An Algorithmic Approach for Managing Orthopaedic Surgical Wounds of the Foot and Ankle

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Abstract

Background Wound breakdown after orthopaedic foot and ankle surgery may necessitate secondary soft tissue coverage. The foot and ankle region is challenging to reconstruct for orthopaedic and plastic surgeons owing to its complex bony anatomy and unique functional demands. Therefore, identifying strategies for plastic surgery of these wounds may help guide surgeons in defining the best treatment plan.

Questions/purposes We evaluated our current algorithmic approach for managing orthopaedic surgical wounds of the

foot and ankle with respect to whether (1) prophylactic or simultaneous soft tissue coverage affected wound-healing complications (secondary plastic surgery, orthopaedic hardware removal, malunion, further orthopaedic surgery, ultimate failure) and (2) postoperative referral for soft tissue management was associated with wound location, size, and orthopaedic procedure.

Methods We retrospectively reviewed 112 patients who underwent elective orthopaedic foot or ankle surgery and required concomitant plastic surgery at our institution. Study end points included secondary plastic surgery procedures, hardware removal for infection, foot or ankle malunion, further orthopaedic surgery, and wound-healing failure as defined by a chronic nonhealing wound or need for amputation. Minimum followup was 0.6 months (mean, 24.9 months; range, 0.6–197 months). Four patients were lost to complete followup. We developed an algorithm that centers on two critical points of care: preoperative evaluation by the orthopaedic surgeon and evaluation and treatment by the plastic surgeon after referral.

Results Compared with postoperative intervention, prophylactic or simultaneous soft tissue coverage did not lead to differences in frequency of secondary plastic surgery procedures ($p = 0.55$), hardware removal procedures ($p = 0.13$), malunions ($p = 0.47$), further orthopaedic surgery ($p = 0.48$), and ultimate failure ($p = 0.27$). Patients referred postoperatively for soft tissue management most frequently had dorsal ankle wounds ($p < 0.001$) of smaller size ($p = 0.03$), most commonly associated with total ankle arthroplasty ($p = 0.004$).

Conclusions Using our algorithmic approach, prophylactic or simultaneous soft tissue coverage did not improve the study end points. In addition, unexpected postoperative wound breakdown necessitating a plastic surgery consultation most commonly occurred on the dorsal ankle after

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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total ankle arthroplasty. Our algorithm facilitates early identification of skin instability and enables prompt soft tissue coverage before or concurrently with orthopaedic procedures. The effect of prophylactic or simultaneous soft tissue coverage on postoperative wound healing requires further investigation.

Level of Evidence Level IV, therapeutic study. See the Instructions for Authors for a complete description of levels of evidence.

Introduction

Reconstruction of the foot and ankle region is challenging owing to its complex anatomy and functional demands. For example, reconstruction of the highly specialized, thick glabrous skin on the plantar surface is difficult, as autologous tissue from other sites will not have the same tissue quality or functional capabilities. In contrast, the skin and soft tissue covering the dorsal foot and ankle are pliable, thin, and devoid of substantial subcutaneous adipose tissue. This allows for increased ROM but places the underlying tendon and bones at risk for exposure after injury or surgical intervention. Furthermore, soft tissue of the foot and ankle has limited mobility secondary to multiple zones of adherence [8, 9]. This is particularly true during times of edema and inflammation.

For this reason, wounds about the ankle are not easily managed with local tissue advancement or rearrangement and often require transfer from distant sites. We have described our experience with free tissue transfer for soft tissue coverage of the foot and ankle in 161 patients [17]. The majority of these patients (75%) required free tissue transfer to treat sequelae of trauma. In contrast to traumatic injuries, unexpected postoperative wounds of the foot and ankle typically have a decreased zone of injury and absolute skin loss. Therefore, they may be amenable to less extensive treatment modalities. During the past decade, new wound care technologies, advances in orthopaedic fixation systems, and early involvement of the plastic surgeon [19, 20] have provided increasing options for soft tissue reconstruction of the foot and ankle. In particular, early coverage of exposed bone, tendon, and neurovascular structures has proven to be critical to limb salvage after traumatic injury [6, 10, 12, 30].

