Published in final edited form as:

J Orthop Trauma. 2017 June ; 31(6): 339–344. doi:10.1097/BOT.0000000000000815.

Open Tibia Shaft Fractures and Soft-Tissue Coverage: The Effects of Management by an Orthopedic Trauma/Microsurgical Team

James VandenBerg, BS¹, Daniel Osei, MD, MSc¹, Martin I. Boyer, MD¹, Michael J. Gardner, MD¹, William M. Ricci, MD¹, Amanda Spraggs-Hughes, BS, MA¹, and Christopher McAndrew, MD, MSc¹

¹Washington University in St. Louis Department of Orthopedic Surgery, St. Louis, MO

Abstract

OBJECTIVES—To compare the timing of soft-tissue (flap) coverage and occurrence of complications before and after the establishment of an integrated orthopedic trauma/microsurgical team.

DESIGN—Retrospective Cohort Study

SETTING—A single level 1 trauma center

PATIENTS—28 subjects (13 pre- and 15 post-integration) with open tibia shaft fractures (OTA/AO 42A, 42B, 42C) treated with flap coverage between January 2009 and March 2015.

INTERVENTION—Flap coverage for open tibia shaft fractures treated before (“pre-integration”) and after (“post-integration”) implementation of an integrated orthopedic trauma/microsurgical team.

MAIN OUTCOME MEASURE—Time from index injury to flap coverage.

RESULTS—The unadjusted median time to coverage was 7 days (95% CI, 5.9–8.1) pre-integration, and 6 days (95% CI, 4.6–7.4) post-integration ($p=0.48$). For pre-integration, 9 (69%) of patients experienced complications, compared to 7 (47%) post-integration ($p=0.23$).

Corresponding Author: Christopher M. McAndrew, M.D., M.Sc., Assistant Professor, Orthopaedic Surgery, Washington University School of Medicine, Campus Box 8233, 660 South Euclid Avenue, St. Louis, MO 63110, Phone (314) 747-2811, Fax (314) 747-2599, mcandrewc@wudosis.wustl.edu.

The remaining authors (VandenBerg, Spraggs-Hughes) have no disclosures to report.

Conflicts of Interest and Source of Funding:

DO Grants: NIH

MIB: Expert testimony: Hand Surgical Medicolegal Consultation, LLC

MJG: Consultancy: DePuy Synthes, Stryker, DGIMed, BoneSupport AB, Pacira PHarma, KCI

Royalties: Lippincott. Grants: DePuy Synthes

WMR: Consultancy: Smith & Nephew, Biomet, Stryker, Wright Medical. Royalties: Lippincott. Grants: Smith & Nephew, AONA, COTA, Smith & Nephew

CM: Grants: Department of Defense, OREF, COTA, AONA, DePuy Synthes, NIH. Speakers' bureau: AONA, AOTNA. Payment for manuscript preparation: JBJS.

CONCLUSIONS—After formation of an integrated orthopedic trauma/microsurgery team, we observed a one-day decrease in median days to coverage from index injury. Complications overall were lowered in the post-integration group, though statistically insignificant.

LEVEL OF EVIDENCE—Therapeutic level III

INTRODUCTION

The management of soft-tissue defects associated with open tibia shaft fractures is critical to outcomes, and an important consideration for orthopedic trauma surgeons. Timely soft-tissue coverage (flap coverage) prevents desiccation of bone and associated tissues, expedites healing, clears bacteria, and minimizes risk of infection.^[1,2] Patients with open tibia fractures that require flap coverage historically have infection rates of 26–67%.^[3–7] Godina and Byrd et al. showed that early flap coverage decreased complications in patients with extremity trauma.^[8,9] These findings led to the concept of “fix and flap”, involving immediate antibiotics, irrigation, debridement, and fixation, followed by flap coverage.^[10] With the exception of one dissenting study,^[11] the literature universally supports earlier flap coverage. Yet, the ideal time to coverage is still unclear, with previous studies demonstrating a decrease in complications with “early” flap coverage ranging from 1 to <15 days from index injury.^[4,9,10,12–16] Despite this, flap coverage <7 days from the index injury is a consensus target.^[4,8,17]

