Full Thickness Skin Autograft from an Amputated Digit for Treatment of Chronic Diabetic Foot and Ankle Ulcerations

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Level of Evidence: Level 3

Introduction

The prevalence of diabetes continues to grow in the general population most due to increasing obesity and sedentary lifestyle habits; this has led to an increase in complicated diabetic foot ulcerations (DFU)[1,2]. An estimated 25% of individuals with diabetes will experience a foot ulceration at some point[3]. A DFU can be challenging to treat due to complicating factors including poor glycemic control, peripheral neuropathy, smoking, increased glycosylation of soft tissue, pressure, wound bioburden, peripheral vascular disease and an impaired immune response[4–7]. Foot and leg ulcerations are among the leading causes of hospitalization[2]. Additionally, one in five infected diabetic ulcers leads to amputation[22]. The difficulties in healing DFUs are apparent.

Several split thickness skin grafts (STSGs) and cellular and tissue products (CTPs) have been found to improve healing rates of DFUs when standard wound care regimens have failed[2,3,8–15]. Previous studies examining the healing rates with STSGs[2,3,15] and human skin allograft[14] have shown variable success . The use of STSGs and human skin allograft have inherent limitations and shortcomings.

The literature is limited in regards to full thickness skin grafts (FTSGs) and their therapeutic effect on stagnant non-healing DFUs. Additionally, there are variations in harvesting techniques and donor sites reported in the literature[16–20]. A case study by Lalehparvar et al[16] reviewed the use of a pinch graft harvested from the sinus tarsi for coverage of a surgical wound following excision of cutaneous horns in the foot; this case did not involve a DFU. Other studies have reviewed a technique of pinch grafting whereby several small full thickness sections of skin were harvested and placed into a wound bed[17,18,20,21]. Ramanujam et al reported on a case report involving the use of several full thickness pinch grafts harvested from the plantar forefoot to cover a plantar medial arch DFU[19]. Simman and colleagues report on nine patients that had undergone pinch grafting harvested from the medial arch; four of the nine patients had a DFU[20]. Pinch grafting by this technique was proven to be a viable option for treatment of several venous and diabetic leg ulcerations. The use of FTSGs is not a new concept and have been found to be effective in the treatment of wounds of several etiologies.

The purpose of this poster is to propose a novel technique; utilizing the healthy skin of an amputated toe as a FTSG for a chronic DFU. The primary goal of this pilot study is to evaluate time to healing of DFUs with the use of a full thickness autograft from an amputated toe and to compare these findings to STSGs and human skin allograft.

Patients and Methods

Eleven patients with chronic non-healing DFUs that had undergone full thickness pinch skin grafting harvested at the time of definitive toe amputation using our novel technique over a period of 5 years from 2014 to 2018 were included in this retrospective review. An inclusive table of patient demographics is included (see table 1). All procedures were performed by two authors (R.G., P.N.). Information was obtained from operative reports, clinic notes and clinic photography. All patients underwent digital amputation. The glabrous skin present to the distal tuft of the amputated toe was harvested in all cases. A full-thickness pinch graft from the amputated toe was applied to an unrelated ulceration to achieve coverage.

Surgical Technique

All FTSG applications were performed in an operative setting. All patients underwent general anesthesia. Debridement was performed to all recipient wound beds whereby all nonviable tissue was excised and the wound bed prepared using a scalpel or curette until only healthy, granular bleeding tissue remained. Hemostasis was accomplished with direct pressure (see figure 1).

Digital amputation was performed using a racquet type or modified fish mouth incision (see figure 2). Care was taken in an effort to achieve closure under little tension while preserving healthy skin for later use as a full thickness pinch graft. Other types of amputation were completed in similar fashion.

The healthy skin from the distal tuft of the amputated toe was fashioned in an effort to maintain full thickness (see figure 3). The subcutaneous fat was removed and the skin from the pinch graft (see figure 4). The remainder of the amputated toe was sent to pathology or discarded. The pinch graft was prepared by a pie crusting technique using a scalpel or by a mesher to increase the surface area of the graft and to prevent a collection of drainage (see figure 5). The autograft was then placed into the wound bed and sutured in place (see figure 6). The recipient site was covered with a living cellular tissue product, a non-adherent gauze followed by a bolster dressing of 4 x 4's and Webril. The patient was placed in a posterior splint or a protective boot and instructed to remain partial to non-weight bearing. Patients were followed up on a weekly basis after surgery until closure was achieved.