We therefore evaluated our current algorithm for the involvement of plastic surgery consultation in the management of foot and ankle wounds with respect to (1) whether prophylactic or simultaneous soft tissue coverage led to lower rates of secondary plastic surgery procedures, removal of orthopaedic hardware attributable to infection, foot or ankle malunion, need for further orthopaedic surgery, and ultimate failure defined as either a chronic

nonhealing foot and ankle wound or the need for amputation, and (2) whether postoperative referral for soft tissue management was associated with wound location, size, and the specific type of orthopaedic procedure performed.

Patients and Methods

We retrospectively reviewed the medical records of 112 patients who underwent elective orthopaedic foot or ankle surgery and who also underwent concomitant soft tissue management by the plastic surgery service between January 1997 and March 2013 at our institution. The orthopaedic procedure was considered elective if it was performed on a nonemergent basis to repair defects that were not directly related to trauma.

Collected data included patient demographics, such as age, sex, associated medical comorbidities, original foot and ankle diagnosis, surgical procedures performed, and any associated wound characteristics. In addition, we evaluated the need for a secondary plastic surgery procedure, need for removal of orthopaedic hardware to eradicate infection, foot or ankle malunion, and whether patients had a chronic nonhealing wound or required an amputation. Foot and ankle wounds were further characterized as superficial or deep. Superficial wounds were confined to the skin and subcutaneous tissue only, whereas deep wounds involved exposed bone, tendon, or orthopaedic hardware. The plastic surgery intervention was categorized as prophylactic if performed before the planned orthopaedic surgery, simultaneous if performed concurrently with the orthopaedic surgery, and postoperative if performed after the orthopaedic surgery. Secondary plastic surgery procedures were defined as any plastic surgical procedure required after the original plastic surgery intervention.

The algorithm we used during the study period centered on two critical points of care: the evaluation by the orthopaedic surgeon before surgery (Fig. 1) and the evaluation and treatment given by the plastic surgeon after a referral for management of these patients (Fig. 2). During the preoperative orthopaedic evaluation, particular attention was paid to the lower-extremity neurovascular status and the quality of the overlying soft tissue. If an unfavorable soft tissue environment was identified, the patient would be referred to the plastic surgery service for soft tissue coverage before the procedure (prophylactic) or concurrently with the procedure (simultaneous). The choice of soft tissue coverage was guided by patient comorbidities and wound characteristics, including defect size, depth, and location. Planning of the surgical procedure was influenced by the patient's medical history and current medications; special attention was paid to diseases

Fig. 1 Our algorithm for initial evaluation by the orthopaedic surgeon before elective orthopaedic surgery is shown. Tx = treatment; Y = yes; N = no; 1°/2° closure = primary or secondary closure.

Fig. 2 Our algorithm for postoperative wound management by the plastic surgeon after a referral from the orthopaedic surgeon is shown. Y = yes; N = no; ABX = antibiotic treatment; STSG = split-thickness skin graft.

or habits that might affect the peripheral capillary circulation or increase the risk of infection. After elective orthopaedic surgery, patients who had postoperative wound complications develop also were referred to the plastic surgeon for local wound care or flap coverage. Wounds first were assessed for exposed vital structures and infection, and it was determined whether antibiotic treatment or hardware removal was necessary. Excessive edema also was encountered sometimes at this stage, and decisions

were made regarding timing of definitive closure. Frequently, a vacuum-assisted wound dressing was applied until the swelling improved. Actual treatment choices (local wound care or flap coverage) and timing of intervention were guided by these critical findings. A chronic, persistent wound occasionally required flap coverage after failed local wound treatment, and recalcitrant wounds that failed to heal after flap surgery sometimes necessitated a second flap for definitive coverage. In some situations, flap

Table 1. Common indications and elective procedures in patients undergoing orthopaedic foot and ankle surgery

