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Hardware Salvage in the Lower Extremity after Flap Coverage: 10-Year Single Center Outcomes Analysis

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Background: An unanswered question with open tibial fractures is whether the type of flap used affects hardware retention. Flap survival may not equate hardware retention or limb salvage. In this study, we performed a 10-year single institution review and analysis of all patients who had placement of hardware for open tibial fractures followed by flap coverage.

Methods: Inclusion criteria consisted of patients who underwent pedicled or free flap coverage of Gustilo IIIB or IIIC tibial fractures requiring open reduction and internal fixation. Outcomes and complications were statistically analyzed based on flap type. Flap type was stratified into free versus pedicled flaps and muscle versus fasciocutaneous flaps. Primary outcome measures included hardware failure and infection requiring hardware removal. Secondary outcome measures included limb salvage, flap success, and fracture union.

Results: Overall primary outcome measures were better for pedicled flaps (n = 31), with lower rates of hardware failure and infection (25.8%; 9.7%) compared with free flaps (n = 27) (51.9%; 37.0%). Limb salvage and flap success was not different comparing pedicled and free flaps. There was no significant difference in outcomes between muscle and fasciocutaneous flaps. Multivariable analysis showed that patients who had free versus pedicled flaps or muscle versus fasciocutaneous flaps had a higher chance of hardware failure. A formal orthoplastic team was established in the period from 2017 to 2022, after which flap numbers were higher and hardware failure less for pedicled and fasciocutaneous flaps.

Conclusions: Pedicled flaps were associated with lower rates of hardware failure and infection requiring hardware removal. A formal orthoplastic team improves hardware-related outcomes. *(Plast Reconstr Surg Glob Open 2023; 11:e5105; doi: 10.1097/GOX.0000000000005105; Published online 6 July 2023.)*

INTRODUCTION

Lower extremity trauma with open fractures often necessitates placement of implants for stable fracture fixation followed by immediate or staged flap coverage of the soft tissue defect.[1,2] Unfortunately, with open tibial fractures, the incidence of hardware failure and infection is significant,[3] with a reported infection rate of 25% in Gustilo type III open fractures.[4] Even in open tibial fractures where the soft tissue envelope is sufficient and flap coverage is not needed, the subsequent incidence of infection is significant.[5] Hardware exposure in almost all cases results in infection and the need for further surgery. Multiple-staged procedures, including debridement, placement of an antibiotic cement spacer, removal, and exchange of hardware, are needed to salvage the limb. In most cases, failure of limb salvage leads to amputation.[6–8] The necessity of flaps for soft tissue coverage of open tibial fractures to reduce wound complications has been well described.[9–14]

Historically, Godina reported that there were lower rates of flap failure, infection, and nonunion when flap coverage was performed within 72 hours.[15] Other studies have confirmed this, showing that early washout and debridement followed by expeditious flap coverage is essential to optimize surgical outcomes for limb salvage. Optimal outcomes resulted when flap coverage was performed within 3–4 days of definitive internal fixation.[4,16,17] The development of orthoplastic teams focused on early management of musculoskeletal trauma has facilitated early flap coverage and improved outcomes.[2]

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A topic of frequent investigation in the lower extremity is the efficacy of pedicled compared with free flaps and muscle compared with fasciocutaneous flaps. Although the location of the defect often dictates choice of coverage with a pedicled or free flap,[18] surgeon preference and institutional practices in many cases still lead to preference for a particular type of muscle or fasciocutaneous flap where there are many options that can lead to a successful outcome. The majority of the published literature has focused on flap survival and postoperative infection, with most articles showing no difference in outcomes between pedicled and free flaps or between muscle and fasciocutaneous flaps.[13,19–23]

An unanswered question is whether the type of flap used affects hardware retention. This is an important clinical question that has not been analyzed well in the published literature. In many instances, flap survival does not necessarily equate hardware retention, or even eventual limb salvage. Nevertheless, hardware failure or infection would at the very least necessitate multiple repeat procedures and long-term intravenous antibiotics with a decreased chance of limb salvage. Accordingly, our study is unique because it investigates whether there is an association between the types of flaps used for reconstruction and subsequent hardware-related complications.