Statistical Analysis

All statistics were calculated using Microsoft Excel 2010 (Microsoft Corporation, Redmond, WA). Descriptive statistics were calculated for all demographic factors and treatment outcomes. These findings were then compared to those reported in the literature for STSGs and human skin allograft.

Results

Eleven consecutive patients (7 male, 4 female) with a mean age of 61 years (range, 41-78 years) were included in this study that had undergone grafting where 11 full thickness pinch grafts were harvested on 4 left and 7 right feet. The average BMI was 31.2 kg/m^2. All patients had DFUs present to the plantar aspect of the foot. One recipient wound bed had exposed bone. Three patients had a diagnosis of osteomyelitis and one patient had a diagnosis of cellulitis of the operative limb at the time of surgery. Eight patients had a previous amputation. Levels of amputation ranged anatomically from digital at the metatarsophalangeal joint (MTP) to a transmetatarsal amputation (TMA). Three patients had negative pressure wound therapy utilized as an adjunct at the time of surgery and/or in the post-operative setting. Seven patients had live cell amnion placed with the graft at the time of surgery. Comorbidities include diabetes and peripheral neuropathy in 11 patients, smoking in 2 patients, peripheral vascular disease in 9 patients, end stage renal disease in 1 patient and Charcot neuroarthropathy in 2 patients. Patient demographics are reported in Table 1.

Time to healing of the grafted wounds was 8.44 weeks. One patient was lost to follow up at 8 weeks following application of the FTSG. Of the 10 remaining patients, nine patients healed by final follow-up. Rates to healing are reported in Table 2. These findings were compared to those reported in the literature for STSGs and human skin allograft. Post operative complications include infection in 2 patients; only 1 patient with a post operative infection healed. One patient was weight bearing on the operative limb. All graft donor/amputation sites healed without complication.

Table 1.

Demographics	No. of Cases (%)
Patients (N)	11 (100%)
Age	61 (range, 41-78)
Gender	
Male	7 (64%)
Female	4 (36%)
BMI[a]	31 (range, 18-46)
Laterality	
Total (N)	11 (100%)
Right	7 (64%)
Left	4 (36%)
Previous Surgery	
Amputation	8 (73%)
Comorbidities	
Diabetes	11 (100%)
Peripheral neuropathy	11 (100%)
Peripheral Vascular Disease	9 (82%)
Smoking	3 (27%)
End Stage Renal Disease	1 (9%)
Charcot Neuroarthropathy	2 (18%)
Infection Present at Time of Surgery	
Cellulitis	1 (9%)
Osteomyelitis	3 (27%)
Surgeon	
R.G.	9 (82%)
P.N.	2 (18%)

[a]Body mass index

Table 2.

Comparison to Other Studies

Author	McCabe et al	Anerson et al[2]	Ramanujam et al[3]	Marston et al[10]	Edmonds et al[15]	Landsman et al[30]
Graft Type	FTSG [a]	FTSG [a]	STSG [b]	CTP [c]	CTP [c]	STSG[b]
Graft Material	Autograft	Autograft	Autograft	Allograft	Allograft	Allograft
Cases (N)	11	107	90	130	33	54
No. (%) of Wounds Healed	9 (82%)	79(74%)	NR[d]	39 (30%)	17 (51%)	40 (74%)
Reported Time to Healing (Weeks)	8.4	4.8	6.8	12*	12*	20*

[a] Full thickness skin graft; [b] Split thickness skin graft; [c] Cellular and tissue product; [d] Not Reported; * Percentage of wounds healed at determined post graft times- no average time to healing reported.

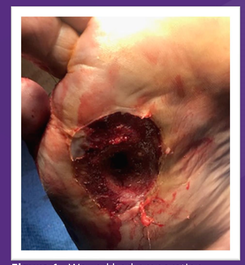

Figure 1 - Wound bed preparation. All nonviable tissue is sharply debrided.