Variable	Number of patients
Common indications for treatment	
Ankle arthritis	40 (36%)
Osteomyelitis	25 (22%)
Foot or toe deformity	14 (13)
Tendon rupture or tendinitis	11 (10%)
Common elective procedures	
Total ankle arthroplasty	25 (22%)
Ankle, subtalar, or pantalar arthrodesis	24 (21%)
Sequestrectomy, hardware removal, and/or antibiotic bead treatment	25 (22%)
Correction of foot or toe deformity	14 (13%)
Tendon repair and reconstruction	11 (10%)

Table 2. Foot and ankle wound characteristics

Characteristic	Value
Site (number of wounds)	
Foot	
Dorsal	17 (15%)
Plantar	4 (3%)
Ankle	
Dorsal	28 (24%)
Achilles	24 (21%)
Lateral	16 (14%)
Medial	27 (23%)
Defect (number of wounds)	
Superficial*	53 (46%)
Deep†	46 (40%)
Deep† with exposed hardware	17 (15%)
Size (cm ²) (n = 90)	
Mean	21.2
Range	0.1–120.0

* Superficial is defined as a defect confined to skin and subcutaneous tissue; †deep is defined as the exposure of bone or tendon.

failure ultimately required amputation if the wound persisted.

A total of 112 patients underwent soft tissue management for 116 foot or ankle wounds associated with elective orthopaedic surgery. The mean $\pm$ SD patient age at the time of the orthopaedic procedure was 50.3 ± 18.0 (range, 3–84 years). Sixty-three patients were male (56%), 41 used tobacco (37%), 37 had hypertension (33%), and 18 had diabetes (16%). The most common indications for orthopaedic surgical treatment were ankle arthritis and chronic osteomyelitis (Table 1). The most common orthopaedic procedures included total ankle arthroplasty, total or partial

Table 3. Wound management

Definitive intervention*	Value
Prophylactic intervention† (number of patients)	
Local flap	1 (1%)
Free flap	5 (4%)
Mean time to prophylactic intervention (months)	7.3
Simultaneous intervention‡	
Simple closure	2 (2%)
Local flap	1 (1%)
Free flap	11 (9%)
Mean time to simultaneous intervention (months)	0
Postorthopaedic surgery intervention	
Wound care	96 (83%)
Split-thickness skin graft	35 (30%)
Local flap	2 (2%)
Free flap	12 (10%)
Free flap	47 (41%)
Mean time to postorthopaedic intervention (months)	2.6

* Definitive is defined as the final intervention for wound closure; in the case of failure of the primary intervention, it is the last salvage attempt; †prophylactic is defined as the preventative intervention performed before orthopaedic surgery; ‡simultaneous is defined as the intervention performed concurrently with orthopaedic surgery.

ankle arthrodesis, and ablation of chronic infection. The minimum followup of this group was 0.6 months (mean, 24.9 months; range, 0.6–197 months).

Of the 116 soft tissue defects evaluated, 95 (82%) were located on the ankle and 21 (18%) were located on the foot. Soft tissue defects of the ankle were most commonly on the dorsal or medial surfaces or associated with the Achilles tendon posteriorly (Table 2). Fifty-three foot and ankle wounds were classified as superficial (46%), and 63 were deep with exposed bone or tendon (54%). Of the deep wounds, 17 (15%) were associated with exposed hardware. Defect size was measured and documented for 90 patients who received local wound care or surgical intervention, with a mean area of 21.2 ± 26.9 cm² (range, 0.1–120 cm²).

The timing and choice of soft tissue intervention varied and were based on defect size, wound characteristics, and underlying exposure (Table 3). Of the 116 final interventions, 96 (83%) were postoperative, 14 (12%) were simultaneous, and six (5%) were prophylactic. Free tissue transfer was performed as the definitive intervention in 63 cases (54%). Local wound care was the final treatment in 35 cases (30%), local and regional flaps in 14 (12%), and split-thickness skin grafts or simple closure in four (4%).

