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The Value of an Orthoplastic Approach to Management of Lower Extremity Trauma: Systematic Review and Meta-analysis

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Background: Management of traumatic lower extremity injuries requires a skill set of orthopedic surgery and plastic surgery to optimize the return of form and function. A systematic review and meta-analysis was performed comparing demographics, injuries, and surgical outcomes of patients sustaining lower extremity traumatic injuries receiving either orthoplastic management or nonorthoplastic management.
Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analysis, Cochrane, and GRADE certainty evidence guidelines were implemented for the structure and synthesis of the review. PubMed, Embase, Cochrane Library, Web of Science, Scopus, and CINAHL databases were systematically and independently searched. Nine studies published from 2013 through 2019 compared 1663 orthoplastic managed patients to 692 nonorthoplastic managed patients with traumatic lower extremity injuries.
Results: Orthoplastic management, compared to nonorthoplastic management likely decreases time to bone fixation [standard mean differences: −0.35, 95% confidence interval (CI): −0.46 to −0.25, $P < 0.0001$; participants = 1777; studies = 3; $I^2 = 0\%$; moderate certainty evidence], use of negative pressure wound therapy [risk ratios (RR): 0.03, 95% CI: 0.00–0.24, $P = 0.0007$; participants = 189; studies = 2; $I^2 = 0\%$; moderate certainty evidence] with reliance on healing by secondary intention (RR: 0.02, 95% CI: 0.00–0.10, $P < 0.0001$; participants = 189; studies = 2; $I^2 = 0\%$; moderate certainty evidence), and risk of wound/osteomyelitis infections (RR: 0.37, 95% CI: 0.23–0.61, $P < 0.0001$; participants = 224; studies = 3; $I^2 = 0\%$; moderate certainty evidence). Orthoplastic management likely results in more free flaps compared to nonorthoplastic management (RR: 3.46, 95% CI: 1.28–9.33, $P = 0.01$; participants = 592; studies = 5; $I^2 = 75\%$; moderate certainty evidence).
Conclusion: Orthoplastic management of traumatic lower extremity injuries provides a synergistic model to optimize and expedite definitive skeletal fixation and free flap-based soft-tissue coverage for return of extremity form and function. *(Plast Reconstr Surg Glob Open 2021;9:e3494; doi: 10.1097/GOX.0000000000003494; Published online 22 March 2021.)*

INTRODUCTION

The orthoplastic approach, described in 1993 by L. Scott Levin, MD, FACS, incorporates immediate multidisciplinary collaboration and embodies philosophies of both orthopedic and plastic surgeons for the management of traumatic lower extremity injuries.[1] For high-energy trauma, orthopedic surgeons provide expertise for osseous fixation and frequently plastic surgeons are consulted to optimize conditions for soft-tissue reconstruction relying heavily on microvascular techniques.[2]

Many but not all specialized trauma centers or major trauma centers (MTCs) around the world have adopted the orthoplastic approach for management. Proponents of this approach endorse the importance of optimizing both bony restoration and soft-tissue coverage to facilitate healing, ultimately leading to return to function

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and positive patient outcomes.[3] By definition, Gustilo–Anderson (GA) IIIB injuries require soft-tissue coverage, and we believe free tissue transfer is the standard of care. However, since the early 1990s, negative pressure wound therapy (NPWT) has been used to provide temporary wound care until definitive soft-tissue reconstruction can safely be performed. Attempting to use NPWT to avoid microsurgical reconstruction has been associated with high infection rates that include osteomyelitis.[3]

This systematic review and meta-analysis of traumatic lower extremity injury patients compared the orthoplastic approach to management to nonorthoplastic approach to management. It is hypothesized that the orthoplastic approach to management of traumatic lower extremity injuries resulted in improved patient outcomes, compared to the nonorthoplastic approach.

MATERIALS AND METHODS

Preferred Reporting Items for Systematic Reviews and Meta-Analysis and Cochrane guidelines were followed to structure the review.[4,5]

Selection Criteria

Participants, interventions, comparisons, outcomes, and study design (PICOS) was followed throughout the selection process. Participants sustained traumatic lower extremity injuries (distal to the femoral neck), managed at an MTC or equivalent. Interventions were orthoplastic management or nonorthoplastic management. Orthoplastic management was defined as multidisciplinary management by both orthopedic and plastic surgeons at the time of hospital admission.[1] Nonorthoplastic management was defined as management involving any service other than the both orthopedic and plastic surgeons at the time of admission. Nonorthoplastic management may involve plastic surgeons following evaluation and/or management by other services, even days following admission. Comparisons were made between interventions. Outcomes measured were GA classification (Table 1),[6–8] time to first surgery (time from injury to surgery), time to bone fixation (time from injury to fixation), time to soft-tissue coverage (time from injury to coverage), NPWT, healing by secondary intention, primary wound closure, skin grafting (split-thickness or full-thickness), tissue transfer/flaps (pedicled or free), number of reoperations (surgeries following fixation and soft-tissue coverage), total number of surgeries (related to lower extremity injury), hospital length of stay (LOS), time to soft-tissue healing (time to complete repair of soft tissue overlying injury), time to bone healing/union (time to return of bone anatomic continuity at fracture site), time to full weight-bearing/return to work (time from fixation to full weight-bearing), partial and/or complete flap failure, infection (wound/osteomyelitis requiring systemic antibiotic administration), and amputations. There were no predetermined lengths of follow-ups or years considered for publication. Study designs considered were randomized/nonrandomized, prospective/retrospective, observational, cohort, and before-and-after studies. Studies excluded were non-English, reviews, nonreviewed peer literature, cadaver, animal, abstracts/conference presentations, case reports, unrelated outcomes, no comparisons between orthoplastic and nonorthoplastic management, and studies with less than a sample size of 10 patients in each cohort to perform the meta-analysis.

Table 1. GA Classification of Open Fractures of the Tibia[6–8]

Type	Subtype	Description
I		Clean wound <1 cm in diameter with simple fracture pattern with no soft-tissue damage
II		Open fracture, laceration >1 and <10 cm without significant soft-tissue damage
III		Open fracture with extensive soft-tissue injury >10 cm, loss or an open segmental fracture
	A	Adequate soft-tissue coverage of the fracture despite high-energy trauma or extensive laceration or skin flaps
	B	Inadequate soft-tissue coverage with periosteal stripping
	C	Any open fracture that is associated with vascular injury that requires repair

Search

Literature searches were performed by K.M.K. using 6 databases (PubMed, Embase, Cochrane Library, Web of Science, Scopus, and CINAHL) from inception to June 3, 2020 (**see appendix A, Supplemental Digital Content 1**, which displays search strategies, http://links.lww.com/PRSGO/B603). Reference lists of relevant articles were searched to identify additional studies. Duplicates were removed.