In this study, we performed a 10-year single institution review and analysis of all patients who had hardware placement for open tibial fractures followed by flap coverage. Primary outcome measures analyzed included hardware failure and infection requiring hardware removal. Secondary outcome measures included limb salvage, flap success, and fracture union. The primary aim of the study was to investigate if there was a relationship between flap type (pedicled versus free and muscle versus fasciocutaneous flaps) and primary and secondary outcome measures. A secondary aim of the study was to determine if there was any difference in primary and secondary outcome measures when comparing the period of time from 2012 to 2016 (where there was not a formal orthoplastic collaboration) and from 2017 to 2021, where our institution had a formal orthoplastic team.

Takeaways

Question: Does the type of flap used for coverage of Gustilo IIIB or IIIC tibial fractures requiring open reduction and internal fixation affect hardware retention?

Findings: A 10-year single institution review was performed demonstrating that pedicled flaps were associated with lower rates of hardware failure and infection requiring hardware removal compared with free flaps. There was no significant difference in hardware retention between muscle and fasciocutaneous flaps.

Meaning: Pedicled flaps were associated with better hardware retention outcomes compared with free flaps for coverage of Gustilo IIIB or IIIC tibial fractures requiring open reduction and internal fixation.

PATIENTS AND METHODS

Patient data were retrieved from the electronic medical record based on CPT codes at a single center over a 10-year period from January 1, 2012, to December 31, 2021. All patients had procedures that included CPT codes from category 1 (flap surgery) AND category 2 (ORIF of tibial fracture). Category 1 CPT codes used for data retrieval were 15756, 15757 and 15738. Category 2 CPT codes used for data retrieval were 27758, 27759, 27766, 27769, 27784, 27792, 27814, 27822, 27826, 27827, 27828, 27829, 27832, 27846, and 27848. Institutional review board approval was obtained for the study.

An initial cohort of 100 unique patients was retrieved based on electronic medical record analysis by CPT codes. Detailed chart review was then performed of individual patient records to determine eligibility for inclusion in the study for further analysis. Inclusion criteria for the study included patients aged 5–89 years who underwent pedicled or free flap coverage of an open (Gustilo IIIB or IIIC) tibial fracture requiring eventual open reduction and internal fixation (ORIF). Patients were excluded if they were lost to follow-up after their flap coverage, underwent flap coverage in bilateral lower extremities, or underwent further reconstruction at other institutions. These exclusion criteria were chosen to avoid insufficient and inconsistent data that could potentially confound outcomes obtained in our study.

After individualized chart review, a cohort of 58 patients had sufficient data for inclusion in the study. Of these, 31 had pedicled flap reconstruction, whereas 27 had free flap reconstruction. In addition, in this cohort, 36 had reconstruction with muscle flaps, whereas 22 had reconstruction with fasciocutaneous flaps. Within the pedicled flap cohort, there were 14 fasciocutaneous and 17 muscle flaps. Within the free flap cohort, there were eight fasciocutaneous and 19 muscle flaps. All patients had at least 9 months of follow-up from the index flap surgery.

For the purposes of this study, flap type was stratified into free versus pedicled flaps and muscle versus fasciocutaneous flaps. Primary outcome measures included hardware failure and infection requiring hardware removal. Hardware failure was defined as failure following definitive ORIF to achieve fracture union, with subsequent removal of revision of hardware. Examples requiring hardware removal included infection related to the implant, hardware loosening, and fracture nonunion requiring revision ORIF. Infection requiring hardware removal was specifically defined as a perioperative or delayed surgical site infection that led to the removal of the implant that was placed during the definitive ORIF. Secondary outcome measures included limb salvage, flap success, and fracture union. Fracture union was determined by the treating orthopedic traumatologist, based on clinical and radiological evidence of union.

Additional data retrieved included patient age at time of flap coverage; gender; body mass index; smoking status; medical history, including history of diabetes; Gustilo classification of fracture; anatomical location of tibial fractures (proximal, middle, or distal 1/3); whether external fixation was performed at presentation or was delayed; whether ORIF was performed at presentation or was delayed; estimated blood loss for all procedures; presence and details of complications during hospital stay and upon discharge; and overall infection rate.

