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Stepwise surgical approach to diabetic partial foot amputations with autogenous split thickness skin grafting

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In the surgical treatment of severe diabetic foot infections, substantial soft tissue loss often accompanies partial foot amputations. These sizeable soft tissue defects require extensive care with the goal of expedited closure to inhibit further infection and to provide resilient surfaces capable of withstanding long-term ambulation. Definitive wound closure management in the diabetic population is dependent on multiple factors and can have a major impact on the risk of future diabetic foot complications. In this article, the authors provide an overview of autogenous skin grafting, including anatomical considerations, clinical conditions, surgical approach, and adjunctive treatments, for diabetic partial foot amputations.

Keywords: *diabetic foot infections*; *amputations*; *osteomyelitis*; *wounds*; *skin grafting*

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Diabetic foot infections and/or subsequent partial foot amputations can result in a large soft tissue loss that can become quite challenging for the reconstructive surgeon to heal. Major diabetic foot infections may require several surgical debridements in the presence of deep abscess, gangrene, peripheral vascular disease, osteomyelitis, and/or septic arthritis. Staged reconstructive procedures are also necessary when the infection is extending proximally and is involving multiple compartments of the foot and lower extremity.

Numerous plastic reconstructive procedures have been described for closure of the diabetic foot ranging from negative pressure wound therapy (NPWT) and local random flaps to pedicle and free flaps. The ultimate selection of the most suitable skin graft or flap for the diabetic patient may be dependent on the patient's medical comorbidities, vascular status, presence of infection, anatomical location of the wound, and donor site availability. After significant soft tissue loss has occurred in the diabetic foot, restoration of healthy intact skin is necessary to maintain function, to prevent infection, and to avoid future breakdown. Despite the development of numerous skin graft substitutes, autogenous skin grafting has reliably been performed for centuries and still represents one of the most useful and effective techniques for wound closure in the diabetic foot.

Stepwise surgical approach for the infected diabetic foot with or without osteomyelitis

Diabetic foot infections may present with clinical and systemic signs of sepsis that may necessitate urgent and/or emergent surgical intervention. In these clinical case scenarios, the diabetic patient may proceed to surgery for the initial staged procedure that includes but is not limited to incision and drainage and/or partial foot amputation. It is imperative to note that aggressive medical management of the patient's uncontrolled blood sugars and medical comorbidities are necessary for medical optimization and during the patient's staged reconstructive procedures. Initial intraoperative soft tissue and bone cultures as well as bone biopsies are performed to assist in the selection of antibiotic therapy.

The concept of a multidisciplinary team approach for the hospitalized diabetic patient with a foot infection is

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initiated with further medical consultations as applicable and according to the patient's comorbidities. Such medical team members may include and are not limited to medicine, cardiology, nephrology, vascular surgery, orthopedic surgery, wound care, nutrition, and physical therapy. Staged reconstructive procedures may proceed with further surgical debridement, amputation, and adjunctive modalities when necessary. If wide surgical debridement leaves a large defect, antibiotic impregnated cement beads or spacers can be placed to accomplish both local delivery of antibiosis and structural stabilization of the surrounding tissues and bone. These antibiotic beads and/or spacers can be left in place for the same duration as parenteral antibiotics and subsequently removed surgically prior to wound closure (Fig. 1).

NPWT has been shown to facilitate decreases in bacterial loads, control drainage, decrease edema, and can be used for irregular wound surfaces often found in the diabetic foot. NPWT is beneficial during the initial reconstructive staged procedures as it can promote adequate granulation and prepare the recipient diabetic foot wound site for a split thickness skin graft (STSG) when indicated. Postoperative care and monitoring of the patient's wound with NPWT is paramount in the overall successful outcome (Fig. 2).

When the patient is medically optimized and ready for the final reconstructive procedure and soft closure of the diabetic foot, the lower extremities should be evaluated for peripheral vascular disease through non-invasive vascular testing (ankle brachial index, toe brachial index, Doppler waveforms, and segmental pressures) and consultation by a vascular surgeon if needed. If the patient has a prior history of lower extremity revascularization, appropriate routine surveillance with the vascular surgeon is also recommended to facilitate proper wound healing. Barshes et al. found skin grafting to be a useful option for early primary closure of diabetic foot wounds after lower extremity arterial bypass procedures (1). Smoking has also been shown to adversely affect wound healing through decreased tissue oxygenation and a subsequent decrease in collagen synthesis (2). Efforts for smoking cessation should be made in those diabetic patients with both acute and chronic foot wounds, especially when considering surgical wound closure.