Data Extraction

Two reviewers (K.M.K. and C.S.K.) systematically and independently performed the title/abstract screening, followed by full-text review to ensure quality and accuracy. Any disagreements regarding studies included/excluded were resolved by discussion. If disagreements were unresolved, a third reviewer resolved the remaining conflict (S.J.K.). Data were qualitatively and quantitatively planned for extraction of 123 variables **(see appendix B, Supplemental Digital Content 2,** which displays data extraction variables, http://links.lww.com/PRSGO/B604). One data collection form was completed from all reports to avoid duplicating results.

Quality Assessment and Unit of Analysis Issues

Two reviewers (K.M.K. and C.S.K.) assessed the risk of bias individually for each study at a study level, followed by assessments across all studies using ROBINS-I and the Cochrane risk of bias tool.[9,10] Part 1 was categorized as low, high, or unclear risk. Part 2 used quality of evidence GRADE, categorized as high, moderate, low, and very low certainty evidence. Studies with incomplete outcomes data were removed from the meta-analysis if data could not be acquired. Variables were compared at similar follow-up intervals. Study heterogeneity was measured using I^2. Heterogeneity was tested with chi square using forest plots to determine what percentage of variability was not due to sampling error. I^2 values <50% were low, 50%–75% were medium, and >75% were high or indicated significant heterogeneity. If significant heterogeneity was present, certainty of evidence was downgraded. Sensitivity analyses were performed if a minimum of 10 studies were present for funnel plots. Each patient was counted for study totals, not each extremity. Data were extracted in the form the authors reported. Variables subdivided were combined or averaged from respective studies into 1 value for appropriate comparisons. All time intervals were converted and reported in days.

Data Synthesis and Statistical Analysis

A summary of findings table was created for variables of interest using GRADEpro GDT software (Evidence Prime Inc., McMaster University, 2015). Medians, interquartile ranges, and ranges were converted to means and SDs for studies.[11] Data were converted to risk ratios (RRs) for dichotomous data and standard mean differences (SMDs) for continuous data.[4] RevMan software, Version 5.4 (©2020 The Cochrane Collaboration) was used to perform the meta-analysis. Descriptive statistics were applied to quantify data. Due to retrospective study designs, variations in timelines at MTCs, converting variables to comparable units, discrepancies in measurements, injury etiologies, and surgical procedures, the random effects model was used for comparisons.[4]

RESULTS

Study Selection and Characteristics

Searches resulted in a total of 636 citations. After removing 154 duplicates and adding 1 additional study, 481 citations remained. Following title/abstract review, 32 studies underwent full-text review. Following full-text review, 9 studies were included in qualitative and quantitative synthesis (Fig. 1; Tables 2 and 3).[12–20]

Nine studies included were published from 2013 through 2019. A total of 1663 orthoplastic managed patients and 692 nonorthoplastic managed patients with traumatic lower extremity injuries were managed at an MTC. Six studies were retrospective,[12,15–17,19,20] 2 were prospective,[13,18] and 1 consisted of a prospective orthoplastic cohort and retrospective nonorthoplastic cohort.[14] Eight before-and-after studies compared orthoplastic management at the same MTC.[12,14–20] Six studies were performed solely in the United Kingdom,[12,14–16,18,20] 1 in the United Kingdom, Pakistan, and Italy,[13] 1 in Sweden,[17] and 1 in Italy.[19]

Results, Risk of Bias of Individual Studies

Tables 2 and 3 summarize demographics and surgical outcomes assessed individually by included studies. Risk of bias was assessed using the Cochrane risk of bias tool (Fig. 2).

Synthesis of Results and Risk of Bias across Studies

Nine studies included in the systematic review were included in the meta-analysis. Of the 123 possible outcome variables queried, 54 had reportable results, and 27 were eligible for meta-analysis (Fig. 3). Table 4 summarizes the findings of surgical outcomes of interest.

Demographics

Mean ages ranged from 34 to 49 years in orthoplastic cohorts compared to 34 to 52 years in nonorthoplastic cohorts.[13,14,16–19] Orthoplastic patients (men: n = 1278/1440, 89%; women: n = 162/1440, 11%) were compared to nonorthoplastic patients (men: n = 516/580, 89%; women: n = 64/580, 11%).[13,14,16–19] Twelve GA type I orthoplastic cohort injuries (n = 12/164, 7%) were compared to 9 GA type I nonorthoplastic cohort injuries (n = 9/95, 9%) (RR: 0.92, 95% CI: 0.34–2.47, $P = 0.87$; participants = 259; studies = 2; $I^2 = 9\%$; moderate certainty evidence).[13,14] Sixteen GA type II orthoplastic cohort injuries (n = 16/235, 7%) were compared to zero GA type II nonorthoplastic cohort injuries (n = 0/122, 0%) (RR: 4.19, 95% CI: 0.97–18.07, $P = 0.05$; participants = 357; studies = 4; $I^2 = 0\%$; moderate certainty evidence).[13,14,17,18] Forty-three GA type IIIA orthoplastic cohort injuries (n = 43/235, 18%) were compared to 27 GA type IIIA nonorthoplastic cohort injuries (n = 27/122, 22%) (RR: 0.94, 95% CI: 0.61–1.46, $P = 0.79$; participants = 357; studies = 4; $I^2 = 0\%$; moderate certainty evidence).[13,14,17,18] One hundred forty GA type IIIB orthoplastic cohort injuries (n = 140/251, 56%) were compared to 76 GA type IIIB nonorthoplastic cohort injuries (n = 76/141, 54%) (RR: 0.90, 95% CI: 0.66–1.23, $P = 0.53$; participants = 392; studies = 5; $I^2 = 49\%$; moderate certainty evidence).[13,14,17–19] Twenty-four GA type IIIC orthoplastic cohort injuries (n = 24/251, 10%) were compared to 17 GA type IIIC nonorthoplastic cohort injuries (n = 17/141, 12%) (RR: 0.83, 95% CI: 0.47–1.47, $P = 0.53$; participants = 392; studies = 5; $I^2 = 0\%$; moderate certainty evidence).[13,14,17–19] No differences were observed for severities of GA injuries between both cohorts. Mean follow-up was 309 days for both orthoplastic and nonorthoplastic cohorts.[12–20]

SURGICAL OUTCOMES

Time to First Surgery

Mean times to debridement and temporary skeletal stabilization ranged from 0.44 to 0.56 days in orthoplastic cohorts compared to 0.38 to 0.77 days in nonorthoplastic cohorts.[14,18] Two studies suggest orthoplastic management likely does not differ in the time to first surgery compared to nonorthoplastic management (SMD: −0.07, 95% CI: −0.40 to 0.26, $P = 0.67$; participants = 149; studies = 2; $I^2 = 0\%$; moderate certainty evidence).

Time to Bone Fixation

Mean times ranged from 0.56 to 9.1 days in orthoplastic cohorts compared to 0.77 to 29.9 days in nonorthoplastic cohorts.[14,16,18] Three studies suggest orthoplastic management likely decreases the time to bone fixation compared to nonorthoplastic management (SMD: −0.35, 95% CI: −0.46 to −0.25, $P < 0.0001$; participants = 1777; studies = 3; $I^2 = 0\%$; moderate certainty evidence).