The patients who were included in this study were either admitted to our institution immediately after their injury or were transferred to our institution after receiving initial care at an outside hospital for a certain time period. Accordingly, the timing from injury to flap coverage varied among patients. All patients with open tibial fractures admitted to our level I trauma center underwent a standardized protocol for initial management, with formal irrigation and debridement (I&D) in the operating room to remove foreign bodies and nonviable tissue within 6 hours of injury. Provisional external fixation of the tibial fracture was performed at the time of the initial I&D where this was feasible. This was followed by repeated staged I&D until the wound was clean, followed by definitive hardware placement. Upon the establishment of a formal orthoplastic collaborative surgical team in our institution in 2017, flap coverage has been performed at the time of definitive internal fixation or within 72 hours of final hardware placement.

Descriptive statistics are presented at N (%) for categorical variables and mean (SD); median [IQR] (range) for continuous variables. Subjects were grouped by flap type three ways (Pedicled versus Free, Muscle versus Fascio, and Muscle-Free|Muscle-Pedicle|Fasciocutaneous-Free|Fasciocutaneous-Pedicle). Univariate comparisons on patient characteristics and outcomes within these groupings were performed using Fisher exact test (categorical variables) and Mann-Whitney or Kruskal-Wallis tests (continuous variables). Logistic regression was used to assess the effect of flap type on the primary outcomes (hardware failure and infection). Because of the small effective sample size for these outcomes (22 hardware failures and 21 infections), covariates included in multivariable analysis were limited to two: flap type and either flap location (distal versus proximal or middle) or ORIF at presentation (yes or no). All analyses were performed using the R statistical software package (V.4.1.3, The R Foundation for Statistical Computing), with the aid of a statistician.

RESULTS

In total, 58 patients were analyzed in our study. Overall primary outcome measures were better for patients who had pedicled flaps (n = 31) compared with free flaps (n = 27). Full data for outcomes of univariate analysis comparing patients with pedicled and free flaps are shown in Table 1. There was not a significant difference in age, gender, body mass index, smoking status, or presence of diabetes mellitus as a comorbidity when comparing between groups. The rate of hardware failure was 25.8% for the pedicled flaps compared with 51.9% for the free flaps. The rate of infection requiring hardware removal was 9.7% for the pedicled flaps compared with 37.0% for free flaps ($P < 0.05$). With regard to secondary outcomes, limb salvage and flap success rates were not statistically different when comparing pedicled and free flaps. Fracture union rate was 77.4% for pedicled flaps and 51.9% for free flaps. The postoperative complication rate after flap surgery was 12.9% for pedicled flaps and 14.8% for free flaps. The complication rate at follow-up after discharge was 60% for pedicled flaps and 66.7% for free flaps.

When comparing patients who had muscle (n = 36) and fasciocutaneous (n = 22) flaps, there was not a significant difference in age, gender, body mass index, smoking status, or presence of diabetes mellitus as a comorbidity when comparing between groups. There was also not a statistically significant difference in primary and secondary outcome measures. Full data for outcomes of univariate analysis comparing patients with muscle and fasciocutaneous flaps is shown in Table 2. The postoperative complication rate after flap surgery was 16.7% for muscle flaps and 9.1% for fasciocutaneous flaps. The complication rate at follow-up after discharge was 57.1% for muscle flaps and 72.7% for fasciocutaneous flaps.

Multivariable analysis was performed for primary outcome measures, controlling for location of the fracture (distal versus proximal or middle 1/3 of the leg). Patients who had free compared with pedicled flaps had a higher chance of hardware failure (OR 2.9; 95% CI, 0.948 to 9.4; $P = 0.066$), after adjustment for location of the fracture. When comparing patients who had fasciocutaneous compared with muscle flaps, patients who had fasciocutaneous flaps had a significantly lower chance of hardware failure (OR 0.24; 95% CI, 0.062 to 0.831; $P < 0.05$), after adjustment for location of the fracture. When a four-way comparison was performed comparing the rate of hardware failure between free fasciocutaneous, pedicled fasciocutaneous, free muscle and pedicled muscle flaps, patients who had free muscle flaps had a significantly higher risk of hardware failure compared with those who had pedicled fasciocutaneous flaps (OR 0.15; 95% CI, 0.026 to 0.687; $P < 0.05$). Full data for multivariable analysis are shown in Table 3.