The plastic surgery service was consulted before the orthopaedic surgical procedure for 41 patients (37%). Of these 41 patients, six (15%) underwent prophylactic soft tissue coverage. Seventeen (41%) patients initially underwent simultaneous management of skeletal and soft tissue

Table 4. Postoperative outcomes

Outcome	All patients	Prophylactic or simultaneous intervention	Postoperative intervention	p value
Number of patients	112	23	89	
Number of surgical procedures required to close wound*		23	89	
Mean	1.8	1.7	1.8	
Range	0.0–9.0	1–5	0–9	
Wound-healing complications (number of patients)				
Secondary procedure	45 (40%)	8 (35%)	37 (42%)	0.55
Hardware removal for infection	16 (14%)	1 (4%)	15 (17%)	0.13
Malunion	9 (8%)	1 (4%)	8 (9%)	0.47
Further orthopaedic surgery	31 (28%)	5 (22%)	26 (29%)	0.48
Failure (chronic wound or amputation)	12 (11%)	1 (4%)	11 (12%)	0.27
Extremity amputation	9 (8%)	0 (0%)	9 (10%)	0.11

* Includes amputation procedure if ultimately performed.

defects. The simultaneous intervention was definitive in 14 (34%) patients; that is, a postoperative intervention was not required for final wound closure. Overall, 23 patients (21%) underwent prophylactic or simultaneous soft tissue coverage. The remaining 18 patients who were referred by the orthopaedic surgeon to the plastic surgery service did not receive preoperative plastic surgery treatment and proceeded directly to orthopaedic surgery.

Of the 81 surgical interventions, 40 (50%) required one or more secondary procedures. Most commonly, this was revision of a prior surgical flap. Of the 47 postoperative free flap interventions, 10 (21%) required emergent flap reexploration within 72 hours of the procedure. Final, stable wound closure was achieved after plastic surgery treatment in 104 cases (91%) at a mean time of 2.5 ± 3.3 months (range, 0–45 months) after the orthopaedic procedure. A mean of 1.8 ± 1.6 surgical procedures (range, 0–9) was required before achieving final wound closure (Table 4). Nine patients (8%) had foot or ankle malunions develop and 16 patients (14%) underwent hardware removal for infection eradication after the plastic surgery intervention. Complete free flap loss occurred in six patients (14%), all of whom subsequently required an amputation. The overall rate of failure (chronic wound or amputation) was 11% ($n = 12$). A total of nine patients (8%) underwent lower-extremity amputation at a mean of 32.7 ± 40.7 months (range, 0.4–121 months) after the final plastic surgery intervention.

Complete followup was performed for 108 (96%) patients, for whom all study end points were recorded (secondary plastic surgery, hardware removal for infection, foot or ankle malunion, further orthopaedic surgery, and ultimate failure). Four patients (4%) were lost to followup before all study end points were reached.

Descriptive statistics are reported as numbers and percentages of patients or as means, SDs, and data ranges. Continuous data were analyzed by two-tailed Student's *t*-tests, whereas categorical data were analyzed by chi-square analysis. Comparisons among wound sites were investigated with logistic regression models using generalized estimating equations to account for patient correlation. Statistical significance was assigned for *p* values less than 0.05. Statistical analyses were performed using SAS Version 9.3 (SAS Institute, Inc, Cary, NC, USA).

Results

In patients treated under our algorithm, prophylactic or simultaneous soft tissue coverage did not reduce the frequency of wound-healing complications. Compared with postoperative plastic surgery management, prophylactic or simultaneous soft tissue coverage did not lead to differences in the frequency of secondary plastic surgery procedures, necessity of orthopaedic hardware removal attributable to infection, incidence of foot or ankle malunion, need for further orthopaedic surgery, and ultimate failure as defined by either a chronic nonhealing wound or need for amputation. Secondary plastic surgery was performed in eight patients (35%) who underwent prophylactic or simultaneous soft tissue coverage and in 37 patients (42%) who did not ($p = 0.55$) (Table 4). Hardware removal for infection was performed in one patient (4%) who underwent prophylactic or simultaneous soft tissue coverage and in 15 patients (17%) who did not ($p = 0.13$). Foot or ankle malunion occurred in one patient (4%) who underwent prophylactic or simultaneous soft tissue coverage and in eight patients (9%) who did not ($p = 0.47$). Further orthopaedic surgery was required in five patients (22%) who

underwent prophylactic or simultaneous soft tissue coverage and in 26 patients (29%) who did not ($p = 0.48$). Ultimately, wound-healing failure occurred in one patient (4%) who underwent prophylactic or simultaneous soft tissue coverage and in 11 patients (12%) who did not ($p = 0.27$).