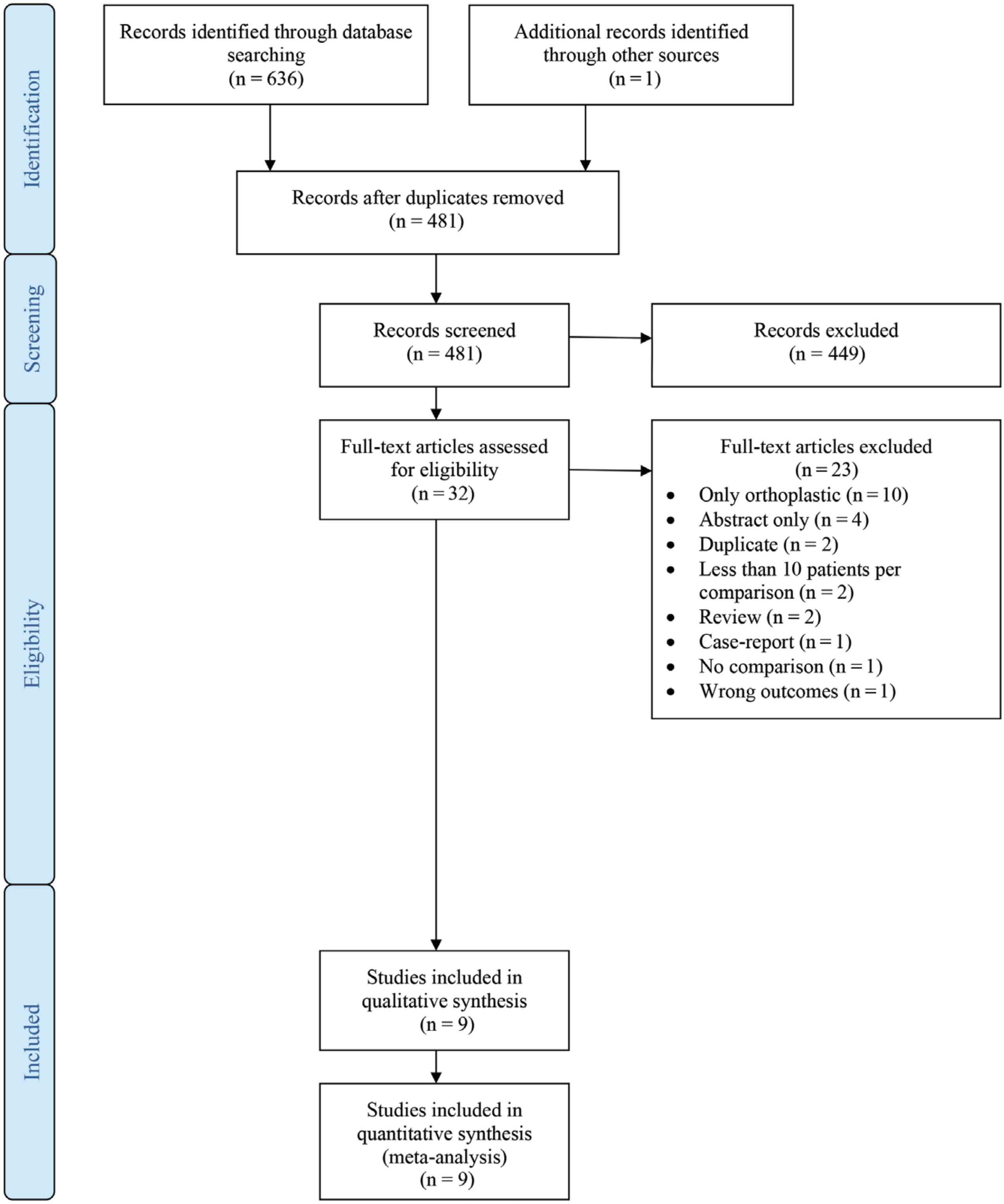

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis flow chart summarizes the results of the screening process and final article selections.

NPWT and Healing by Secondary Intention

Zero NPWTs (n = 0/126, 0%) and 1 healing by secondary intention (n = 1/126, 1%) in orthoplastic cohorts were compared to 20 NPWTs (n = 20/63, 32%) and 44 healing by secondary intention (n = 44/63, 70%) in non-orthoplastic cohorts.[13,19] Two studies suggest orthoplastic management likely decreases NPWT (RR: 0.03, 95% CI: 0.00–0.24, P = 0.0007; participants = 189; studies = 2;

Table 2. Summary of 9 Studies Included in Systematic Review and Meta-analysis (Demographics)

Author	Year	Study Design	Cohort	Sample	Location	MTC	Age	Sex (M:F)	Injury Etiologies	Injury Locations	GA I	GA II	GA IIIA	GA IIIB	GA IIIC
Ali et al[12]	2015	Retrospective cohort, before and after	OP Non-OP	13 22	United Kingdom	John Radcliffe Hospital in Oxford	Median = 38 (range: 11–79)	N/A	MVA = 4, MVA vs motorcycle = 20, falls = 15, MVA vs pedestrian = 8, sports = 2, kicked by horse = 1	Open lower extremity fractures	0	0	0	38	4
Boriani et al[13]	2017	Prospective cohort	OP	110	United Kingdom, Pakistan	Lower Limb Reconstruction Unit, North Bristol NHS Trust, and the Plastic Surgery Department, Jinnah Hospital	43 ± 22	82:28	MVA = 99	Open tibia fractures	6		12	86	5
			Non-OP	44	Italy	Orthopedic and Trauma Unit, Maggiore Hospital	51 ± 18	32:12			1		7	33	3
Fernandez et al[14]	2015	Prospective/ retrospective cohort, before and after	OP	54	United Kingdom	University Hospitals Coventry and Warwickshire NHS Trust	49 ± 2	32:22	MVA = 28, fall = 18, crush = 5, blow = 2, other = 1	Tibia = 36, ankle = 18	6	5	15	26	2
			Non-OP	51			44 ± 2	35:16	MVA = 31, fall = 17, crush = 1, blow = 1, other = 1	Tibia = 35, ankle = 16	8	8	15	18	2
Hardwicke et al[15]	2016	Retrospective cohort, before and after	OP Non-OP	195 62	United Kingdom	University Hospitals Coventry and Warwickshire NHS Trust	N/A	N/A	N/A	Open lower extremity fractures	N/A	N/A	N/A	N/A	N/A
Hay-David et al[16]	2018	Retrospective cohort, before and after	OP Non-OP	1189 439	United Kingdom	Glasgow Royal Infirmary, Salford Royal NHS Foundation Trust, Morriston Hospital	34 ± 61 34 ± 55	1109:80 412:27	Motorcycle = 1564, pillion passengers = 64	Open lower extremity fractures	N/A	N/A	N/A	N/A	N/A
Sommar et al[17]	2015	Retrospective cohort, before and after	OP	42	Sweden	Karolinska University Hospital	48 ± 18	27:15	MVA = 16, bike = 2, riding = 1, fall = 11, GSW = 2, MVA vs pedestrian = 2, wheelchair accident = 1, moped accident = 3, work = 2, lawnmower = 1	Tibia = 29, patellar = 2, ankle = 3, radius = 1, humerus = 2, ulna = 1, fibula = 2, calcaneus = 1	0	1	6	9	9
			Non-OP	12			43 ± 16	9:3	MVA = 5, fall = 4, climbing = 1, moped accident = 1, excavator accident = 1	Tibia = 9, calcaneus = 2, femur = 1	0	0	2	6	2
Stammers et al[18]	2013	Prospective cohort, before and after	OP Non-OP	29 15	United Kingdom	St. George's Healthcare NHS Trust London	44 ± 70 37 ± 52	16:13 12:3	N/A	Tibia = 29 Tibia = 15	0 0	4 3	10 3	13 9	2 0
Toia et al[19]	2019	Retrospective cohort, before and after	OP	16	Italy	University of Palermo	49 ± 56	12:4	N/A	Tibia = 16 (open tibia fracture = 6, septic pseudoarthrosis = 10)	0	0	0	6	
			Non-OP	19			52 ± 49	16:3		Tibia = 19 (open tibia fracture = 10, septic pseudoarthrosis = 9)	0	0	0	10	
Trickett et al[20]	2015	Retrospective cohort, before and after	OP Non-OP	15 28	United Kingdom	Morriston Hospital	N/A	N/A	N/A	Tibia = 15 Tibia = 28	N/A	N/A	N/A	N/A	N/A

