

Comparing Early Total Care and Damage Control Orthopedics in Polytrauma Patients: A Systematic Review and Meta-Analysis of the Outcomes

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ABSTRACT

Optimal timing of definitive fracture fixation in polytrauma patients remains controversial. This study aimed to compare clinical outcomes between Early Total Care (ETC) and Damage Control Orthopedics (DCO). A systematic review and meta-analysis was conducted in accordance with PRISMA guidelines. PubMed, CENTRAL, Scopus, and Web of Science were searched through August 2025. Observational and interventional studies comparing ETC and DCO were included. Outcomes included mortality, sepsis, acute respiratory distress syndrome (ARDS), multiple organ dysfunction syndrome (MODS), infections, delayed union, hospital stay, and number of surgical procedures. Methodological quality of observational studies was assessed using the Newcastle–Ottawa Scale, while risk of bias for randomized controlled trials was assessed using the Cochrane RoB 2 tool. The NIH Quality Assessment Tool was used for the included case series. Twenty studies (18,852 patients) were analyzed. ETC was associated with reduced hospital stay (WMD = -4.91 days, 95% CI: -6.89 to -2.93), surgical procedures (WMD = -3.39, 95% CI: -3.57 to -3.22), sepsis risk (OR = 0.63, 95% CI: 0.48 to 0.81), and delayed union (OR = 0.23, 95% CI: 0.06 to 0.93). No significant differences existed for mortality (OR = 0.59, 95% CI: 0.28 to 1.24), MODS (OR = 0.85, 95% CI: 0.55 to 1.30), ARDS (OR = 1.18, 95% CI: 0.64 to 2.17), or infections (OR = 1.38, 95% CI: 0.92 to 2.07). ETC was associated with a lower risk of sepsis, shorter hospital stay, and fewer surgical procedures in patients with polytrauma. Major complications and mortality, however, were similar between the two approaches. These findings highlight the importance of patient selection and individualized decision-making based on physiological status.

Keywords: Polytrauma, Multiple injuries, Orthopedic procedures, Fracture fixation, Treatment outcome.

INTRODUCTION

Polytrauma is a term used for patients usually with two or more severe injuries. It is classified according to the Berlin definition as having an Abbreviated Injury Scale (AIS) score of ≥ 3 in multiple body regions, along with additional physiological parameters¹. An Injury Severity Score (ISS) of ≥ 16 is often used to define severe trauma, correlating with increased mortality risk^{2,3}.

Trauma remains a major global cause of mortality and disability, particularly in young adults due to high rates of road traffic accidents^{4,7}. It accounts for approximately 9.8% of global deaths, with nearly six million fatalities annually^{7,8}. The management of severe trauma patients focuses on preventing the “lethal triad” of acidosis, coagulopathy, and hypothermia⁹⁻¹³.

Two primary strategies are used to manage polytrauma patients: damage control orthopedics (DCO) and early total care (ETC). ETC involves early definitive fixation of fractures, ideally within 24–48 hours, and has shown benefits such as shorter hospital stays¹⁴. DCO, in contrast, prioritizes provisional stabilization of fractures to minimize physiological stress, reducing complications in hemodynamically unstable patients¹⁵⁻¹⁷. Definitive fixation is performed after the patient stabilizes to reduce complications¹⁶.

ETC may lead to life-threatening conditions due to the “second hit” phenomenon, where early definitive surgery exacerbates systemic inflammation and organ dysfunction¹⁸⁻²⁰. Consequently, clinical practice has shifted toward a more individualized approach^{21,22}.

Despite numerous studies comparing ETC and DCO, findings remain inconsistent, particularly regarding mortality and major complications²³. Many

studies lack detailed subgroup analyses, limiting understanding of which patient populations benefit most from each approach²⁴. This meta-analysis aims to address these inconsistencies in outcomes by comparing ETC to DCO regarding number of surgeries needed, length of hospital stay, delayed union and infection rates, systemic complications including sepsis and mortality. Unlike prior meta-analyses focusing primarily on timing of fixation, this study directly compares ETC versus DCO strategies across a broader range of clinically relevant outcomes in a larger patient population²⁵.