Unfortunately, logistical difficulties often impede efficient time to flap coverage. Delay is attributed to the availability of the surgical team/operating rooms, late referrals, and the condition of the patient.^[4,9,10,18] At our institution, we previously managed these patients through two divisions in two different departments: Orthopedic Trauma and Plastic Surgery. An orthopedic trauma team treated the fracture, while a plastic surgery team separately managed the flap coverage. In February 2012, this paradigm was replaced with an integrated orthopedic trauma/microsurgical team. Using one department streamlined communication and coordination by combining clinic time and requiring the attendance of microsurgeons at orthopedic trauma conferences twice weekly. The primary aim of this study was to compare the timing of flap coverage before and after the establishment of an integrated orthopedic trauma/microsurgical team. Our hypothesis was that the establishment of an integrated orthopedic trauma/microsurgery team would lead to decreased time to coverage. Secondary aims included comparison of nonunion, infection, flap failure, partial-flap necrosis, amputation, and rehospitalization/reoperation events before and after establishment of this new team.

PATIENT AND METHODS

Subjects and Eligibility Criteria

The Institutional Review Board approved this retrospective cohort study at a level 1 academic trauma center. Patients were selected from a date range of January 2009 through March 2015. These dates were chosen because the integrated orthopedic trauma/microsurgical team was established on February 2012, and by starting data collection at January 2009, we allowed the same amount of time to abstract data for both cohorts. We

included adult patients (≥ 18 years old) who underwent flap coverage for an open tibia shaft fracture at our institution. The initial search was performed using current procedural terminology codes for fracture fixation, fasciotomies, incision and drainage, and open tibia fractures: “27535”, “27536”, “27758”, “27759”, “27827”, “27828”, “20690”, “20692”, “20696”, “27602”, “11010”, “11011”, and “11012”. We then removed patients <18 years old or patients with upper extremity injuries only. An additional 13 patients were added from the personal records of referrals to the orthopedic microsurgeons. We excluded those who received primary amputation, definitive fixation at an outside institution, or had secondary flap coverage, defined as injuries that were not treated with flap coverage during the index hospitalization, ultimately failed conservative management, and received flap coverage. We also excluded flap coverage by an orthopedic surgery team before February 2012, or flap coverage by a plastic surgery team after February 2012. One patient was excluded because the tibia fracture was not acute (three-week delay of presentation to the hospital). In total, 28 patients met our criteria (see Figure, Supplemental Digital Content 1). Clinical follow-up was recorded from the medical records, and defined as a clinical visit performed by either an orthopedic trauma or microsurgery attending.

Comparison Groups

The main analysis groups were defined as flap coverage performed before (pre-integration) or after (post-integration) February 2012. Due to a theoretical concern for implant colonization and secondary infection, we also analyzed the time between definitive fixation and flap coverage for these groups. Any patient who received definitive fixation after flap coverage was excluded from this analysis. In addition, subanalysis was done on patients covered <7 (“early”) and ≥ 7 (“late”) days from index injury. This threshold helped investigate factors that caused delay beyond the consensus goal for coverage, and the effect of time to coverage on the occurrence of complications.^[4,8,17] Subanalysis was also done on all primary (“primary group”) versus secondary (“secondary group”) coverage cases. Primary flap coverage was defined as operations planned during the index hospitalization. This subanalysis included those with flap coverage done by an orthopedic surgery team before February 2012 or by a plastic surgery team after February 2012.

Clinical and Radiographic Data

Age, gender, race, insurance status, Charlson Comorbidity Index (CCI), Body Mass Index (BMI), diabetes mellitus status (absent/insulin/non-insulin dependent), tobacco use (current/former/none), American Society of Anesthesiology (ASA) score, injury mechanism, index operation, length of hospital stay, number of debridements, vacuum assisted closure device (VAC) use, duration of VAC use, time between injury and coverage, and time between definitive fixation and coverage were abstracted from the medical records. All demographic and past medical history data was recorded from the day of flap coverage. Number of debridements was defined as the number of times the patient returned to the operating room (OR) for a debridement procedure prior to flap coverage or intended definitive wound closure.