Continuous variables were reported at means and SDs.
GSW, gunshot wound; MVA, motor vehicle accident; N/A, not applicable; NHS, National Health Service; Non-OP, nonorthoplastic; OP, orthoplastic.;

Table 3. Summary of 9 Studies Included in Systematic Review and Meta-analysis (Surgical Outcomes)

Author	Cohort	Sample	Time to First Surgery	Time to Bone Fixation	Bone Fixation	NPWT: Healing by Secondary Intention	Primary Closure	Time to Soft-tissue Coverage	Skin Graft	Pedicled Flap
Ali et al[12]	OP	13	N/A	Median = 2	External,	N/A	N/A	Median = 3.5	N/A	Local = 4
	Non-OP	22		Median = 5	internal			Median = 6		
Boriani et al[13]	OP	110	N/A	N/A	ORIF = 65, IMN = 35, long arm frame = 12	0:1	2	98 ± 7	5	43 (hemisoleus, gastrocnemius, anterior and posterior tibial perforator, random pedicled fasciocutaneous, sural, medial plantar, dorsalis pedis)
	Non-OP	44	N/A	N/A	External = 44	10:25	5	1225 ± 245	2	1
Fernandez et al[14]	OP	54	0.6 ± 1.5	0.56 ± 1.7	N/A	N/A	20	2.7	10	15
	Non-OP	51	0.8 ± 1.7	0.77 ± 1.7			30	4.7	8	6
Hardwicke et al[15]	OP	195	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	Non-OP	62								0
Hay-David et al[16]	OP	1189	N/A	9.1 ± 28	Fixation = 439	N/A	N/A	10.1 ± 28	N/A	N/A
	Non-OP	439		29.9 ± 96	Fixation = 215			31.1 ± 96		
Sommar et al[17]	OP	42	N/A	N/A	N/A	N/A	N/A	221 ± 574	N/A	Medial gastrocnemius = 8, fasciocutaneous = 4, soleus = 2, sural = 2, propeller = 2, extensor digitorum brevis = 2, lateral gastrocnemius = 1, radial forearm = 1, latissimus dorsi = 1
	Non-OP	12						223 ± 515		Fasciocutaneous = 3, sural = 2, soleus = 1, lateral gastrocnemius = 1, medial gastrocnemius = 1
Stammers et al[18]	OP	29	0.4 ± 0.7	2.2 ± 7	N/A	N/A	N/A	7 ± 23	N/A	N/A
	Non-OP	15	0.4 ± 0.5	4.7 ± 16				8.3 ± 26		
Toia et al[19]	OP	16	N/A	N/A	External, ORIF = 1, IMN = 2, long-arm frame = 3	0:0	N/A	N/A	N/A	N/A
	Non-OP	19				10:19				N/A
Trickett et al[20]	OP	15	N/A	N/A	External, IMN	N/A	N/A	N/A	N/A	N/A
	Non-OP	28								

(*Continued*)

I^2 = 0%; moderate certainty evidence), and decreases reliance on healing by secondary intention (RR: 0.02, 95% CI: 0.00 –0.10, $P < 0.0001$; participants = 189; studies = 2; I^2 = 0%; moderate certainty evidence), compared to non-orthoplastic management.

Primary Wound Closure

Twenty-two primary wound closures in orthoplastic cohorts (n = 22/164, 13%) were compared to 35 closures in non-orthoplastic cohorts (n = 35/95, 37%).[13,14] Two studies suggest orthoplastic management may not differ in primary wound closure compared to nonorthoplastic management (RR: 0.40, 95% CI: 0.11–1.44, $P = 0.16$; participants = 259; studies = 2; I^2 = 63%; low certainty evidence).

Time to Soft-tissue Coverage

Mean times ranged from 7 to 221 days in orthoplastic cohorts compared to 8 to 1225 days in nonorthoplastic cohorts.[13,16–18] Four studies suggest orthoplastic management may not differ in the time to soft-tissue coverage compared to nonorthoplastic management, but we are very uncertain (SMD: −2.20, 95% CI: −4.53 to 0.13, $P = 0.06$; participants = 1880; studies = 4; I^2 = 99%; very low certainty evidence).

Skin Graft

Fifteen split-thickness skin grafts in orthoplastic cohorts (n = 15/164, 9%) were compared to 10 skin grafts in nonorthoplastic cohorts (n = 10/95, 11%).[13,14] Two studies suggest orthoplastic management likely does not differ in skin grafting compared to nonorthoplastic management (RR: 1.14, 95% CI: 0.54–2.41, $P = 0.73$; participants = 259; studies = 2; I^2 = 0%; moderate certainty evidence).

Pedicled Tissue Transfer/Flap

Eighty-one pedicled flaps in orthoplastic cohorts (n = 81/206, 39%) were compared to 15 flaps in nonorthoplastic cohorts (n = 15/107, 14%).[13,14,17] Three studies suggest orthoplastic management may not differ in pedicled flap reconstruction compared to nonorthoplastic management, but we are very uncertain (RR: 2.71, 95% CI: 0.43–17.11, $P = 0.29$; participants = 313; studies = 3; I^2 = 91%; very low certainty evidence).

Free Tissue Transfer/Flap

One hundred sixty-three free flaps in orthoplastic cohorts (n = 163/404, 40%) were compared to 18 flaps in nonorthoplastic cohorts (n = 18/188, 10%).[13–15,17,19] Five studies suggest orthoplastic management likely increases free flap reconstruction compared to nonorthoplastic management (RR: 3.46, 95% CI: 1.28–9.33, $P = 0.01$; participants = 592; studies = 5; I^2 = 75%; moderate certainty evidence).