MATERIALS AND METHODS

Search strategy

In this meta-analysis, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PROSPERO registration number: CRD420251132251. The following databases were searched up to August 19, 2025: PubMed, the Cochrane Central Register of Controlled Trials (CENTRAL), Scopus, and Web of Science. The search was conducted using terms selected through the Medical Subject Headings (MeSH). The following keywords and their related MeSH terms were used; (Polytrauma OR Multiple Injuries OR Multiple Trauma OR Multiple Wounds) AND (Early Total Care OR ETC OR Early definitive stabilization OR Damage Control Orthopedics OR DCO OR Temporary fixation OR External fixation). Afterwards, the search results were cross-matched, and discrepancies were resolved. The search results were then imported to Rayyan (www.rayyan.ai) and duplicates were removed.

The inclusion criteria for studies were:

- Observational studies that assessed the Outcomes of ETC and/or DCO in Polytrauma patients.
- Interventional studies that investigated outcomes of ETC and/or DCO in polytrauma patients.

The studies were excluded if they were reviews, editorials, case reports, animal studies, abstract only, or written in languages other than English. Also, the studies were excluded if they did not report the timing of definitive intervention in polytrauma patients. Moreover, we excluded studies that did not include orthopedics related trauma in their population. The study selection was performed first by abstract screening, then full text screening. The selection was done and any discrepancy was resolved by team discussion.

Data extraction and quality assessment

For data extraction, a standardized data extraction sheet was created to collect the following variables: title, year of publication, study design, country of origin (referring to the location of the study), sample size, male: female ratio, age, type of fractures, mechanism of injury, severity score, cutoff time to definitive treatment, infection rate, delayed union, average number of surgeries, sepsis, multiorgan failure, ARDS, length of hospital stay, mortality, and the follow-up period. The data extraction process was conducted by six independent researchers, and any disagreements were resolved through discussion until a consensus was reached.

Methodological quality of observational studies was assessed using the Newcastle–Ottawa Scale, while risk of bias for randomized controlled trials was assessed using the Cochrane RoB 2 tool. The NIH Quality Assessment Tool was used for the included case series. The NOS evaluates studies across three domains: selection of study groups, comparability of groups, and ascertainment of outcomes. The results of the quality assessment are presented in Table I.

Data analysis

Meta-XL v5.2 Epigear, Australia, was used to conduct the analysis. The odds ratio (OR) and its related 95% confidence intervals (95% CIs) were used as the effect measure for binary variables, while the weighted mean difference (WMD) and its 95% CIs were used for continuous variables. The heterogeneity was assessed using the I^2 statistic and the Cochrane Q test of heterogeneity. The random effect model was used if the heterogeneity was $>50\%$, while the fixed effect model was used if the heterogeneity was $\leq 50\%$.

RESULTS

Search results

The search yielded 2196 records across the selected databases. After removal of 255 duplicate records, 1941 records remained for title and abstract screening. Of these, 1582 records were excluded because they were reviews, editorials, or did not include the interventions of interest. A total of 359 full-text reports were sought for retrieval, of which 34 could not be retrieved. Consequently, 325 full-text articles were assessed for eligibility. Of these, 305 were excluded for the following reasons: ineligible study, not reporting outcomes of interest, not mentioning the timing of definitive intervention, and not being

Table I. — Methodological quality and risk-of-bias assessment.