Post-coverage complications included: nonunion (return to OR for nonunion repair surgery), infection (surgically collected positive culture), flap failure (return to the OR for flap

revision surgery, additional coverage surgery, re-anastomosis of vessels, or amputation specified as a treatment for flap failure), partial-flap necrosis (return to OR for debridement of necrotic tissue), amputation, and rehospitalization/reoperations. We classified the presence of post-coverage nonunion, infection, flap failure, partial-flap necrosis, or amputation as “overall complications”. We characterized tibia shaft fractures using the OTA/AO classification (42A, 42B, 42C) along with all available operative notes, and radiographic images.^[19] An orthopedic trauma attending (CMM) reviewed the OTA/AO classification in any case where the diagnosis was uncertain. For patients with bilateral tibial shaft fractures with flap coverage (n=1), a random-number generator was used to pick the studied side. This minimized bias that could have been introduced by selection according to severity, time to coverage, or subsequent complications. Only one limb was chosen to preserve the independence of observations for statistical testing. The indication for flap coverage was determined from surgical/medical notes, and included soft-tissue damage from index injury, infection, chronic non-healing wound, or extensive debridements.

Statistical Analysis

Kaplan-Meier survival curves and log-rank tests were done to compare the time to coverage pre- and post-integration. Bivariate-statistical analyses were utilized to compare the pre- vs. post-integration, early vs. late, and primary vs. secondary groups against demographic, medical history, treatment, and complication variables. Student’s t-test was used for normal, continuous variables, and the Mann-Whitney U test for non-normal, continuous variables. Chi-square and Fisher’s exact tests were used for categorical variables as appropriate. Tests were performed using two sided p-values at $\alpha = 0.05$. All statistical tests were performed using a standard software package (IBM SPSS Statistic for Windows, Version 22.0, Armonk, NY). The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement was used as a guideline for reporting this paper.^[20]

RESULTS

Pre- vs. Post-Integration

Of the patients with open tibia shaft fractures (108 pre-integration and 115 post-integration), the percentage of patients that received flap coverage was 15.7% (17/108) pre-integration and 22.6% (26/115) post-integration. A total of 28 patients met our inclusion criteria (13 pre-integration and 15 post-integration). Table, Supplemental Digital Content 2 shows that there was no statistically significant difference amongst demographic variables, and that both groups were predominately middle-aged-white males. Table, Supplemental Digital Content 3 shows that motorcycle accidents were the most common cause of injury pre- (39%) and post-integration (40%), followed by other motor vehicle collisions and gun-shot wounds. Median (range) time from injury to last clinical follow up was 13 (2–53) months for pre-integration and 9 (0.7–28) months post-integration. Table 1 demonstrates treatment characteristics for each group.

Median (range) time to coverage was 7 (3–17) days (95% CI, 5.9–8.1) and 6 (4–12) days (95% CI, 4.6–7.4) for pre- and post-integration groups respectively (Figure 1, $p=0.48$). Table 2 shows that 69% of pre-integration patients experienced overall complications compared to

47% post-integration ($p=0.23$). There was no statistical significance for the between-group differences amongst individual complications. However, pre-integration flap failure was 23% vs. 13% post-integration ($p=0.64$). Only one case, which was pre-integration, required amputation. All other flap failures were treated successfully with revision surgeries. The median (range) number of post coverage rehospitalizations and reoperations were 1 (0–5) and 2 (0–7) pre-integration versus 0 (0–5) and 1 (0–7) post-integration.