Number of Reoperations

Mean reoperations ranged from 0.6 to 3.3 in orthoplastic cohorts compared to 1.2 to 4.5 in nonorthoplastic

Table 3. (*Continued*)

Free Flap	No. Reoperations	Total No. Surgeries	Hospital LOS	Time to Soft-tissue Healing	Time to Bone Healing/Union	Time to Full Weight-bearing/Return to Work	Flap Failures (Partial: Complete)	Infection (Wound/ Osteomyelitis)	Amputations	FU
Gracilis = 27, latissimus dorsi = 17, latissimus dorsi/serratus anterior chimeric = 2	N/A	N/A	N/A	N/A	N/A	N/A	0:0	2	0	365
							4:1	6	1	365
55 (ALT, scapular, radial forearm, chimera)	0.6 ± 0.1	N/A	22 ± 2	28 ± 12	168 ± 14	112 ± 7	N/A	16	4	365
0	1.2 ± 0.2		55 ± 7	51 ± 12	280 ± 28	224 ± 21		18	1	365
6	N/A	N/A	20	N/A	N/A	N/A	N/A	N/A	3	N/A
5			25						2	N/A
65 emergency	N/A	N/A	N/A	N/A	N/A	N/A	N/A:17	N/A	N/A	N/A
7 emergency							N/A:4			N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30
										30
ALT = 7, latissimus dorsi = 6, gracilis = 5, fibula osteocutaneous = 2, palmer = 1	3.3 ± 7.4	3.3 ± 5.8	47 ± 92	N/A	256	N/A	5:4	N/A	4	365
Latissimus dorsi = 3, gracilis = 1, fibula osteocutaneous flap, medial gastrocnemius flap = 1	4.5 ± 8.5	3.5 ± 7.7	59 ± 61		296		1:1		1	365
N/A	N/A	2.3 ± 4.1	16 ± 48	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		4.2 ± 7.6	21 ± 34							N/A
ALT = 14, VL = 2	N/A	N/A	42 ± 30	196 ± 123	280 ± 165	364 ± 188	N/A:0	3	N/A	365
ALT = 1			55 ± 7	210 ± 58	504 ± 444	560 ± 444	N/A:0	10		365
N/A	2.1 ± 1.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	365
	3 ± 1.9									365

Continuous variables were reported at means and SD. Times were reported in days.
ALT, anterior lateral thigh; FU, follow-up; IMN, intramedullary nail; N/A, not applicable; Non-OP, nonorthoplastic; OP, orthoplastic; ORIF, open reduction internal fixation; VL, vastus lateralis.

cohorts.[13,17,20] Three studies suggest orthoplastic management may not differ in the number of reoperations compared to nonorthoplastic management, but we are very uncertain (SMD: −1.68, 95% CI: −4.39 to 1.03, P = 0.22; participants = 251; studies = 3; I^2 = 98%; very low certainty evidence).

Total Number of Surgeries

Mean surgeries ranged from 2.3 to 3.3 in orthoplastic cohorts compared to 3.5 to 4.2 in nonorthoplastic cohorts.[17,18] Two studies suggest orthoplastic management likely does not differ in the total number of surgeries compared to nonorthoplastic management (SMD: −0.19, 95% CI: −0.64 to 0.26, P = 0.40; participants = 98; studies = 2; I^2 = 0%; moderate certainty evidence).

Hospital LOS

Mean LOS ranged from 16.4 to 46.8 days in orthoplastic cohorts compared to 21.1 to 59.8 days in nonorthoplastic cohorts.[13,17–19] Four studies suggest orthoplastic management may not differ in the time to soft-tissue coverage compared to nonorthoplastic management, but we are very uncertain (SMD: −2.20, 95% CI: −5.19 to 0.80, P = 0.15; participants = 287; studies = 4; I^2 = 99%; very low certainty evidence).

Time to Soft-tissue Healing

Mean times ranged from 28 to 196 days in orthoplastic cohorts compared to 51 to 210 days in nonorthoplastic cohorts.[13,19] Two studies suggest orthoplastic management may not differ in the time to soft-tissue healing compared to nonorthoplastic management (SMD: −1.03, 95% CI: −2.73 to 0.66, P = 0.23; participants = 189; studies = 2; I^2 = 95%; low certainty evidence).

Time to Bone Healing/Union

Mean times ranged from 168 to 280 days in orthoplastic cohorts compared to 280 to 504 days in nonorthoplastic cohorts.[13,19] Two studies suggest orthoplastic management may not differ in the time to bone healing compared to nonorthoplastic management (SMD: −3.24, 95% CI: −8.36 to 1.88, P = 0.21; participants = 189; studies = 2; I^2 = 99%; low certainty evidence).

Time to Full Weight-bearing/Return to Work

Mean times ranged from 112 to 364 days in orthoplastic cohorts compared to 224 to 560 days in nonorthoplastic cohorts.[13,19] Two studies suggest orthoplastic management may not differ in the time to full weight-bearing/return to work compared to nonorthoplastic management (SMD: −4.67, 95% CI: −12.77 to 3.44, P = 0.26; participants = 189; studies = 2; I^2 = 99%; low certainty evidence).

Flap Failures

Five partial failures in orthoplastic cohorts (n = 5/55, 10%) were compared to 5 failures in nonorthoplastic

