevant samples, a firm conclusion could not be drawn. Therefore, we think that the evidence available now is insufficient to conclude that NPWT can lower the anticipation for flap surgery and the percentage of free flaps. A firm decision should be postponed until additional data has been gathered. However, there has been discussion regarding how NPWT affects flap survival. Utilizing NPWT has been shown in some earlier research to considerably raise the flap survival rate (DeFranzo et al., 2001). One may also consider a high-level negative pressure over -100 mmHg to be a potential risk factor for flap necrosis (Krug et al., 2011). Despite the constant use of relatively high negative pressure of –125 mmHg, a modestly significant difference in the flap survival was detected in favor of NPWT depending on the discoveries of the existing meta-analysis (Labler et al., 2004; Joethy et al., 2013). There was little clinical relevance to this small variation, but it was explained by the fact that the subjects in the control group had suffered less severe injuries. Unambiguous evidence of a lower flap survival rate following NPWT application under a constant high negative pressure above -100 mmHg was not found. This suggests that using NPWT with flaps is most likely safe. Notwithstanding the delicate nature of flap blood supply and the lack of pertinent, high-quality RCT indication with a sufficient sample size in the existing meta-analysis, NPWT in conjunction with flaps ought to be utilized cautiously until the specifics of its impact on flaps are thoroughly clarified. Regarding the healing of fractures, no RCT data was discovered. Cohort study data was unable to identify any benefits or drawbacks between NPWT and traditional wound dressings. However, this might be due to the minor sample size or preoperative intergroup incomparability. Before a firm conclusion is reached, more research is required. In this systematic review, only one RCT suggested that NPWT could enhance the infected open tibia fracture patients' life quality as measured by the SF-36 physical component score; however, additional research was necessary to corroborate this finding. In contrast, a prior systematic review conducted by Janssen and colleagues found that the use of NPWT for wound care may create anxiety in patients, which could result in a temporary decline in their quality of life (Janssen et al., 2016). It should be noted, nevertheless, that seven distinct scales with varying dimensions and emphases were used, and that the studies encompassed in the analysis of Jansen's review comprised a variety of patient types, such as those with acute trauma, chronic ulcers, and diabetic foot. When the findings of these clinically heterogenic investigations are directly combined to form a single assumption about life quality, some components might be hidden by others. However, the small sample size makes subgroup analysis difficult. As a result, we believe that more research is necessary before drawing firm conclusions about the impact of NPWT on subject life quality for open tibia fracture therapy (Kim et al., 2019; Qian et al., 2022).

The limitations of the meta-analysis include the potential for selection bias, as some nominated studies were excluded from the analysis. However, the study was excluded because it did not meet the inclusion criteria of the meta-analysis. Additionally, data were needed to detect the effects of confounding variables, including gender, ethnicity, and age. The objective of the meta-analysis was to examine the impact of NPWT in the treatment of open tibia fracture wounds compared with the CWD. Bias may have been exacerbated by relying on previous studies with inaccurate or incomplete data. The primary factors that likely led to judgement were the person's ethnicity, nutritional, age, and gender status. Inaccurate data and unpublished research may result in inadvertent value modifications.

Conclusions

The examined data revealed that NPWT had a significantly lower post-operative infection rate, wound coverage rate, wound healing rate, and patient hospital stay rate compared to CWD in open-fracture wound subjects. Nevertheless, no significant difference was found between NPWT and CWD in flap surgery, and non-union rate in open tibia fractures wound subjects. Nevertheless, agreed that some studies encompassed a minor number of subjects 12<100 subjects out of 18 attentions ought to be given to its values and some comparisons involved low number of studies.

Author Contributions

Conceptualization, M.S.I and M.E.A.A; methodology, formal analysis, investigation, resources, data curation, writing original draft preparation, writing review and editing, M.S.I., L.S., M.A., K.Y.A., S.M., N.A.J.A., M.H.A., L.S.M.A., L.A.A., N.S.A.B., K.L.F.A., M.G., M.A.A., M.E.B. and M.E.A.A.; visualization, M.S.I and M.E.A.A.; supervision, M.S.I and M.E.A.A.; project administration, M.S.I. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

On request, the corresponding author is required to provide access to the meta-analysis database.

Conflicts of Interest

The authors declare no conflicts of interest.

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