A formal orthoplastic collaborative surgical team was established in our institution in 2017, after which overall flap numbers were higher. Of the 58 patients in this study, 16 had flap coverage between 2012 and 2016, and 42 had flap coverage between 2017 and 2021. There was a statistically significant ($P < 0.05$) lower rate of hardware failure for pedicled flaps and fasciocutaneous flaps performed in the period from 2017 to 2022 compared with before 2017 (Table 4). The rate of hardware failure was 5.9% for pedicled flaps from 2017 to 2022 and 50% for pedicled flaps before 2017 ($P < 0.05$). Of note, pedicled flaps performed between 2017 and 2022 were associated with higher fracture union rates and higher limb salvage rates compared with pedicled flaps performed before 2017. With regard to fasciocutaneous flaps, the rate of hardware failure was 8.3% from 2017 to 2022 and 40% before 2017 ($P < 0.05$).

DISCUSSION

In the presence of open tibial fractures, successful soft tissue reconstruction is essential for limb salvage. Unfortunately, successful soft tissue coverage may not necessarily result in hardware preservation and bony union.[24–26] Fracture nonunion primarily affects young individuals,

Table 1. Univariate Analysis and Comparison of Outcomes between Pedicled versus Free Flaps

Parameters	Overall (N = 58)	Pedicled (N = 31, 53.4%)	Free (N = 27, 46.6%)	*P*
Primary outcomes				
Infection requiring hardware removal	13 (22.4)	3 (9.7)	10 (37.0)	0.025
Hardware failure	22 (37.9)	8 (25.8)	14 (51.9)	0.059
Secondary outcomes				
Flap success	51 (87.9)	30 (96.8)	26 (96.3)	1
Fracture union	38 (65.5)	24 (77.4)	14 (51.9)	0.055
Limb retention	51 (87.9)	29 (93.5)	22 (81.5)	0.233
Other variables				
Age	38.5 (17.1); 38 [25, 48] (12, 80)	39.6 (18.3); 37 [26, 50] (13, 80)	37.2 (16.0); 40 [25, 48] (12, 80)	0.792
Men	44 (75.9)	23 (74.2)	21 (77.8)	1
BMI	27.9 (6.0); 28 [22, 32] (18, 40)	26.6 (5.9); 26 [21, 31] (18, 39)	29.3 (5.9); 31 [24, 34] (18, 40)	0.109
Smoker	29 (50.0)	15 (48.4)	14 (51.9)	1
DM	2 (3.4)	1 (3.2)	1 (3.7)	1
Gustilo class = IIIc (versus IIIb)	3 (5.2)	2 (6.5)	1 (3.7)	1
Tibia fracture location				
Proximal	6 (10.3)	4 (12.9)	2 (7.4)	0.675
Middle	17 (29.3)	12 (38.7)	5 (18.5)	0.148
Distal	35 (60.3)	15 (48.4)	20 (74.1)	0.062
Multiple fractures	51 (87.9)	27 (87.1)	24 (88.9)	1
Fibula fracture	50 (86.2)	28 (90.3)	22 (81.5)	0.453
Femur fracture	11 (19.0)	5 (16.1)	6 (22.2)	0.739
Other injuries	39 (68.4)	20 (66.7)	19 (70.4)	0.784
ExFix done	47 (81.0)	22 (71.0)	25 (92.6)	0.047
ExFix at presentation	45 (77.6)	21 (67.7)	24 (88.9)	0.066
ORIF at presentation	13 (22.4)	12 (38.7)	1 (3.7)	0.001
ORIF delayed	43 (74.1)	19 (61.3)	24 (88.9)	0.033
Days from injury to flap	64.7 (167); 6 [6, 34] (2, 1051)	79.0 (212); 8 [4, 35] (2, 1051)	47.5 (90.3); 18 [13, 32] (5, 425)	0.109
EBL	272 (290); 200 [100, 325] (20, 1500)	285 (349); 200 [100, 300] (20, 1500)	250 (160); 250 [100, 388] (50, 500)	0.686
Complications between fix and flap surgery	20 (34.5)	13 (41.9)	7 (25.9)	0.271
In-hospital complication after flap surgery	8 (13.8)	4 (12.9)	4 (14.8)	1
Complication at follow-up	36 (63.2)	18 (60.0)	18 (66.7)	0.784
Infection	21 (36.2)	9 (29.0)	12 (44.4)	0.279