Pre- vs. Post-Integration: Time from Definitive Fixation to Flap Coverage for Primary Cases

28 subjects received primary coverage and had complete data regarding definitive fixation timing and flap coverage. Three of these were excluded for having definitive fixation placed after flap coverage. These were all pre-integration, but we could not confirm the reason why fixation was done after flap coverage. In the remaining subjects, the median (range) days to coverage after definitive fixation was 3.5 (1–17) days pre-integration ($n=10$, 95% CI, 0.9–5) compared to 4 (0–11) days post-integration ($n=15$, 95% CI, 2.5–5.5), with no statistically significant difference ($p=0.92$).

Early vs. Late Coverage

Of the 28 patients, 14 were in the early group (flap coverage performed <7 days) and 14 in the late group (flap coverage performed ≥ 7 days). There were no statistically significant differences in demographic factors or flap type used between the two groups. Table 3 shows that patients experiencing overall complications was 50% in the early group and 64% in the late group ($p=0.45$). There was no statistically significant difference amongst the individual complication percentages, but the late group had 29% flap failures (with one limb amputation), compared to 7% in the early group ($p=0.33$).

Table, Supplemental Digital Content 4 lists variables for patients who were covered ≥ 7 days ($n=14$), including factors that delayed coverage as well as subsequent complications. The pre-integration cases ($n=7$) had a time to coverage that ranged from 7–17 days and experienced delays due to logistical planning, with some delays due to polytrauma, patient complications, OSH transfers and planning for a complex osteoseptocutaneous flap. In comparison, post-integration cases ($n=7$) ranged from 7–12 days, with delays primarily due to polytrauma and patient complications.

Primary vs. Secondary Coverage

There were 42 subjects for this subanalysis (primary $n=31$ and secondary $n=11$), which included the four patients who were managed by a plastics team after February 2012 or by an orthopedic team before February 2012. All primary cases were covered due to soft-tissue damage from index injury, while 64% of secondary cases were due to infection and 36% from chronic non-healing wounds. No secondary cases received coverage due to extensive index debridements. The mean ages were 51 for the primary group and 40 for the secondary group ($p=0.04$, 95% CI, 0.4–22), while male gender was 87% versus 55% for the primary and secondary groups respectively ($p=0.02$, 95% CI, 0.04–0.6). No other demographic factors were statistically significant. However, the primary group had 65% insured patients compared to 91% in the secondary group ($p=0.1$). The primary group received more debridements than the secondary group, as 71% versus 27% received three debridements or

more ($p=0.01$, 95% CI, 0.1–0.7). The length of stay was longer for the primary group by a median difference of 10 days, which was statistically significant, ($p=0.001$, 95% CI, 1–12). The difference in time to coverage was also statistically significant, with median times for primary versus secondary groups of 7 days (95% CI, 5.7–8.3) vs. 67 days (95% CI, 41.1–92.9) respectively ($p<0.001$). Table 4 shows that the percentage of patients with overall complications was 55% versus 73% for primary and secondary groups, respectively ($p=0.3$).

DISCUSSION

The time to flap coverage has been consistently identified as a predictive factor in outcomes following treatment of open fractures.^[8,9,14] A number of system-based improvements have been suggested to achieve a decreased time from injury to coverage. We postulated that the formation of an integrated orthopedic trauma/microsurgery team would decrease time to coverage by improving communication with and accessibility to reconstructive microsurgical specialists. While the median time to coverage decreased from 7 to 6 days after formation of a combined service, these results were not statistically significant. One limitation to our approach was that flap surgeries were only performed on available Tuesdays and Thursdays. This limited our efficiency, especially for those who were injured near the end of the business week, and may have decreased the impact it had on the time to flap coverage.

There are inherent difficulties to implementing a system-wide paradigm shift, and the integrated orthopedic trauma/microsurgery team was only recently implemented, limiting the study to its first three years of implementation. It is possible that this new treatment paradigm was less efficient during its onset, which would have influenced the time to coverage. There were also three instances where our new protocol was broken and the flap procedures were performed by the plastic surgical team. It is unclear why this deviation occurred, but by comparison it only occurred once pre-integration (a patient received a STSG four days after injury by an orthopedic surgeon). Of the post-integration cases, one patient received a STSG 11 days after injury, another received temporary integra/wound vac placement with planned STSG 48 days after injury, and one was secondarily covered 48 days after injury with a pedicled muscle flap due to a post-operative infection.