The recipient wound must be free of infection and exudates must be minimal. Experimental studies suggest that a bacterial load of between 10^5 and 10^6 organisms per gram in a wound bed will negatively affect wound and skin graft healing (3). However, more virulent organisms, such as *Pseudomonas aeruginosa* and *Staphylococcus aureus*, may cause adverse effects in lower numbers (4). Necrotic tissue at the wound base should be debrided since this can contain bacteria and lead to further wound infection. Resolution of clinical infection in the diabetic foot wound is required prior to STSG application and can be achieved by means of surgical debridement and systemic antibiotics. In the case of diabetic foot soft tissue infections, such as extensive abscess, surgical decompression with wide incision and drainage may create large surgical wounds. These should be treated with culture-specific systemic antibiotics and proper local wound care postoperatively to decrease edema, control wound exudates, and prevent deeper infection. Repeated soft tissue and bone cultures as well bone biopsies and resected surgical margins for histopathological analysis are also recommended at the time of each surgical intervention and to further target the isolated organisms. For cases of osteomyelitis, open partial foot amputation such as

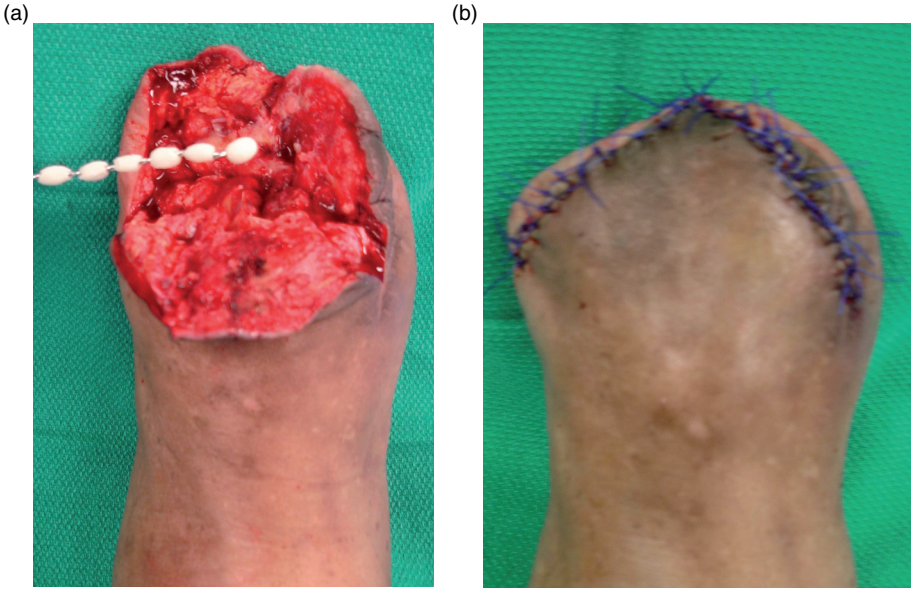

Fig. 1. An example of a midfoot amputation with insertion of non-biodegradable cemented antibiotic beads (a) and subsequent closure (b).

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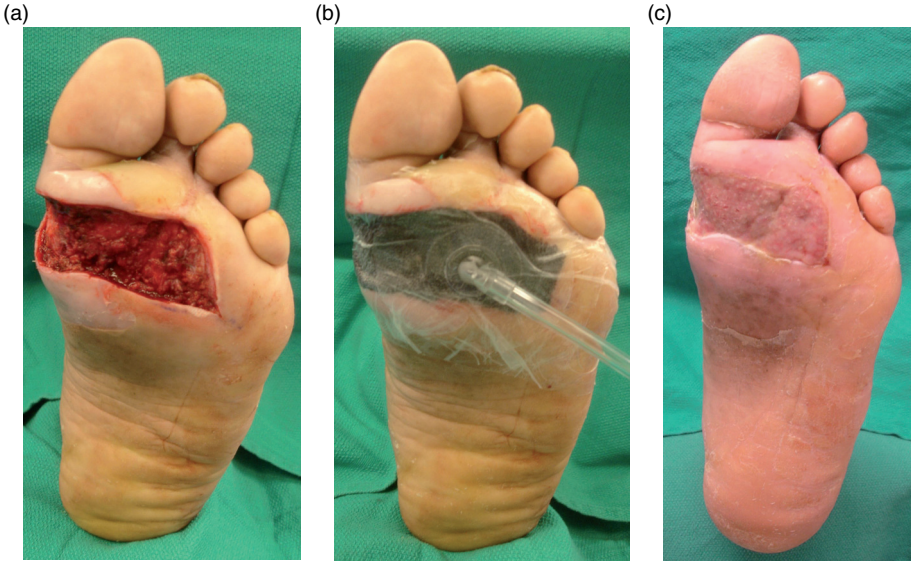