with a significant effect on their psychological, physical well-being and quality of life.[27] Ideally, fracture union is achieved through definitive fixation at the time of presentation. Revision surgery unfortunately results in a lower rate of limb salvage, due to more complicated hardware issues, higher risk of infection, and a poorer soft tissue envelope.[28]

This study focused on analysis of hardware related complications after coverage with different flaps. This is an important clinical question that has not been discussed well in the published literature. Outcomes related to flap survival have been well-described, with most previous studies demonstrating no significant difference between pedicled and free flaps.[13,21,23] In addition, early flap coverage has been shown to be superior to skin grafting for coverage of lower extremity Gustilo type III fractures.[29]

In our study, we found better hardware-related outcomes with pedicled compared with free flaps. Interestingly, our results correlate with a systematic review comparing outcomes between pedicled and free flaps for salvage of exposed hardware.[14] A higher implant preservation rate was found with patients who had pedicled flaps compared with free flaps. The authors attributed this finding to most surgeons' preference of a pedicled flap for less complicated cases with limited tissue loss.

This has also been our institutional experience, and likely reflects a trend where more complicated fractures with larger wounds require free instead of pedicled flap coverage. In a large randomized controlled trial of 2500 patients with open fractures, factors found to be associated with infection included fracture location (highest in tibial fractures), low energy injury, degree of wound contamination, and need for flap coverage.[30] Another study showed that the severity of fracture comminution, periosteal stripping, and soft tissue injury was highly correlated with the risk of infection in open tibial fractures.[31] Following these findings, all patients included in this study were already at high risk of infection and hardware failure, having Gustilo

Table 2. Univariate Analysis and Comparison of Outcomes between Muscle and Fasciocutaneous Flaps

Parameters	Overall (N = 58)	Muscle (N = 36, 62.1%)	Fascio (N = 22, 37.9%)	P
Primary outcomes				
Infection requiring hardware removal	13 (22.4)	9 (25.0)	4 (18.2)	0.748
Hardware failure	22 (37.9)	17 (47.2)	5 (22.7)	0.094
Secondary outcomes				
Flap success	51 (87.9)	34 (94.4)	22 (100)	0.521
Fracture union	38 (65.5)	22 (61.1)	16 (72.7)	0.408
Limb retention	51 (87.9)	30 (83.3)	21 (95.5)	0.235
Other variables				
Age	38.5 (17.1); 38 [25, 48] (12, 80)	39.2 (15.9); 38 [27, 50] (12, 77)	37.3 (19.2); 34 [24, 45] (13, 80)	0.481
Men	44 (75.9)	29 (80.6)	15 (68.2)	0.350
BMI	27.9 (6.0); 28 [22, 32] (18, 40)	29.0 (5.7); 30 [25, 34] (18, 40)	25.8 (6.3); 24 [21, 31] (18, 39)	0.068
Smoker	29 (50.0)	17 (47.2)	12 (54.5)	0.787
DM	2 (3.4)	0 (0)	2 (9.1)	0.140
Gustilo class = IIIc (versus IIIb)	3 (5.2)	2 (5.6)	1 (4.5)	1
Tibia fracture location				
Proximal	6 (10.3)	5 (13.9)	1 (4.5)	0.392
Middle	17 (29.3)	13 (36.1)	4 (18.2)	0.234
Distal	35 (60.3)	18 (50.0)	17 (77.3)	0.054
Multiple fractures	51 (87.9)	30 (83.3)	21 (95.5)	0.235
Fibula fracture	50 (86.2)	29 (80.6)	21 (95.5)	0.140
Femur fracture	11 (19.0)	6 (16.7)	5 (22.7)	0.732
Other injuries	39 (68.4)	25 (71.4)	14 (63.6)	0.570
ExFix done	47 (81.0)	29 (80.6)	18 (81.8)	1
ExFix at presentation	45 (77.6)	27 (75.0)	18 (81.8)	0.748
ORIF at presentation	13 (22.4)	6 (16.7)	7 (31.8)	0.208
ORIF delayed	43 (74.1)	30 (83.3)	13 (59.1)	0.063
Days from injury to flap	64.7 (167); 16 [6, 34] (2, 1051)	50.0 (121); 13 [6, 25] (2, 575)	88.0 (223); 22 [8, 55] (2, 1051)	0.131
EBL	272 (290); 200 100, 325] (20, 1500)	333 (326); 275 [163, 388] (50, 1500)	149 (146); 100 [75, 150] (20, 500)	0.026
Complications between fix and flap surgery	20 (34.5)	13 (36.1)	7 (31.8)	0.783
In-hospital complication after flap surgery	8 (13.8)	6 (16.7)	2 (9.1)	0.697
Complication at follow-up	36 (63.2)	20 (57.1)	16 (72.7)	0.272
Infection	21 (36.2)	13 (36.1)	8 (36.4)	1