Two differences that were found between pre- and post-integration groups were that a higher percentage of open tibia shaft fractures received flap coverage post-integration, as well as an increase in secondary coverage cases (post-integration $n=8$, pre-integration $n=2$). These secondary cases are fundamentally different than primary cases, because the patients have been discharged and evaluated in the outpatient setting. When comparing the time to coverage, we believed it was important to distinguish these two situations. It is unclear why the post-integration group contained more secondary flaps. In retrospect, these fractures should have been primarily covered. However, the design of our study limits us from adequately assessing these factors. However, it is possible that having greater access to microsurgeons led to a greater utilization of flap coverage post-integration.

As shown in Table 4, cases from the primary group that were covered 7 days were studied to identify additional barriers to flap coverage. This was done because previous studies

showed a decrease in complications with coverage <7 days, so it was important to identify cases that crossed this threshold.^[4,8,16,17] The causes of delay included logistical planning, polytrauma, patient complications, and OSH transfers. Pre-integration patients were delayed more by logistical planning, with two patients who had wound VACs placed and were scheduled for flap coverage 4 and 9 days after discharge. In comparison, no post-integration cases were discharged with scheduled flap coverage. Patients in both groups experienced delays due to OSH transfers. This is an important factor, as longer transfers are related to worse complications. Transfer delays have been associated with increasing infection rates,^[21] and we believe that the delay in transfer has an only greater effect on patients who ultimately are treated with flap coverage.

Although <7 days is viewed as an acceptable time to coverage, our study did not support the degree of benefit seen in the literature. In our study, the decrease in overall complications from late to early coverage was 14%, while the previous literature ranged from 38–62.5%.^[8,17] In addition, one study showed a statistically significant reduction in infections by 44.5%, whereas ours showed no change.^[4] Yet, caution must be taken when interpreting our results, as this retrospective review was not powered to prevent type-II error. Though the ideal time to coverage remains unclear, past studies have shown a greater benefit with even earlier coverage timing thresholds, so adhering to more stringent timing protocols may produce both a clinically and statistically significant decrease in overall complications.^[9,10,14] While we are unable to claim a clinically important difference from our decrease in time to coverage, financial effects of small changes in length of stay would likely support the effort to decrease this as much as possible.

The limitations of this study included the small sample size. This is a relatively rare injury, combined with a limited study date range, which decreased our available subjects and statistical power, leading to an increased chance of type-II statistical errors. The retrospective design produces data that lack standardization of surgical indications for treatment or its timing. It also limits the availability of clinical information. For instance, we were unable to accurately characterize the severity of tibia fractures with Gustilo-Anderson (GA) classifications, so we abandoned this classification scheme.

Our study was likely subjected to selection bias, given its retrospective nature. In addition, since our data was abstracted from chart review, multiple variables may have biased the results. For instance, we did not obtain Injury Severity Score data or specific wound dimensions. It is possible that these affected both planning and time to coverage. The bias was minimized in our study by adherence to a rigid and pre-specified threshold for inclusion and exclusion. Given that cohorts were separated by time, shifts in practice changes or improved techniques may have confounded the results. The difficulty in instituting systemic policy changes within an institution was represented by the four patients that had to be excluded because of deviation from the paradigm treatment protocol (patient treated by plastics team after February 2012 or by orthopedic team before February 2012). We attempted to minimize bias by excluding these patients, so that the groups adequately reflected the benefit and harm of the protocol.

Future studies can explore other outcomes associated with implementation of this integrated orthopedic/microsurgery team, such as functional results of flap coverage. As our data was limited by a small sample size, creating a patient registry would aid in prospective studies and increasing statistical power. In addition, the benefits and harm of secondary flap coverage versus conservative management also warrants further study.