Fig. 2. Intraoperative clinical picture (a) 4 days after the initial surgical incision and drainage procedure followed by a revisional excisional debridement and application of a negative pressure wound therapy (NPWT) (b). The patient was followed by an outpatient wound care specialty clinic and local wound care with a clinical outcome 3 weeks after the NPWT (c).

partial ray (toe and metatarsal) and transmetatarsal amputations may be performed in order to remove all infected soft tissue and bone. These procedures can leave extensive wounds of varying depths that can be addressed with NPWT to facilitate granulation tissue prior to definitive wound closure with STSG. A previous study at our institution found that amputation history of the grafted limb at any level, whether toe, metatarsal, transmetatarsal, or midtarsal (Chopart's) amputation, conferred no increased risk of STSG complications (5).

Anatomy and pathophysiology of the autogenous skin graft

Autogenous skin grafts are typically divided into full thickness and split thickness; however, among these two types, STSG is used more often for diabetic foot wounds. STSG comprises epidermis and varying amounts of dermis, and it can be further subdivided into thin (0.008–0.012 in.), intermediate (0.012–0.018 in.), and thick (0.018–0.030 in.). Intermediate STSG is ideal for diabetic foot wounds and provides a good quality of repair with the resultant skin sufficiently elastic and less prone to retraction. STSG may be used for primary closure of diabetic foot wounds or when secondary intention is contraindicated. In addition, STSG is useful as coverage for wounds that have closed partially in response to other therapies, or to promote healing of donor sites created by other plastic surgery techniques. In larger wounds, STSG offers more stable coverage than the scar that results from secondary closure and also provides more rapid closure compared with standard local wound care dressings (6). Autogenous STSG is successful when placed on recipient tissues that are capable of producing granulation tissue, specifically subcutaneous tissue, muscle, and periosteum. STSG should not be used to cover delicate structures such as nerves, vessels, and tendons. Phases of healing for skin grafts comprise an initial plasmatic imbibition phase during the first 24–48 hours, a revascularization phase of 5–7 days, and a maturation phase including adjustment and retraction followed by distention (7).

Operative technique

For diabetic foot wounds, wound bed preparation is extremely important and typically consists of sharp debridement of the foot wound to healthy bleeding tissue. Conventional sharp debridement is accomplished with scalpels and other sharp instrumentation followed by wound irrigation via pulsatile lavage with sterile normal saline. Hydrosurgical debridement is a more recent method using high-pressure sterile normal saline pumped through hand-held cutting and aspirating tools to perform precise cutting of tissues while also removing debris. Common STSG donor sites include the ipsilateral or contralateral thigh or leg (Fig. 3). The donor site can be prepared via local subcutaneous infiltration of 1% lidocaine with epinephrine and the skin prepped topically with mineral oil. A power dermatome, preset for the appropriate width and thickness, is utilized to obtain the graft, with additional graft(s) taken if needed based on the size of the recipient site. The donor site can be dressed with nonadherent gauze and topical antibiotic ointment or povidone–iodine solution. This donor site usually heals quickly since some dermal components still remain. The harvested STSG is meshed in a 1:1.5 ratio using a commercially available mesher and then secured to the recipient site by skin staples under minimal tension.