Table 3. Multivariable Analysis and of Hardware Failure Rates, Controlling for Location of Fracture (Distal versus Proximal or Middle 1/3 of the Leg)

Parameters	Odds Ratio	Multivariable Analysis, 95% Confidence Interval	P
Free versus pedicled flaps	2.9	0.948–9.39	0.066
Fasciocutaneous versus muscle flaps	0.24	0.062–0.831	0.032
Four-way flap comparison			
Free fasciocutaneous versus free muscle flaps	0.19	0.023–1.09	0.080
Pedicled fasciocutaneous versus free muscle flaps	0.15	0.026–0.687	0.021
Pedicled muscle versus free muscle flaps	0.31	0.063–1.41	0.134
Pedicled fasciocutaneous versus free fasciocutaneous flaps	0.80	0.102–7.46	0.834
Pedicled muscle versus free fasciocutaneous flaps	1.6	0.228–15.7	0.636
Pedicled fasciocutaneous versus pedicled muscle flaps	0.49	0.071–2.92	0.443

IIIB or IIIC open tibial fractures. Although there was insufficient information in the electronic medical record to quantify the degree of wound contamination in our patients, we did find a statistically higher rate of external fixator placement for patients who had free flaps ($P < 0.05$) compared with pedicled flaps, suggesting that patients who eventually had free flap coverage had more contaminated wounds.

With regard to muscle and fasciocutaneous flaps, most studies have shown that there is no significant difference in outcomes such as implant preservation and flap

Table 4. Comparison of Flap Outcomes between 2017 and 2022 and before 2017

Parameters	Hardware Failure (N (%))	Infection Requiring Hardware Removal (N (%))	Flap Success (N (%))	Fracture Union (N (%))	Limb Retention (N (%))
Total flaps 2017–2022 (n = 42)	14 (33.3)	10 (23.8)	41 (97.6)	28 (66.7)	37 (88.1)
Total flaps before 2017 (n = 16)	8 (50.0)	3 (18.8)	15 (93.8)	10 (62.5)	14 (87.5)
P	0.125	0.343	0.240	0.385	0.476
Pedicled flaps 2017–2022 (n = 17)	1 (5.9)	1 (5.9)	17 (100)	15 (88.2)	17 (100)
Pedicled flaps before 2017 (n = 14)	7 (50.0)	2 (14.3)	13 (92.9)	9 (64.3)	12 (85.7)
P	0.002	0.224	0.139	0.060	0.057
Free flaps 2017–2022 (n = 25)	13 (52.0)	9 (36.0)	24 (96.0)	13 (52.0)	20 (80.0)
Free flaps before 2017 (n = 2)	1 (50.0)	1 (50.0)	2 (100)	1 (50.0)	2 (100)
P	0.479	0.353	0.392	0.479	0.251
Muscle flaps 2017–2022 (n = 30)	13 (43.3)	8 (26.7)	29 (96.7)	19 (63.3)	25 (83.3)
Muscle flaps before 2017 (n = 6)	4 (66.7)	1 (16.7)	5 (83.3)	3 (50.0)	5 (83.3)
P	0.154	0.309	0.102	0.277	0.500
Fasciocutaneous flaps 2017–2022 (n = 12)	1 (8.3)	2 (14.2)	12 (100)	9 (75.0)	12 (100)
Fasciocutaneous flaps before 2017 (n = 10)	4 (40.0)	2 (20.0)	10 (100)	7 (70.0)	9 (90.0)
P	0.042	0.425	1	0.402	0.142