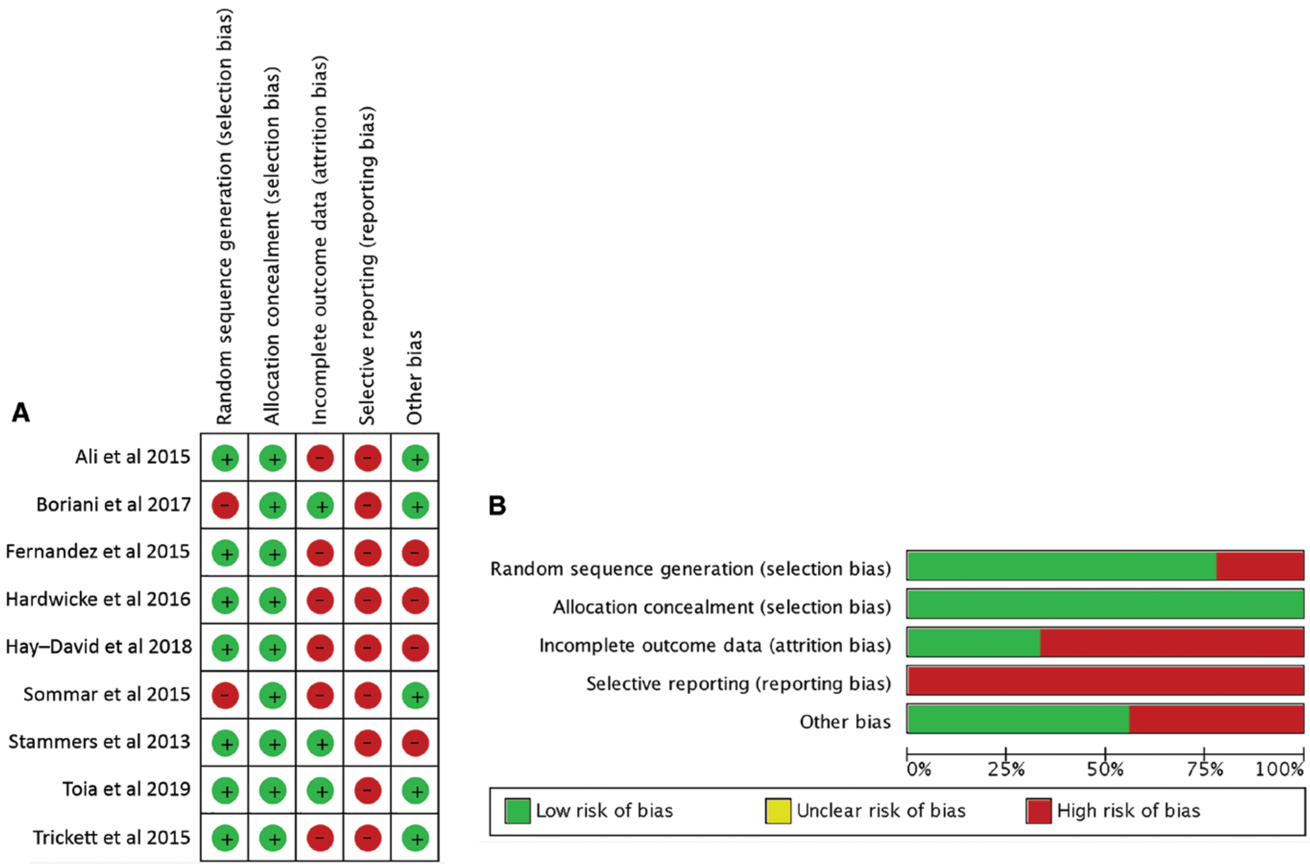

Fig. 2. Risk of bias. A, Risk of bias summary: review authors' judgments about each risk of bias item for each included study. B, Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies.

cohorts (n = 5/34, 15%).[12,17] Two studies suggest orthoplastic management likely does not differ in partial flap failures compared to nonorthoplastic management (RR: 0.65, 95% CI: 0.09–4.81, $P = 0.67$; participants = 89; studies = 2; $I^2 = 28\%$; moderate certainty evidence). Four studies reported complete flap failure.[12,15,17,19] Twenty-one complete failures in orthoplastic cohorts (n = 21/250, 8%) were compared to 6 failures in nonorthoplastic cohorts (n = 6/96, 6%). Three studies suggest orthoplastic management may not differ in complete flap failures compared to nonorthoplastic management (RR: 1.22, 95% CI: 0.49–2.99, $P = 0.67$; participants = 346; studies = 3; $I^2 = 0\%$; low certainty evidence).[12,15,17] One study was removed due to results that were not estimable following pooled analysis.[19]

Infection (Wound/Osteomyelitis)

Twenty-one infections in orthoplastic cohorts (n = 21/139, 15%) were compared to 34 infections in nonorthoplastic cohorts (n = 34/85, 40%).[12,13,19] Three studies suggest orthoplastic management likely decreases the risk of wound/osteomyelitis infections compared to nonorthoplastic management (RR: 0.37, 95% CI: 0.23–0.61, $P < 0.0001$; participants = 224; studies = 3; $I^2 = 0\%$; moderate certainty evidence).

Amputations

Eleven amputations in orthoplastic cohorts (n = 11/219, 5%) were compared to 5 amputations in nonorthoplastic cohorts (n = 5/129, 4%).[12–14,17] Four studies suggest orthoplastic management likely does not differ in amputations compared to nonorthoplastic management (RR: 1.23, 95% CI: 0.42–3.60, $P = 0.70$; participants = 348; studies = 4; $I^2 = 0\%$; moderate certainty evidence).

DISCUSSION

This systematic review and meta-analysis compared studies with the orthoplastic approach to nonorthoplastic approach to management of traumatic lower extremity injuries. The orthoplastic approach decreases time to bone fixation, use of NPWT with reliance on healing by secondary intention, risk of wound/osteomyelitis infections and increases free flaps, compared to the nonorthoplastic approach (Table 4). No statistical differences existed between GA classification injuries, time to soft tissue coverage, number of reoperations, total number of surgeries, hospital LOS, time to soft tissue healing, time to bone healing, and time to full weight-bearing/return to work; however, data from included studies demonstrated increased SMDs with the orthoplastic approach compared to nonorthoplastic approach.

Advancing up the reconstructive ladder from NPWT and reliance on healing by secondary intention to free tissue transfer/flaps, we identified the clinical impact of the orthoplastic approach. Its hallmark is its ability to expedite