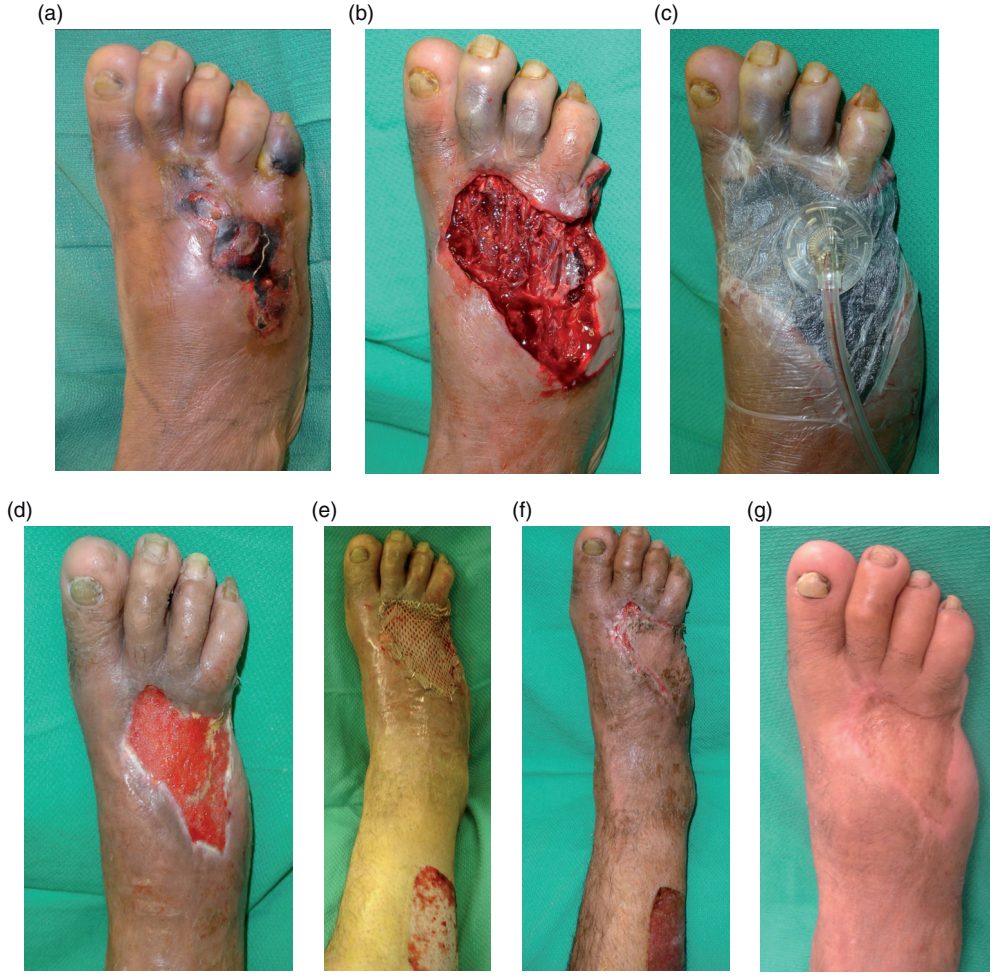

Fig. 3. Initial clinical presentation of a diabetic patient with a severe right foot infection and gangrenous fifth toe (a). Patient underwent a fifth toe amputation at the metatarsophalangeal joint with an incision and drainage and returned to the operating room 2 days after the initial surgery for a partial resection of the fifth metatarsal, revisional incision, and drainage (b) and application of a negative pressure wound therapy (NPWT) (c). The patient was followed closely in an outpatient wound care specialty clinic for approximately 3.5 months (d) with NPWT dressing changes and local wound care before the final reconstructive procedure. Patient was returned to the operating room for an autogenous split thickness skin graft (STSG) from the ipsilateral lower extremity to the right foot (e). The bolster dressing, which consisted of a non-adherent petrolatum gauze with sterile plain sponges moistened in saline, was removed approximately 3 weeks postoperatively (f). Final clinical presentation at 3 months since the STSG application (g).

It is important to make sure there is complete contact between the graft and recipient site so that incorporation can take place. Many components are useful for an effective STSG dressing: compression to prevent hematoma/seroma, control of shear forces to prevent graft movement, maintenance of moisture to promote graft viability, and general protection from the external environment (8). Several studies in diabetic foot wounds have demonstrated the successful use of a bolster dressing consisting of non-adherent petrolatum gauze with sterile plain sponges moistened in saline to firmly secure the graft in place (5, 9–11) or by NPWT securing the STSG continuously for approximately 5 days. In cases of isolated STSG for diabetic foot wounds, the affected lower extremity can also be immobilized in a posterior splint to prevent motion during the healing phase. If STSG is combined with other corrective reconstructive procedures, such as osteotomies or arthrodesis, immobilization of the lower extremity can be accomplished through splinting, casting, or circular external fixation (12).