Study	Year	Study Design	Risk of Bias Tool	Overall assessment
Rixen et al.	2016	RCT	RoB 2	Some concerns
Pape et al.	2007	RCT	RoB 2	Some concerns
Enninghorst et al.	2010	Cohort	NOS	7 Moderate quality
Ethiraj et al.	2022	Cohort	NOS	8 Good quality
Horst et al.	2019	Cohort	NOS	9 High quality
Kountouri et al.	2024	Cohort	NOS	7 Moderate quality
Lubelski et al.	2017	Cohort	NOS	9 High quality
Kobbe et al.	2013	Cohort	NOS	9 High quality
Nahm et al.	2011	Cohort	NOS	9 High quality
Lubken et al.	2022	Cohort	NOS	9 High quality
Probst et al.	2007	Cohort	NOS	8 Good quality
Yu et al.	2023	Cohort	NOS	9 High quality
Vallier et al.	2010	Cohort	NOS	9 High quality
Steinhaus et al.	2014	Cohort	NOS	8 Good quality
Sangkomkamhang et al.	2018	Cohort	NOS	9 High quality
Sala et al.	2010	Cohort	NOS	6 Fair quality
Tuttle et al.	2009	Cohort	NOS	7 Moderate quality
Halvachizadeh et al.	2024	Cohort	NOS	9 High quality
O'Toole et al.	2009	Cohort	NOS	8 Good quality
Vo et al.	2023	Case series	NIH	Fair quality

Note: For observational studies, NOS ratings represent methodological quality rather than risk of bias. RoB 2 ratings represent risk of bias for randomized controlled trials, and NIH ratings represent methodological quality for case series.

comparative between the interventions of interest. Finally, 20 studies were included in the systematic review and meta-analysis. Figure 1 illustrates the study selection process.

Characteristics of the included studies

The total number of included patients was 18,852 across the 20 included studies. Of these, 62.4% were treated with DCO, while 35.9% underwent ETC; the remaining patients received alternative management strategies not classified as either DCO or ETC in the

original studies. The majority of the included studies were retrospective or prospective cohort studies, with one case series and two randomized controlled trials. Table II summarizes the characteristics of the included studies.

Number of surgeries and length of hospital stay

Regarding the number of surgeries, three articles investigated the difference in the number of surgeries between ETC and DCO. ETC was associated with