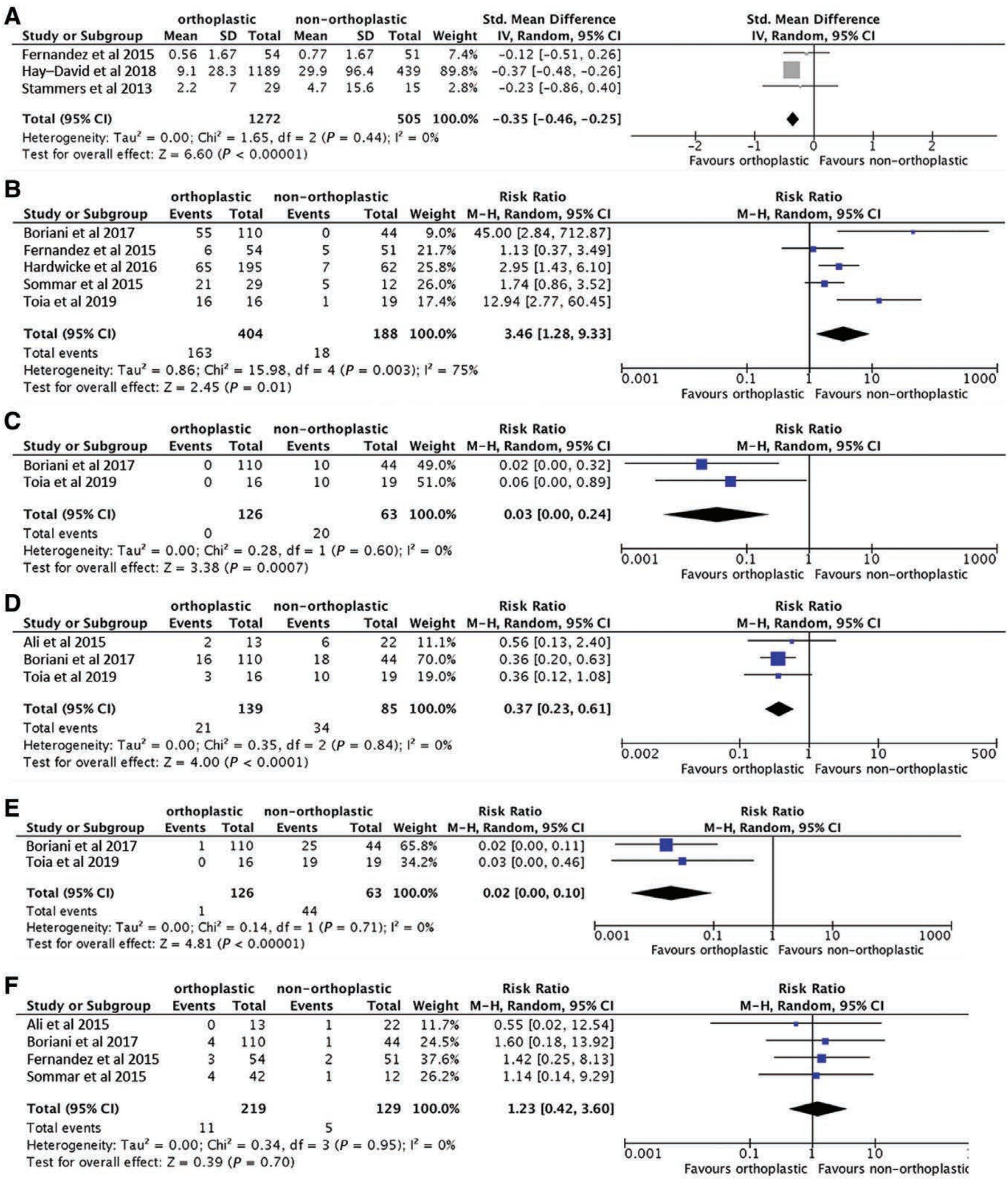

Fig. 3. Forest plots. A, Forest plot of comparison: orthoplastic vs nonorthoplastic, time to bone fixation (days). B, Forest plot of comparison: orthoplastic vs nonorthoplastic, NPWT. C, Forest plot of comparison: orthoplastic vs nonorthoplastic, healing by secondary intention. D, Forest plot of comparison: orthoplastic vs nonorthoplastic, free tissue transfer/flaps. E, Forest plot of comparison: orthoplastic vs nonorthoplastic, infection (wound/osteomyelitis). F, Forest plot of comparison: orthoplastic vs nonorthoplastic, amputations.

Table 4. Summary of Findings: Orthoplastic Approach Compared to Nonorthoplastic Approach for Management of Traumatic Lower Extremity Injuries (Surgical Outcomes)

Patient or Population: Traumatic Lower Extremity Injuries						
Setting: Hospital						
Intervention: Orthoplastic						
Comparison: Nonorthoplastic						
	Anticipated Absolute Effects* (95%CI)					
Outcomes	Risk with Nonorthoplastic	Risk with Orthoplastic	Relative Effect (95%CI)	No. Participants (Studies)	Certainty of the Evidence (GRADE)	Comments
Time to first surgery (d)	—	SMD 0.07 lower (0.4 lower to 0.26 higher)	—	149 (2 observational studies)	⊕⊕⊕○ Moderate†‡§	Risk of bias
Time to bone fixation (d)	—	SMD 0.35 lower (0.46 lower to 0.25 lower)	—	1777 (3 observational studies)	⊕⊕⊕○ Moderate†‡§	Risk of bias
NPWT	317 per 1000	10 per 1000 (0–76)	RR 0.03 (0.00–0.24)	189 (2 observational studies)	⊕⊕⊕○ Moderate‡¶	Risk of bias
Healing by secondary intention	698 per 1000	14 per 1000 (0–70)	RR 0.02 (0.00–0.10)	189 (2 observational studies)	⊕⊕⊕○ Moderate‡¶	Risk of bias
Primary closures	368 per 1000	147 per 1000 (41–531)	RR 0.40 (0.11–1.44)	259 (2 observational studies)	⊕⊕○○ Low†‡§¶‖	Risk of bias, inconsistency
Time to soft-tissue coverage (d)	—	SMD 2.2 lower (4.53 lower to 0.13 higher)	—	1880 (4 observational studies)	⊕○○○ Very low†‡§¶‖**	Risk of bias, inconsistency
Skin grafts	105 per 1000	120 per 1000 (57–254)	RR 1.14 (0.54–2.41)	259 (2 observational studies)	⊕⊕⊕○ Moderate†‡§¶	Risk of bias
Pedicled tissue transfer/flaps	140 per 1000	380 per 1000 (60–1000)	RR 2.71 (0.43–17.11)	313 (3 observational studies)	⊕○○○ Very low†‡§¶‖**	Risk of bias, inconsistency
Free tissue transfer/flaps	96 per 1000	331 per 1000 (123–893)	RR 3.46 (1.28–9.33)	592 (5 observational studies)	⊕⊕⊕○ Moderate †‡§¶‖	Risk of bias, inconsistency, evidence upgraded due to plausible residual confounding
No. reoperations	—	SMD 1.68 lower (4.39 lower to 1.03 higher)	—	251 (3 observational studies)	⊕○○○ Very low †‡¶‖	Risk of bias, inconsistency
Total No. surgeries	—	SMD 0.19 lower (0.64 lower to 0.26 higher)	—	98 (2 observational studies)	⊕⊕⊕○ Moderate†‡§¶	Risk of bias, inconsistency
Hospital LOS (d)	—	SMD 2.2 lower (5.19 lower to 0.8 higher)	—	287 (4 observational studies)	⊕○○○ Very low†‡§¶‖**	Risk of bias, inconsistency
Time to soft tissue healing (d)	—	SMD 1.03 lower (2.73 lower to 0.66 higher)	—	189 (2 observational studies)	⊕⊕○○ Low§¶‖**	Risk of bias, inconsistency, plausible residual confounding
Time to bone healing (d)	—	SMD 3.24 lower (8.36 lower to 1.88 higher)	—	189 (2 observational studies)	⊕⊕○○ Low§¶‖**	Risk of bias, inconsistency, plausible residual confounding
Time to full weight-bearing/return to work (d)	—	SMD 4.67 lower (12.77 lower to 3.44 higher)	—	189 (2 observational studies)	⊕⊕○○ Low§¶‖**	Risk of bias, inconsistency, plausible residual confounding
Flap failures (complete)	63 per 1000	76 per 1000 (31 to 187)	RR 1.22 (0.49–2.99)	346 (3 observational studies)	⊕⊕○○ Low†‡§¶††	Risk of bias, publication bias
Infections (wound/osteomyelitis)	400 per 1000	148 per 1000 (92 to 244)	RR 0.37 (0.23–0.61)	224 (3 observational studies)	⊕⊕⊕○ Moderate†‡¶	Risk of bias
Amputations	39 per 1000	48 per 1000 (16 to 140)	RR 1.23 (0.42–3.60)	348 (4 observational studies)	⊕⊕⊕○ Moderate†‡§¶	Risk of bias

GRADE Working Group grades of evidence: high certainty, we are very confident that the true effect lies close to that of the estimate of the effect; moderate certainty, we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different; low certainty, our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect; very low certainty, we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.

*The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).

†Incomplete outcomes data.

‡Selective reporting.

§No reported follow-up.

¶Random sequence generation.

‖Heterogeneity > 50%.

**Heterogeneity > 75%.

††Publication bias.