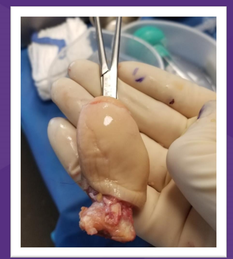

Figure 2 - Amputated Toe; the toe is then placed in saline.

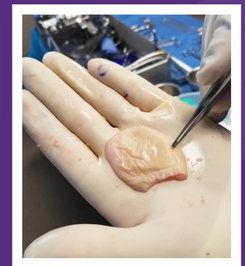

Figure 3 - Skin dissected in full-thickness from the toe leaving the fatty tissue.

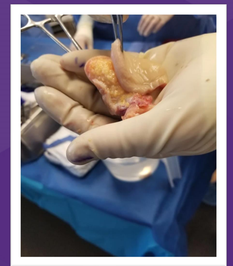

Figure 4 - Full thickness graft harvested.

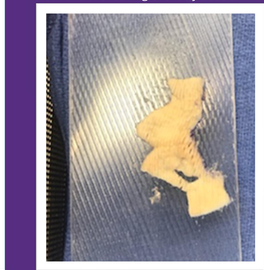

Figure 5 - The graft is then meshed to perforate it to allow drainage.

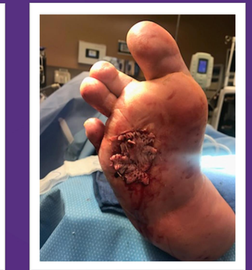

Figure 6 - The autograft is then sutured into the wound bed.

Discussion

The purpose of the present study is to evaluate the healing rate of DFUs with full thickness pinch grafts. The authors also compare these findings to those reported in the literature for STSGs and CTPs (see table 2). To our knowledge, there is no study that evaluates the healing rate of DFUs when full thickness autograft harvested from an amputated toe is used as treatment. This pilot study provides a baseline for other studies to explore this novel technique and to evaluate treatment outcomes.

Rarely does one encounter a patient with DFU's and no comorbidities. There are conflicting opinions regarding limitations in time to healing after grafting DFU's in the face of existing comorbidities. In a retrospective review by Anderson et al. they examined the effectiveness of a STSG on 107 diabetic patients with foot or leg ulcerations, no grafts were placed on a weight bearing surface. All patients underwent some form of local wound care therapy with or without negative pressure therapy in an attempt to optimize and granulate the bed of the ulcerations in preparation for grafting. The healing time ranged from three to sixteen weeks with an average healing time of 5.1 weeks; 90% were healed by six weeks. They found that no comorbidities, such as smoking, diabetes, ESRD, etc. had an effect on healing time. Additionally, they demonstrated that wound size, location and age had no effect on time to healing. The study shows promising results in that STSG can be an effective treatment for optimized wounds to the foot and leg in diabetic patients. They also show that success remains high even in the face of comorbidities.[2]

Conversely, a study was conducted by Ramanujam et al examining the impact of diabetes and comorbidities on STSG for foot wounds. They compared outcomes in time to healing after STSG placement among diabetic patients, diabetic patients with comorbidities and nondiabetic patients. Wounds were optimized with local wound care to build a healthy granular base. Overall, time to healing was 1.99 weeks longer in the diabetic population compared to the nondiabetic population. In the presence of no comorbidities, there was no statistical difference among time to healing among diabetic and nondiabetic patients. Furthermore there was a significant difference in time to healing among diabetics with no comorbidities and diabetics with comorbidities. STSG was found to be an effective treatment modality however the surgeon could expect differences in time to healing when working with a diabetic patient with any comorbidity.[3]

Rose et al evaluated time to healing after STSG placement to the plantar foot and compared this area to other anatomical locations. 94 patients met inclusion criteria. There was no significant difference in time to healing among those with diabetes and those without diabetes. Additionally, there was no statistical significant difference among plantar wounds in those with diabetes and those without diabetes. There was no difference in time to healing among those with ESRD and those without ESRD but they did however show a higher rate of revision (46.2%). They concluded that a STSG was a reasonable option for plantar wounds and did comparatively well to other anatomical areas that receive a STSG.[22]