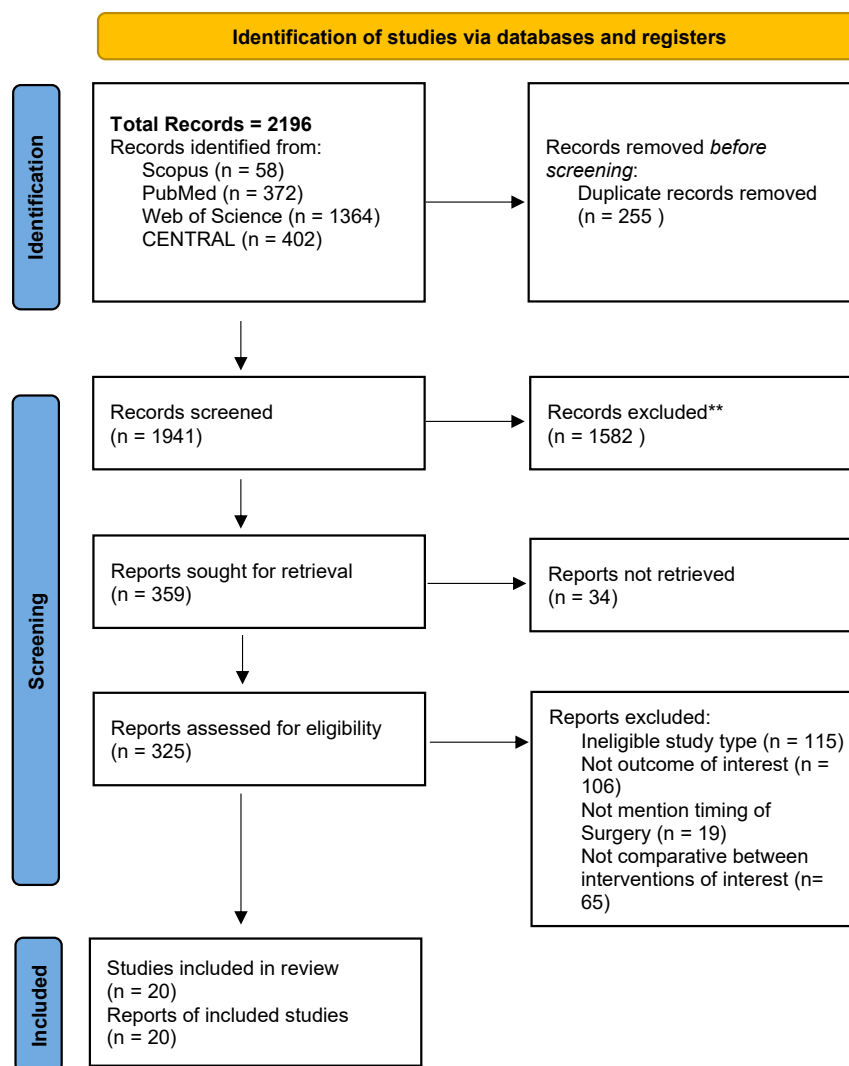


Fig. 1 — PRISMA flow chart describing the study selection process.

significantly fewer surgeries compared to DCO (Figure 2: WMD = -3.39; 95% CI: -3.57 to -3.22); the model had insignificant heterogeneity ($I^2 = 0\%$, $p = 0.390$).

Fourteen studies were included in the pooled analysis of hospital length of stay (LoHS) between ETC and DCO. Pooled analysis showed that ETC was associated with significantly lower length of hospital stay compared to DCO (Figure 3: WMD = -4.91; 95% CI: -6.89 to -2.93); the model had significant heterogeneity ($I^2 = 80\%$, $p < 0.001$).

Delayed Union and Infection

The pooled analysis demonstrated that ETC was associated with lower odds of delayed union compared to DCO (Figure 4: OR = 0.23; 95% CI: 0.06 to 0.93); however, this finding was based on only two studies and should be interpreted with caution. The pooled analysis had insignificant heterogeneity ($I^2 = 0\%$, $p = 0.580$).

Analysis of six studies demonstrated no significant difference in the odds of infections between the two treatment groups (OR = 1.38; 95% CI: 0.92 to 2.07); the model had insignificant heterogeneity ($I^2 = 2\%$, $p = 0.400$).

MODS, ARDS and Sepsis

The difference in the odds of MODS between ETC and DCO was investigated by nine studies. The pooled estimate indicated no difference in the odds of MODS between the two treatment groups (OR = 0.85; 95% CI: 0.55 to 1.30); the model had significant heterogeneity ($I^2 = 77\%$, $p < 0.001$).

Six studies evaluated the difference in the odds of ARDS between the two treatment groups. No significant difference was observed in the odds of ARDS between ETC and DCO (OR = 1.18; 95% CI: 0.64 to 2.17); the model had significant heterogeneity ($I^2 = 92\%$, $p < 0.001$).

Table II. — Characteristics of the included patients.

Study	Country	Study design	Sample size	Sample size of ETC	Sample size of DCO	Male to female ratio ETC	Male to female ratio DCO	Mean age ETC
Enninghorst, 2010	Australia	Retrospective cohort	45	18	27	4.56	3.76	48
Lübken, 2022	Germany	Prospective cohort	12569	4370	8199	3	2.33	47.2
Ethiraj, 2022	India	Retrospective cohort	46	25	21	N/A	N/A	N/A
Halvachizadeh, 2024	Switzerland	Retrospective cohort	806	85	721	2.54	1.68	54.65
Horst, 2019	Germany	Prospective cohort	224	143	81	N/A	N/A	N/A
Kobbe, 2013	Germany	Retrospective cohort	893	435	458	3.06	2.92	N/A
Kountouri, 2024	Greece	Retrospective cohort	29	16	13	4.33	1.6	47
Lubelski, 2017	United States	Retrospective cohort	46	32	14	3	8	38.3
Nahm, 2011	United States	Retrospective cohort	750	656	94	2.5	2.32	34.6
O'Toole, 2009	United States	Retrospective cohort	227	199	28	N/A	N/A	30.5
Pape, 2007	UK and Germany	Randomized controlled trial	165	94	71	N/A	N/A	32.1
Probst, 2007	Germany	Retrospective cohort	182	56	126	2.5	2.6	38
Rixen, 2016	Germany	Randomized controlled trial	33	16	17	N/A	2.4	38.9
Sala, 2010	USA	Retrospective cohort	11	8	3	N/A	N/A	N/A
Sangkomkamhang, 2018	Thailand	Retrospective cohort	1224	415	809	N/A	N/A	N/A
Steinhausen, 2014	Germany	Prospective cohort	288	95	193	N/A	N/A	N/A
Tuttle, 2009	USA	Retrospective cohort	97	42	55	1.8	2.23	N/A
Vallier, 2010	USA	Retrospective cohort	645	233	412	N/A	N/A	40.3
Vo, 2023	Vietnam	Case series	2	1	1	N/A	N/A	31
Yu, 2023	China	Retrospective cohort	181	78	103	N/A	N/A	N/A