Discussion

A retrospective study of 203 patients at our institution revealed that diabetic patients with preexisting comorbidities experienced a significantly increased risk of delayed healing time and postoperative infection and a higher need for revisional surgery compared with non-diabetic patients or diabetic patients without comorbidities (9). Since the harvested STSG is completely separated from its original blood supply, the recipient site must have adequate vascularization.

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Biofilms, which are often present in chronic diabetic foot wounds, can be significant barriers to wound and graft healing. These surface-associated bacterial populations do not constitute active infection, yet parenteral antibiotics are often ineffective in penetrating and eradicating them. Aggressive sharp debridement performed during wound bed preparation can disrupt biofilms and remove surface necrotic tissue that may harbor potentially harmful bacteria. Wolcott et al. demonstrated sharp debridement of chronic wounds provides a window of opportunity before 72 hours in which the bacteria are more susceptible to antimicrobials (13). This therapeutic window may also allow for use of STSG quickly after sharp debridement in combination with antibiotics to produce better wound healing.

Localized edema should be addressed prior to STSG application through mechanical measures such as compressive dressings and limb elevation; in addition, systemic causes for peripheral edema should be addressed, if applicable. Appropriate hemostasis at the recipient wound bed is imperative since bleeding can lead to hematoma formation beneath the graft and may inhibit neoformed capillaries and therefore halt graft incorporation. Bleeding can be a concern in anticoagulated patients, which includes many diabetic patients; however, a systematic review by Jarjis et al. revealed that skin graft failure is rare and that continuation of any medically necessary antithrombotic therapy is recommended in this population (14). Hemostasis can be achieved during wound bed preparation through meticulous tissue handling and strategic use of electrocautery. In addition, topical thrombin can be a useful hemostatic agent especially for large diabetic foot wounds that quickly reduces bleeding intraoperatively and can also be applied to the donor site, without producing adverse effects on wound or graft healing (15).

For cases that may have compromised oxygen delivery to tissues, hyperbaric oxygen (HBO) has been shown to increase the levels of free oxygen from capillaries which can positively impact healing through collagen synthesis and cross-linking, fibroblast proliferation, and angiogenesis (16). HBO is not necessary for normally healing autogenous STSG; however, this modality is clinically indicated for graft salvage. In a large retrospective study analyzing the effects of HBO for several clinical indications, Skeik et al. demonstrated positive outcomes with the use of HBO in 75.7% of 33 subjects treated for failed flaps or skin grafts (17). The use of HBO to maximize the viability of skin grafts has been shown to decrease the need for re-grafting and/or revisional surgery. Despite several case reports, case series, and animal studies supporting the use of HBO for skin grafts, higher level evidence through multicenter prospective clinical studies are needed in order to demonstrate its effectiveness compared to other modalities (18).

NPWT has also been well described in the literature for securing STSG during the immediate postoperative period as opposed to traditional bolster dressings. In a retrospective study by Ross et al. on complex lower extremity wounds treated with NPWT to secure STSG, 39% (23 subjects) included diabetic postdebridement/amputation wounds which had a mean graft survival of 93% after the NPWT device was removed (19). Their study suggests the success of NPWT in STSG healing is related to macrodeformation, removal of periwound fluid, and maintenance of a moist wound environment.

A review conducted by Achora et al. revealed that the existing evidence on STSG suggests that topical phenytoin and platelet-rich plasma may be used prior to graft application to improve healing rates, and NPWT and fibrin sealant may be used to promote graft adherence (20). The literature surrounding these modalities includes only small numbers of diabetic patients; therefore, further studies are needed to validate the true effects of these modalities on diabetic foot wounds.

Conclusion

STSG is a reliable option for wound closure and will always have a place in the world of soft tissue reconstruction for the diabetic foot. Based on the existing literature, it is clear that there are many factors which impact healing in these patients. A patient-centered approach in surgical management of diabetic foot wounds is essential since each case is unique in which all variables of the patient's health status should be taken into account to produce the best outcomes for STSG healing.