survival.[19,20,22,23] In addition, a comparative meta-analysis of outcomes after coverage of total knee arthroplasty wounds with pedicled muscle or fasciocutaneous flaps did not show a difference in rates of prosthetic salvage.[21] We had similar findings in this study for open tibial fractures, with no statistically significant difference in primary and secondary outcomes when comparing muscle and fasciocutaneous flaps. The only significant difference was noted with multivariable analysis, where patients who had fasciocutaneous flaps had a significantly lower risk of hardware failure ($P < 0.05$), after adjustment for location of the fracture. This finding could also be confounded by institutional surgeon bias and preference for muscle flaps for complicated and contaminated wounds.

A secondary objective of our study was to assess the efficacy of our institutional orthoplastic limb salvage team, which evolved to a more formal collaboration after 2017. Orthoplastic surgery has been defined as “the principle and practice of both specialties (plastic surgery and orthopedic surgery) applied to clinical problems simultaneously,” with the aim of achieving better outcomes relating to limb salvage.[32] An orthoplastic approach to management of lower extremity trauma has been shown to decrease time to bone fixation, use of negative pressure wound therapy with reliance on healing by secondary intention, risk of wound/osteomyelitis injections, and increase in use of free flap coverage.[33] We found similar trends in our study, with overall increased numbers of flaps after 2017 performed in association with open tibial fractures requiring implant placement. Looking at specific flap types in our series (Table 4), the number of free flaps performed before 2017 was two, and 25 were performed after 2017.[25] This is likely reflective, after 2017, of more appropriate use of free flaps for coverage in the lower extremity as well as increased regional referrals in recognition of institutional willingness to perform free tissue transfer. In addition, in the absence of a formal orthoplastic collaboration before 2017, there was likely a strong selection bias towards pedicled flaps during that period of time.

We also found in our series that for pedicled flaps performed in the context of an orthoplastic surgical team after 2017, hardware failure rates were significantly lower, with improved rates of fracture union and limb salvage. Hence, we show that an orthoplastic surgical collaboration can have improved outcomes not only with flap success rates,[34] but also with hardware related outcomes. With increasing numbers of publications showing the efficacy of orthoplastic teams, education of trauma and reconstructive surgeons on appropriate timing and choice of flaps for reconstruction of Gustilo type III fractures in the lower extremity is a decisive factor to optimize outcomes.

Our study had several limitations. First, this was a single center study. As such, the numbers of patients analyzed were limited and not as high as in multicenter studies. Therefore, the overall sample size was small, particularly for flaps performed before 2017, and as such, the corresponding high failure rate may have skewed the data. In addition, the age range for the patients included in this study was wide (12–80 years old), which may have affected the complication rates observed among the different types of flaps. Second, the sample size was not uniformly distributed among the different types of flaps. However, the type of flap performed, in this institution and others, depends on severity and location of the lower extremity wound as well as surgeon preference. Nevertheless, as a 10-year univariate and multivariable analysis correlating flap type with hardware-related outcomes in management of open tibial fractures, this study provides valuable information specifically relating to hardware failure and deep infection requiring hardware removal. It also provides future direction and highlights the need to conduct prospective, multicenter clinical trials that could yield more robust high-quality data on whether there is a relationship between flap type and hardware retention. Secondarily, our institutional experience provides further support for the orthoplastic surgical approach in management of lower extremity trauma. We show an exponential increase in the numbers of free flaps performed as well as improved hardware-related outcomes following the establishment of an orthoplastic limb salvage team.

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DISCLOSURE

The authors have no financial interests to declare in relation to the content of this article.

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