The difference in the odds of sepsis was investigated in six studies. The pooled analysis showed that ETC was associated with significantly lower odds of sepsis compared to DCO (Figure 5: OR = 0.63; 95% CI: 0.48 to 0.81); the model had insignificant heterogeneity.

Mortality

The difference in the odds of mortality was investigated by ten studies. Analysis of ten studies demonstrated

no significant difference in the odds of mortality between two treatment groups (OR= 0.59; 95% CI: 0.28 to 1.24); the model had significant heterogeneity ($I^2=87\%$, $p<0.001$).

DISCUSSION

This systematic review and meta-analysis evaluated the outcomes of DCO versus ETC in polytrauma

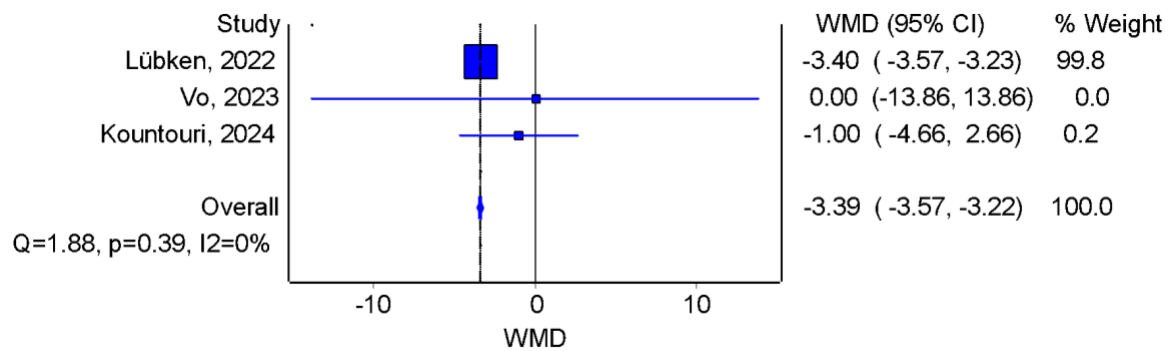


Fig. 2 — The difference in the number of surgeries between Early Total Care (ETC) and Damage Control Orthopedics (DCO). Values are presented as Weighted Mean Difference (WMD) with 95% confidence intervals (CI).