Patients who were referred postoperatively for soft tissue management most frequently presented with smaller dorsal ankle wounds precipitated by total ankle arthroplasty. Overall, dorsal ankle wounds accounted for 27 (36%) postoperative referrals for soft tissue management, compared with one (2%) dorsal ankle wound that was evaluated preoperatively by the plastic surgery service ($p < 0.001$). Patients who were referred postoperatively had a smaller mean wound size of $17.4 \pm 24.5 \text{ cm}^2$ (range, 0.1–119 cm^2), compared with patients who were referred preoperatively with a mean wound size of $32.1 \pm 31.0 \text{ cm}^2$ (range, 1.0–120 cm^2) ($p = 0.03$). Patients undergoing total ankle arthroplasty accounted for 22 (31%) of postoperative referrals for soft tissue management, compared with three (7%) preoperative plastic surgery consultations. Patients undergoing total ankle arthroplasty were more likely to be referred for plastic surgery management postoperatively rather than preoperatively ($p = 0.004$).

Discussion

During the past few decades, advancement of reconstructive techniques in plastic surgery and orthopaedic surgery has revolutionized the treatment of traumatic foot and ankle injuries [21, 23, 25] and enabled improved success in limb salvage [3, 15, 18, 22, 29]. Concerted efforts of the plastic surgeon and orthopaedic surgeon have improved treatment of complex foot and ankle wound problems that once may have been considered unsalvageable, particularly in the case of open fractures [7, 11, 13, 14]. The orthoplastic approach, which integrates the expertise and surgical techniques of the two specialties, also may permit improvements in the management of foot and ankle problems that are not related to trauma. We previously described our subunit approach for soft tissue coverage of foot and ankle wounds with free tissue transfer in 161 patients [17]. This approach allows the selection of flap tissue to be tailored to the functional demands of a specific anatomic region of the foot and ankle. The subunit principles hold true for trauma reconstruction and postoperative wound management. In the current study, we evaluated our current algorithmic approach for managing orthopaedic surgical wounds of the foot and ankle, specifically with respect to whether prophylactic or simultaneous soft tissue coverage affected wound-healing complications, as measured by the frequency of secondary plastic surgery procedures, necessity of orthopaedic

hardware removal attributable to infection, incidence of foot or ankle malunion, need for further orthopaedic surgery, and ultimate failure as defined by either a chronic nonhealing wound or need for amputation. We further examined whether postoperative referral for soft tissue management was associated with wound location, size, and the specific orthopaedic procedure performed.

The limitations of our study must be acknowledged. First, this is a retrospective review of a nonrandomized patient population with no patient-reported outcomes, and inherent selection bias may exist in the study design. Patients were selected carefully for wounds amenable to plastic surgery treatment. That is, patients with simple wound needs or clearly unsalvageable soft tissue defects were likely managed by the referring orthopaedic service. In addition, our study focuses on soft tissue considerations in the plastic surgery management of wounds. There may be important skeletal considerations from the orthopaedic standpoint that contribute to primary wound development or that prolong recalcitrant wounds from healing. Strategies for the orthopaedic management of deformities, joint instability, and malalignment were not the focus of this study. The patient sample size also was insufficient for adequately powered comparisons with respect to the timing of referral and treatment, and followup was relatively short for some patients who underwent plastic surgery in 2013. Finally, as foot and ankle clinicians at our institution have gained a better understanding of critical soft tissue considerations, patient referral patterns may have evolved during the study period. Although our management strategy was not compared with other potential approaches, our current algorithm may serve as a guideline for orthopaedic and plastic surgeons who treat patients with foot and ankle injuries.