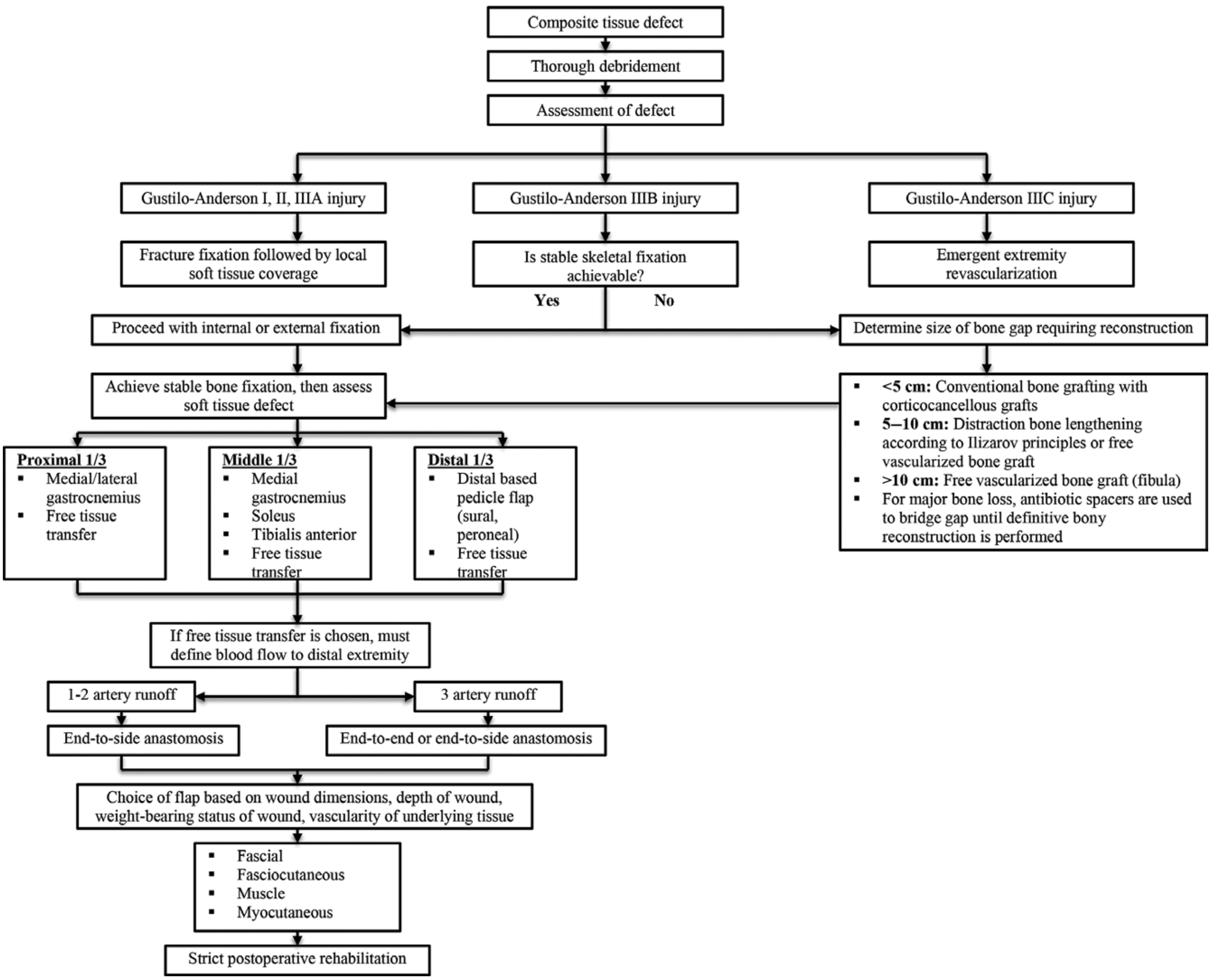

Fig. 4. Algorithm for orthoplastic management of composite defects of the lower extremity below the knee.[32]

soft tissue coverage concurrently with orthopedic fixation and stabilization to restore form and function.[1] Although there were risks of bias and significant heterogeneity for free flaps, evidence was upgraded from low to moderate certainty evidence based on clinical implications and plausible residual confounding. Concurrent free flap reconstruction may not result in a greater number of reoperations, total number of surgeries, hospital LOS, and flap failures. The effectiveness of the team-based approach is critical to complex reconstruction.[21–26] Microsurgical flap reconstruction mastered by any specialty and aided by protocols can optimize both immediate and long-term patient outcomes, hospital resources, and timing of surgeries.[19,27–29] Reducing NPWT use, reliance on healing by secondary intention, and associated care provides potential cost benefits.[17,30,31] Thus, free flap coverage should be pursued to decrease risks of infection and osteomyelitis. Principles of restoring and optimizing distal blood flow, bone stabilization, and soft-tissue reconstruction of the lower extremity have been previously been outlined (Fig. 4).[32]

Several limitations existed. Studies that included orthoplastic and non-orthoplastic management were mixtures of prospective and retrospective observational studies performed primarily in the United Kingdom with possible selection bias. Combining prospective and retrospective cohorts were performed in compliance with methods outlined by the Cochrane Collaboration to include all relevant data from the literature. Nine studies were available for comparison, limiting the ability to use funnel plots to assess study heterogeneity. Studies were inconsistent with reporting. Only 27 of 123 variables (**see appendix B, Supplemental Digital Content 2,** which displays data extraction variables, http://links.lww.com/PRSGO/B604) were comparable by a minimum of 2 studies. Sample demographics lacked comorbidities, limiting the ability to assess the influence of plausible confounding on patient variables and outcomes. No study evaluated donor site morbidities. Donor sites may contribute to secondary areas of impairment. Four patients (0.02%) included in the orthoplastic cohort had upper extremity fractures (radius = 1, humerus = 2, ulna = 1), potentially influencing interpretations of lower extremity injuries. By using the random effects model for all outcomes, we may have underestimated the true clinical impact of the orthoplastic approach. Downgrading the certainty of evidence for number of reoperations, hospital LOS, time to soft tissue healing, time to bone healing, and time to full weight-bearing/return to work reflects uncertainty with evidence. Although the majorities of studies were performed in the United Kingdom with higher proportions of male patients, the highest level of care was provided to participants at MTCs. Limitations were accounted for while determining certainties of evidence for each recommendation using study designs, risks of bias, inconsistencies, indirectness, imprecision, effect sizes, and plausible confounding. We identified future areas of research and compared outcomes with the highest levels of evidence available to cautiously guide recommendations for the orthoplastic approach to management of traumatic lower extremity injuries.

CONCLUSIONS

The orthoplastic approach decreases time to bone fixation, use of NPWT with reliance on healing by secondary intention, risk of wound/osteomyelitis infections and increases free flaps, compared to the nonorthoplastic approach. Orthoplastic management of traumatic lower extremity injuries provides a synergistic model to optimize and expedite definitive skeletal fixation and free flap-based soft-tissue coverage for return of extremity form and function.

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