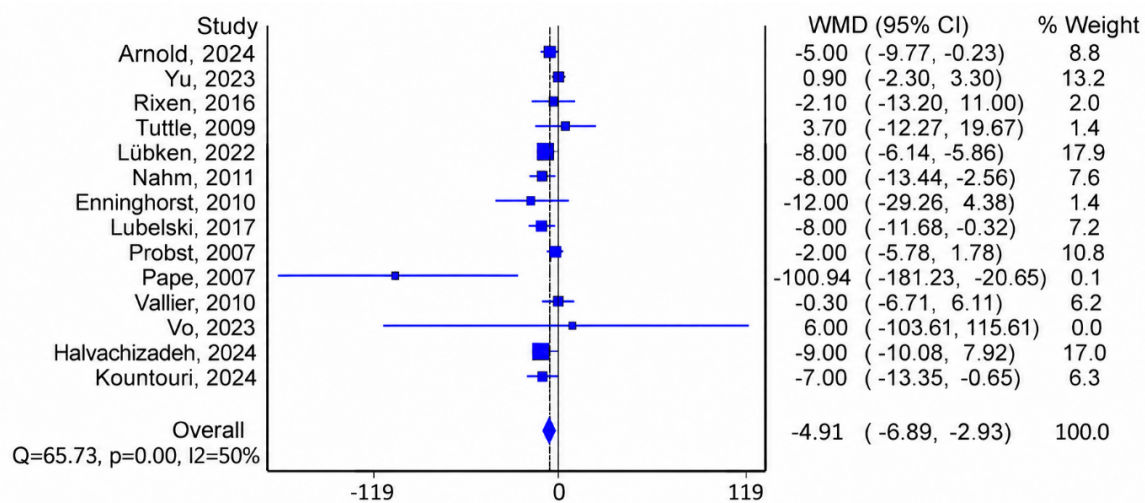


Fig. 3 — The difference in length of hospital stay between Early Total Care (ETC) and Damage Control Orthopedics (DCO). Values are presented as Weighted Mean Difference (WMD) with 95% confidence intervals (CI).

patients with orthopedic injuries. Our findings suggest that ETC is associated with a shorter length of hospital stay and fewer surgical interventions compared to DCO. Additionally, ETC was associated with a lower risk of sepsis and lower odds of delayed union. However, the finding regarding delayed union is based on only two studies and should therefore be considered hypothesis-generating rather than definitive. No significant differences were observed between the two approaches in mortality, MODS, ARDS or infection rates. These findings should be interpreted cautiously, particularly given the likelihood of confounding by indication, as patients selected for DCO are often more severely injured or physiologically unstable. The shorter hospital stay observed with ETC is supported by recent literature, which suggests that early definitive fixation may improve outcomes, including reduced intensive care unit (ICU) stay and duration of mechanical ventilation, compared to staged DCO approaches²⁵.

A recent meta-analysis by Steinfeld et al. (2025) included 5 randomized trials (335 patients) and focused primarily on timing-related outcomes such as ICU stay and ventilation duration. In contrast, our study includes 20 studies with 18,852 patients, providing greater statistical power. Additionally, while Steinfeld et al. examined timing of fixation, our analysis directly compares treatment strategies (ETC vs DCO) and evaluates a wider range of outcomes, including sepsis, delayed union, and surgical burden. Thus, our findings extend existing evidence by offering a more comprehensive perspective²⁵.

Feldman et al. (2021) found that ETC patients had a median LoHS of 21.5 days vs. 24 days for DCO, reinforcing these benefits²⁶. Another study by Lübken et al. reported that early definitive fixation is associated with shorter hospitalization periods, facilitating quicker patient mobilization and recovery²³. Early stabilization allows for immediate rehabilitation, reducing complications associated with prolonged

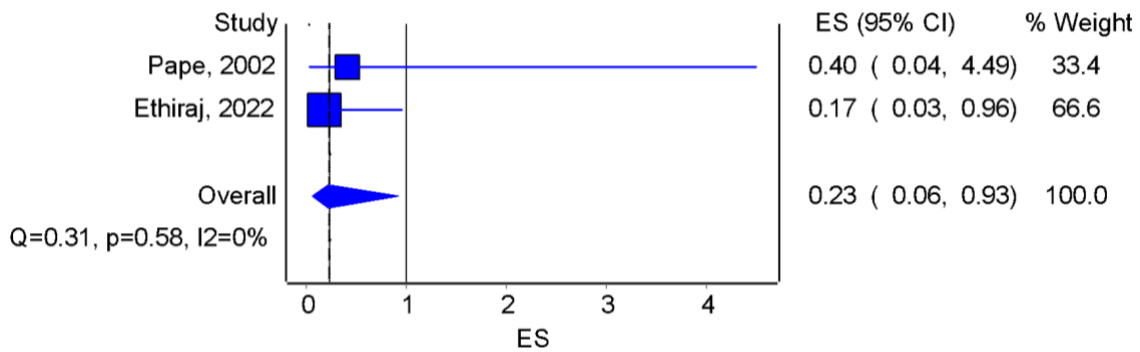


Fig. 4 — The difference in delayed union between Early Total Care (ETC) and Damage Control Orthopedics (DCO). Values are presented as Odds Ratio (OR) with 95% confidence intervals (CI).