In conclusion, this current study demonstrated that an integrated orthopedic/microsurgery team led to a statistically insignificant decrease in the time to coverage and decrease in overall complications. This new management paradigm is still relatively young, but is a promising approach to managing these complex patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors wish to thank Dorina Kallogjeri, MD, MPH, provided statistical support. Vanessa L. Kronzer, BA, helped edit the initial manuscript.

This publication was made possible by Grant Number UL1 TR000448 and TL1 TR000449 from the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

References

1. Holden CE. The role of blood supply to soft tissue in the healing of diaphyseal fractures. An experimental study. *J Bone Joint Surg Am.* 1972; 54(5):993–1000. [PubMed: 5057112]
2. Mathes SJ, Alpert BS, Chang N. Use of the muscle flap in chronic osteomyelitis: experimental and clinical correlation. *Plast Reconstr Surg.* 1982; 69(5):815–29. [PubMed: 7071227]
3. Alberts KA, Loochagen G, Einarsdottir H. Open tibial fractures: faster union after unreamed nailing than external fixation. *Injury.* 1999; 30(8):519–23. [PubMed: 10707206]
4. Bhattacharyya T, et al. Routine use of wound vacuum-assisted closure does not allow coverage delay for open tibia fractures. *Plast Reconstr Surg.* 2008; 121(4):1263–6. [PubMed: 18349645]
5. Castillo RC, et al. Impact of smoking on fracture healing and risk of complications in limb-threatening open tibia fractures. *J Orthop Trauma.* 2005; 19(3):151–7. [PubMed: 15758667]
6. Dedmond BT, et al. The use of negative-pressure wound therapy (NPWT) in the temporary treatment of soft-tissue injuries associated with high-energy open tibial shaft fractures. *J Orthop Trauma.* 2007; 21(1):11–7. [PubMed: 17211263]
7. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma.* 1984; 24(8):742–6. [PubMed: 6471139]
8. Byrd HS, Spicer TE, Cierney G 3rd. Management of open tibial fractures. *Plast Reconstr Surg.* 1985; 76(5):719–30. [PubMed: 3903801]
9. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg.* 1986; 78(3):285–92. [PubMed: 3737751]
10. Gopal S, et al. Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia. *J Bone Joint Surg Br.* 2000; 82(7):959–66. [PubMed: 11041582]
11. Pollak AN, McCarthy ML, Burgess AR. Short-term wound complications after application of flaps for coverage of traumatic soft-tissue defects about the tibia. The Lower Extremity Assessment Project (LEAP) Study Group. *J Bone Joint Surg Am.* 2000; 82-a(12):1681–91. [PubMed: 11130641]

12. Fischer MD, Gustilo RB, Varecka TF. The timing of flap coverage, bone-grafting, and intramedullary nailing in patients who have a fracture of the tibial shaft with extensive soft-tissue injury. *J Bone Joint Surg Am.* 1991; 73(9):1316–22. [PubMed: 1918113]
13. Hertel R, et al. On the timing of soft-tissue reconstruction for open fractures of the lower leg. *Arch Orthop Trauma Surg.* 1999; 119(1–2):7–12. [PubMed: 10076937]
14. Liu DS, et al. Early soft tissue coverage and negative pressure wound therapy optimises patient outcomes in lower limb trauma. *Injury.* 2012; 43(6):772–8. [PubMed: 22001504]
15. Francel TJ, et al. Microvascular soft-tissue transplantation for reconstruction of acute open tibial fractures: timing of coverage and long-term functional results. *Plast Reconstr Surg.* 1992; 89(3): 478–89. [PubMed: 1741471]
16. Cierny G 3rd, Byrd HS, Jones RE. Primary versus delayed soft tissue coverage for severe open tibial fractures. A comparison of results. *Clin Orthop Relat Res.* 1983; 178:54–63.
17. Caudle RJ, Stern PJ. Severe open fractures of the tibia. *J Bone Joint Surg Am.* 1987; 69(6):801–7. [PubMed: 3597491]
18. Sinclair JS, et al. Primary free-flap cover of open tibial fractures. *Injury.* 1997; 28(9–10):581–7. [PubMed: 9624333]
19. Marsh JL, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma.* 2007; 21(10 Suppl):S1–133. [PubMed: 18277234]
20. von Elm E, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg.* 2014; 12(12): 1495–9. [PubMed: 25046131]
21. Pollak AN, et al. The relationship between time to surgical debridement and incidence of infection after open high-energy lower extremity trauma. *J Bone Joint Surg Am.* 2010; 92(1):7–15. [PubMed: 20048090]

Figure 1. Kaplan-Meier curve of primary coverage cases in pre- (n=13) and post-integration (n=15) groups. Time (days) is measured from the day of index injury to the date of flap coverage.