Our study did not conclusively show that prophylactic or simultaneous soft tissue management influenced wound-healing outcomes. Further studies of a larger patient population are needed to rigorously assess whether earlier plastic surgery involvement affects postoperative wound-healing outcomes. Clearly, it is critical for the orthopaedic surgeon to recognize an at-risk soft tissue environment before bony manipulation and placement of hardware. Our algorithm highlights that the early identification of potential problems can enable expeditious management by the plastic surgeon before or concurrently with the orthopaedic procedure. This early (prophylactic) mode of intervention may provide patients with more stable soft tissue coverage before their planned orthopaedic procedure, although larger studies will be needed to show this more conclusively. As reported by Baumeister et al. [3], Marco Godina, a pioneer in modern orthoplastic surgery, introduced the approach of immediate soft tissue coverage after complete resection of all

Fig. 3A–D A 67-year-old man underwent arthrodesis of the first toe for hallux varus deformity. (A) He presented 11 weeks postoperatively with deep wounds with exposed hardware. (B) An intraoperative view shows the foot after inset of a radial forearm

free flap. (C) Postoperative followup at 4 months shows good soft tissue coverage and healing. (D) The healed donor site at 4 months after treatment is shown.

nonviable tissue, similar to the method used in ablative tumor surgery. The concept of a one-stage procedure in which maximal skeletal and soft tissue reconstruction is performed in one operation is critical for optimizing functional outcome, regardless of the cause of threat to the limb [24, 26]. Unfortunately, not all postoperative wounds can be anticipated. Unexpected wound complications can be slow to heal and devastating for the patient and the orthopaedic surgeon. Swift referral to a plastic surgeon is necessary in these cases to prevent devitalized superficial tissue from becoming infected and generating a deep infection that involves tendon, bone, or hardware.

The most common type of unexpected postoperative wound in our patients was relatively small and occurred on the dorsal ankle after total ankle arthroplasty. In this instance, determination of wound depth is critical in guiding the choice of soft tissue coverage. For wounds that extend to the tendons or joint hardware, flap reconstruction almost always is required for adequate closure (Fig. 3) [15, 20, 22]. The use of free tissue transfer remains at the highest level on the reconstructive ladder and may be performed in combination with skin grafting or local tissue arrangement [16, 20]. Although it is the most complex, free tissue transfer may not be necessary in all circumstances. Our algorithm and prior publications indicate that it is often the most suitable first option in accordance with our subunit approach and established

orthoplastic principles [17, 19]. However, for superficial wounds that do not extend to the level of tendon or joint, use of a xenograft matrix may be an effective alternative with less morbidity (Fig. 4). This treatment is well tolerated by most patients and allows for relatively early return to motion [1, 4, 27]. Additionally, we advocate prophylactic flap reconstruction as one method to potentially avoid anticipated postoperative total ankle arthroplasty dorsal ankle wound complications when the dorsal ankle skin is perceived as unfavorable before elective surgery. In our experience, patients with unfavorable skin typically have had previous delayed wound healing or have extensive prior surgical scars on the dorsal ankle. The presence of avascular scar tissue in the skin and subcutis presents a challenge for adequate wound closure and stability. The use of prophylactic flaps in foot and ankle reconstruction is of ongoing interest and, to our knowledge, has not been reported to date. We continue to offer prophylactic flaps to patients with high skin risk who are otherwise suitable candidates for total ankle arthroplasty.

The treatment of complex foot and ankle wounds has seen tremendous progress during the past decade. Some of these advancements have been spurred by innovative technology, such as the use of vacuum-assisted closure therapy [2, 5, 28] and xenograft wound matrix, but others have been born by a better appreciation of the highly

Fig. 4A–D A 61-year-old woman with ankle arthritis underwent total ankle arthroplasty. (A) She presented 6 weeks postoperatively with a superficial wound over the dorsal ankle. (B) She was treated with débridement and application of a porcine wound matrix. The wound is shown at (C) 2 and (D) 6 weeks after treatment.

specialized tissues and demands of the foot and ankle region. Often, patients with challenging foot and ankle wounds have inextricably linked bony and soft tissue defects. Clear guidelines for the coordinated management of such complex problems are critical to the ultimate goal, a functional and pain-free limb.

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