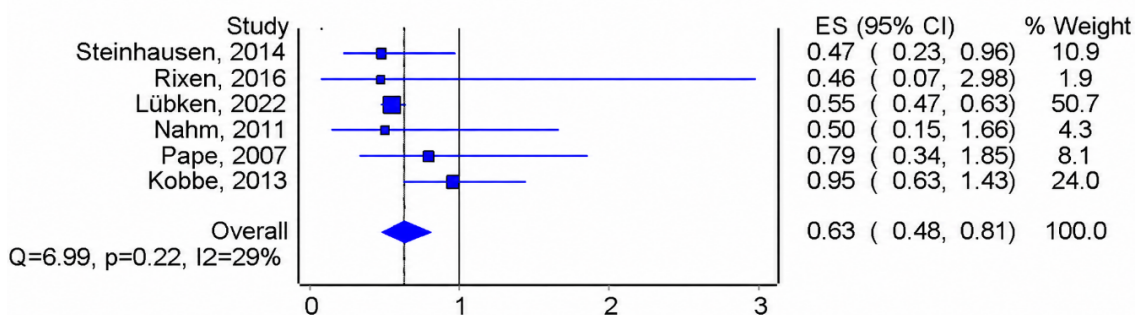


Fig. 5 — The difference in sepsis between Early Total Care (ETC) and Damage Control Orthopedics (DCO). Values are presented as Odds Ratio (OR) with 95% confidence intervals (CI).

immobilization²³. These results highlight the advantages of early definitive fixation in facilitating rapid mobilization and minimizing complications related to prolonged immobilization.

However, the advantage of ETC is not universal and depends critically on patient selection and injury severity. A 2014 review on polytrauma care indicated that DCO remains preferable in cases of severe chest or abdominal trauma where physiological instability contraindicates early definitive surgery²¹. Conversely, a 2025 study examining femur fractures in pediatric patients with traumatic brain injury found that DCO was associated with increased length of stay, though this may reflect the severity of underlying injuries rather than the surgical approach itself²⁷. These conflicting findings underscore the importance of individualized treatment decisions based on hemodynamic stability and overall physiological status, with DCO typically reserved for patients at high risk of the “second hit” phenomenon. This principle is especially relevant in unstable pelvic ring injuries, where temporary external fixation may provide rapid mechanical stabilization and contribute to hemorrhage control as part of staged damage-control management²⁸.

ETC was also associated with fewer surgical interventions, although this finding was derived from

a limited number of studies. This aligns with the concept that early definitive fixation can obviate the need for subsequent surgeries, as ETC involves better surgical outcomes in terms of vascularization, better functioning with anatomical reduction and fixation and more control over bleeding, thereby reducing the need for additional procedures, including those related to staged fixation, thus reducing the overall surgical burden^{14,23}. A recent review that agrees with our findings highlighted that ETC minimizes the need for additional procedures, contributing to improved patient outcomes^{14,23}. Addressing fractures definitively at an early stage prevents local complications and additional surgeries often necessitated by temporary fixation methods. However, temporary external fixation remains a cornerstone of damage control orthopedics, particularly in high-energy trauma, where staged stabilization allows rapid mechanical fracture control while minimizing additional physiological insult until definitive fixation becomes feasible²⁹.

Our analysis revealed that ETC was associated with lower risk of sepsis compared to DCO. These findings may be attributed to several factors inherent to DCO. First, patients selected for DCO typically present with higher ISS, coagulopathy, hypothermia, and acidosis—all of which are associated with immune

dysfunction and greater susceptibility to infections and sepsis^{14,30}. Therefore, the observed difference in sepsis rates may reflect baseline patient severity and underlying physiological compromise rather than the fixation strategy itself.

Moreover, DCO necessitates at least two surgical interventions²³, which amplify the risk of secondary inflammatory responses and subsequent sepsis³⁰. The timing of these secondary procedures further exacerbates the risk, as days 2–4 post-injury are relevantly unsafe for definitive surgery due to the marked increase in immune reactions and generalized edema³¹. Delaying definitive surgery in DCO prolongs exposure to untreated potential infection sources, such as open wounds or internal contamination, creating a window of vulnerability that may progress to sepsis if unaddressed³².