Meanwhile, studies evaluating the treatment outcomes using CTPs for DFUs have yielded promising results. A study done by Marston et al evaluated healing rates of DFU's after application of an human fibroblast– derived dermal substitute allograft and compared healing rates to a control group. At 12 weeks 30% of the DFU's had healed. Among the DFU's located at the heel, 33% (6 of 18) achieved closure compared with 8% (1 of 13) of the control group.[8] Healing rates among other CTP publications yielded similar results. A study done by Edmonds et al compared the healing rates of a bi-layered living cell tissue product on DFU's to standard wound care therapy. They found that among the group treated with the CTP, 51.5% were healed at 12 weeks compared to the control group (26.3%).[13] Landsman et al conducted a study evaluating cryopreserved human allograft tissue and healing rates on DFU's and found that at 20 weeks 74% of the wounds had healed.[14]

Discussion cont.

Seven out of nine patients with PVD healed, of those patients with diagnosed PVD, one had a non-palpable pedal pulses and three had weakly palpable pedal pulses. Our study shows that this can be an effective treatment in patients with peripheral vascular disease. It is well documented that those with PVD have a difficult time healing due to reduced tissue perfusion, in fact, this is a limiting factor in the success of graft take and incorporation.[23] Although PVD was diagnosed in the two patients that didn't heal, there were seven others that healed that had a diagnosis of PVD. This finding will need a closer examination as to why seven out of nine patients with PVD healed, utilizing exams such as an arm brachial index or angiograms will better help understand the extent of the PVD in each of the patients.

Faulty biomechanics and plantar pressure distribution are two important variables to consider in the selection of an appropriate graft for treatment of DFUs. Full thickness skin grafts are effectively durable and can withstand the pressure and forces delivered to the plantar foot during ambulation. The distal tuft and glabrous component to the plantar aspect of the toe are a stable autograft source. The distal tuft of the digit is rich in microvascular structure and has a glabrous component to the plantar surface. Glabrous skin displays a larger size and number of epithelial cells and thicker collagen making it durable enough to withstand the forces applied to the plantar aspect of the foot during weight bearing.[24] Additionally, FTSGs have been found to have better function following successful incorporation.[25] STSGs has been found to be less than optimal when applied to the plantar aspect of the foot with complications including painful hyperkeratotic buildup at the periphery of the skin graft, craters, contractures and tight subgraft fibrosis.[26] Other cellular and tissue products would yield similar complications to those observed with STSGs. Another factor to consider is donor site morbidity when using an autograft. Donor site complications associated with full and split thickness skin grafts include infection, hypertrophic scarring, blistering, and changes in pigmentation.[27] A FTSG using our technique and CTPs essentially eliminate these concerns. Additionally, results are comparable despite patient comorbidities.

There are some limitations to this pilot study. First, this is a retrospective examination that explores the treatment outcomes of a novel technique. The intricacies of the technique have not yet been fully developed and more time and patients are needed to identify potential areas of failure and if there are any variables that can be optimized to increase the success of the technique. Second, there are 11 patients enrolled in the pilot study. A higher patient volume will better demonstrate the reproducible success of a FTSG from an amputated toe in a diabetic with a DFU. Third, patients with DFU's are notoriously non-compliant, it is difficult to determine the post procedure compliance after the FTSG had been placed; if a patient was noncompliant then this would lead to a longer time to heal, particularly among those who had a plantar wound grafted. Fourth, it is difficult to fully understand at this point the effects the living cells had on healing times. Living cells have some reported success used alone and the authors propose that this may be one of the reasons our healing times have been lower compared to other reported time to healing. Last, equinus is a morbidity that can be overlooked when evaluating DFU's, particularly those on the plantar forefoot, this variable was not included in the analysis.

The present retrospective study introduces a novel technique utilizing a full thickness skin graft taken from an amputated toe. It is important to note that this pilot study does not attempt to directly compare our technique with that used for STSGs but rather to introduce a technique that can be added to the surgeon's arsenal of surgical options for non-healing chronic DFU's. The comparative tables are simply a way to show that this is a reasonably successful technique that can be utilized. More studies are necessary to fully evaluate the treatment outcomes using this technique and how FTSG compare to STSG and other CTPs. This pilot study shows that a FTSG from an amputated toe is a viable alternative to advanced healing in chronic DFUs, eliminating donor site complications.

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