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References

1. Barshes NR, Bechara CF, Pisimisis G, Kougias P. Preliminary experiences with early primary closure of foot wounds after lower extremity revascularization. Ann Vasc Surg 2014; 28: 48–52.
2. Manchio JV, Litchfield CR, Sati S, Bryan DJ, Weinzweig J, Vernadakis AJ. Duration of smoking cessation and its impact on skin flap survival. Plast Reconstr Surg 2009; 124: 1105–17.
3. Dow G, Browne A, Sibbald RG. Infection in chronic wounds: controversies in diagnosis and treatment. Ostomy Wound Manage 1999; 45: 23–7, 29–40.
4. Aerden D, Bosmans I, Vanmierlo B, Spinnael J, Keymeule B, Van den Brande P. Skin grafting the contaminated wound bed: reassessing the role of the preoperative swab. J Wound Care 2013; 22: 85–9.
5. Ramanujam CL, Stapleton JJ, Kilpadi KL, Rodriguez RH, Jeffries LC, Zgonis T. Split-thickness skin grafts for closure of diabetic foot and ankle wounds: a retrospective review of 83 patients. Foot Ankle Spec 2010; 3: 231–40.

6. Mahmoud SM, Mohamed AA, Mahdi SE, Ahmed ME. Split-skin graft in the management of diabetic foot ulcers. J Wound Care 2008; 17: 303–6.
7. Andreassi A, Bilenchi R, Biagioli M, D'Aniello C. Classification and pathophysiology of skin grafts. Clin Dermatol 2005; 23: 332–7.
8. Wells MD, Kirn DS. A new method of skin-graft stabilization: the Reston technique. Ann Plast Surg 1995; 34: 554–6.
9. Ramanujam CL, Han D, Fowler S, Kilpadi K, Zgonis T. Impact of diabetes and comorbidities on split-thickness skin grafts for foot wounds. J Am Podiatr Med Assoc 2013; 103: 223–32.
10. Roukis TS, Zgonis T. Skin grafting techniques for soft-tissue coverage of diabetic foot and ankle wounds. J Wound Care 2005; 14: 173–6.
11. Zgonis T, Stapleton JJ, Rodriguez RH, Girard-Powell VA, Cromack DT. Plastic surgery reconstruction of the diabetic foot. AORN J 2008; 87: 951–66.
12. Ramanujam CL, Facaros Z, Zgonis T. External fixation for surgical off-loading of diabetic soft tissue reconstruction. Clin Podiatr Med Surg 2011; 28: 211–6.
13. Wolcott RD, Rumbaugh KP, James G, Schultz G, Phillips P, Yang Q, et al. Biofilm maturity studies indicate sharp debridement opens a time-dependent therapeutic window. J Wound Care 2010; 19: 320–8.
14. Jarjis RD, Jørgensen L, Finnerup K, Birk-Sørensen L. Complications in skin grafts when continuing antithrombotic therapy prior to cutaneous surgery requiring skin grafting: a systematic review. J Plast Surg Hand Surg 2014; 7: 1–6.
15. Ofodile FA, Sadana MK. The role of topical thrombin in skin grafting. J Natl Med Assoc 1991; 83: 416–18.
16. Phillips JC. Understanding hyperbaric oxygen therapy and its use in the treatment of compromised skin grafts and flaps. Plast Surg Nurs 2005; 25: 72–80.
17. Skeik N, Porten BR, Isaacson E, Seong J, Klosterman DL, Garberich RF, et al. Hyperbaric oxygen treatment outcome for different indications from a single center. Ann Vasc Surg 2015; 29: 206–14.
18. Friedman HI, Fitzmaurice M, Lefaivre JF, Vecchiolla T, Clarke D. An evidence-based appraisal of the use of hyperbaric oxygen on flaps and grafts. Plast Reconstr Surg 2006; 117: 175S–92S.
19. Ross RE, Aflaki P, Gendics C, Lantis Ii JC. Complex lower extremity wounds treated with skin grafts and NPWT: a retrospective review. J Wound Care 2011; 20: 490, 492–5.
20. Achora S, Muliira JK, Thanka AN. Strategies to promote healing of split thickness skin grafts: an integrative review. J Wound Ostomy Continence Nurs 2014; 41: 335–9.

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