Additionally, the cumulative physiological stress of major trauma (the “first hit”) followed by staged surgeries (the “second hit”) depletes the patient’s biological reserves, inducing immunosuppression¹⁴, and increasing susceptibility to post-traumatic sepsis³¹. Mechanical instability from temporary external fixation devices, commonly used in DCO, can also exacerbate localized tissue trauma, promoting bacterial colonization and biofilm formation³³. Furthermore, prolonged antibiotic use in DCO patients, driven by staged surgeries and external fixation, may foster multidrug-resistant organisms, further elevating sepsis risk³⁰. Finally, extended ventilator dependence and ICU stays in DCO compared to ETC compound these risks by increasing exposure to nosocomial infections and systemic complications^{23,31}.

Our meta-analysis revealed no significant difference in odds ratios for MODS, ARDS, or mortality between ETC and DCO approaches. This aligns with broader orthopaedic trauma literature³⁴, suggesting that systemic outcomes in polytraumatized patients may be strongly influenced by overall trauma system organization and multidisciplinary care rather than fixation strategy alone³⁵. This finding is particularly noteworthy given the theoretical framework suggesting ETC creates additional physiological stress in polytrauma patients through what Volpin et al. termed “the second hit” phenomenon, where early definitive surgery compounds the initial trauma insult³⁵. While this concept has led to widespread acceptance that ETC increases MODS risk in unstable patients, our pooled analysis of 9 studies for MODS and 6 studies for ARDS demonstrated equivalent complication rates between treatment groups. These results suggest that either: (1) current patient selection criteria effectively

identify appropriate ETC candidates, minimizing the second hit phenomenon, or (2) the theoretical risks of ETC may be offset by benefits of early definitive care. This unexpected finding warrants further investigation into patient selection algorithms and timing protocols.

Study Limitations

Our study has several limitations that should be acknowledged. First, most included studies were retrospective or observational, which increases the risk of bias. In particular, confounding by indication is likely, as patients selected for DCO are often more severely injured or physiologically unstable, which may independently influence outcomes. Second, only studies published in English were included, which may have led to the exclusion of relevant research in other languages. Third, some outcomes, including ARDS, mortality, MODS, and length of hospital stay, demonstrated substantial heterogeneity, suggesting that results should be interpreted with caution. This heterogeneity may reflect differences in sample size, injury severity, fracture characteristics, treatment protocols, and healthcare settings, as well as variability in timing definitions for definitive fixation. Furthermore, definitions of polytrauma, ETC, DCO, and timing thresholds varied among the included studies. Such variability likely contributes significantly to heterogeneity and limits direct comparability between studies.

Additional analyses such as sensitivity analyses, subgroup analyses, and publication-bias assessment were not performed, which may limit the robustness of pooled estimates, particularly for outcomes with substantial heterogeneity.

CONCLUSION

This meta-analysis suggests that ETC is associated with shorter hospital stay, fewer surgical procedures, and lower rates of sepsis compared to DCO. However, no significant differences were observed in mortality or major complications. Given the predominance of observational data and the likelihood of confounding by indication, these findings should be interpreted with caution. Clinical decision-making should remain individualized, with careful consideration of patient physiological status and injury severity.

Competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors have approved the final manuscript.

Author contribution: NM conceived the study idea, distributed tasks, performed screening and data extraction, prepared the data sheet, contributed to manuscript writing, and reviewed the final version.

AT contributed to study design and idea development, mentored the team, performed data analysis and quality assessment, wrote the results section, and reviewed the manuscript.

YJ participated in screening, data extraction, manuscript writing, and reviewed and edited the discussion section.

YA, GA, HA, and FA contributed to screening, data extraction, and manuscript writing.

HA provided additional editing and refinement of the discussion section.

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Level of Evidence: Level II: Systematic review and meta-analysis of predominantly observational cohort studies.

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