Table 1

Treatment Characteristics

n (%) unless otherwise noted	Pre (n=13)	Post (n=15)	95% CI	P-Value
Index Operation:			−0.2–0.4	0.74
IMN	6 (46)	6 (40)		
Ex-fix	7 (54)	9 (60)		
LOS (days), med. (range)	14 (7–33)	14 (10–36)	n/a	0.52
Surgical Debridements 3	7 (54)	12 (80)	−0.08–0.5	0.23
VAC used	10 (77)	14 (93)	−0.1–0.4	0.31
VAC length (days), $\bar{X}$ (SD) *	5 (5)	5 (3)	−3–3	0.87
Flap Type:				
Pedicled Muscle	5 (39)	8 (54)	−0.2–0.5	0.43
STSG	3 (23)	2 (13)	−0.2–0.4	0.64
Free Muscle	3 (23)	1 (7)	−0.1–0.4	0.31
Pedicled FC	1 (8)	1 (7)	−0.2–0.3	1.0
Free FC	0 (0)	2 (13)	−0.1–0.4	0.48
Pedicled Muscle+FC	0 (0)	1 (7)	−0.2–0.3	1.0
Pedicled Muscle+BF	1 (8)	0 (0)	−0.1–0.3	0.46

Intramedullary Nail (IMN), External Fixation (Ex-fix), Length of Stay (LOS), Vacuum Assisted Closure (VAC), Split Thickness Skin Graft (STSG), Fasciocutaneous (FC), Bone Flap (BF)

* VAC used during index hospitalization prior to flap coverage

Table 2

Post-Coverage Complications (Pre- vs. Post-Integration Groups)

n (%)	Pre n=13	Post (n=15)	95% CI	P-Value
Overall Complications	9 (69)	7 (47)	−0.1–0.5	0.23
Nonunion	6 (46)	6 (40)	−0.3–0.4	0.74
Infection	3 (23)	3 (20)	−0.3–0.3	1.0
Flap Failure	3 (23)	2 (13)	−0.2–0.4	0.64
Partial Necrosis	0 (0)	0 (0)	n/a	n/a
Amputation	1 (8)	0 (0)	−0.1–0.3	0.46

Table 3

Post-Coverage Complications (Early vs. Late Coverage Groups)

n (%)	Early (n=14)	Late (n=14)	95% CI	P-Value
Overall Complications	7 (50)	9 (64)	−0.2–0.4	0.45
Nonunion	6 (43)	6 (43)	−0.3–0.3	1.0
Infection	3 (21)	3 (21)	−0.3–0.3	1.0
Flap Failure	1 (7)	4 (29)	−0.08–0.5	0.33
Partial Necrosis	0 (0)	0 (0)	n/a	n/a
Amputation	0 (0)	1 (7)	−0.2–0.3	1.0

Table 4

Post-Coverage Complications (Primary vs. Secondary Groups)

n (%)	Primary n=31	Secondary (n=11)	95% CI	P-Value
Overall Complications	17 (55)	8 (73)	−0.2–0.4	0.30
Nonunion	13 (42)	7 (64)	−0.1–0.5	0.22
Infection	7 (23)	2 (18)	−0.3–0.3	0.76
Flap Failure	5 (16)	2 (18)	−0.2–0.3	0.88
Partial Necrosis	0 (0)	1 (9)	−0.04–0.4	0.26
Amputation	1 (3)	1 (9)	−0.09–0.3	0.46