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Covering of Diabetic Foot Ulcers with Local Flaps: A Review of the Literature

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ABSTRACT

Diabetes is a serious chronic disease which affects about 415 million people globally. The most common complication of diabetes is diabetic foot ulceration, which increases the risk of lower leg amputation by a factor 8. To avoid such catastrophic consequences a multidisciplinary approach for limb sparing has been developed. The purpose of this review article was to present the possible surgical reconstructive options in covering diabetic foot ulcers with local flaps. There are many different reconstructive modalities described in the literature and are based on the complexity and the size of the defect and comorbidities of the patient. Local flaps, especially muscle flaps, provide a good, vascularized tissue cover and produce lower 5-year mortality rate and lower economic cost, as compared to limb amputation.

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Introduction

Diabetes is a serious chronic disease which affects about 415 million people globally, which accounts for 1 in 11 people [1]. The most common complication of diabetes is diabetic foot ulceration [2]. Diabetic foot means changes that form on the foot of the diabetic patient and are a consequence of diabetes (polyneuropathy or angiopathy or both). The main pathogenesis of diabetic foot ulceration involves ischemia, neuropathy and infection, and the addition of external trauma, peripheral edema, and foot deformity. Based on Meklav et al. 20% of patients with diabetes in Slovenia have diabetic foot changes. The numbers are a bit lower as compared to global population where are around 25%. The main problem of diabetic ulcer is that once it develops, the risk of lower leg amputation increases by a factor 8, according to the statistics given in the United States. In the United States diabetic foot wounds leads to 71000 limb amputations annually [3-6].

To avoid such catastrophic consequences a multidisciplinary approach has been developed. It consists of endocrinologist, cardiologist, infectious disease specialist, nutritionist, interventional radiologist, wound care nurse, vascular surgeon, orthopedic surgeon, and plastic surgeon [4,7]. If there was a trend in amputating a nonhealing ulcer in the past, the management nowadays has shifted in limb salvaging operations [4]. Foot-sparing reconstructive procedures have become fundamental strategies for limb preservation [8].

The purpose of this review article is to present the possible surgical reconstructive options in covering diabetic foot ulcers with local flaps. When limb amputation is not an option and when free flaps or skin grafts are not the best choice. We performed electronic searches in PubMed and Ovid database based on covering diabetic foot ulcers with local flaps. We included review articles, research articles and case reports. We used English and Slovenian literature.

The Diabetic Foot Reconstructive Pyramid

As I said before, treatment of diabetic foot ulcer must be multidisciplinary. When considering diabetic foot reconstruction, there are multiple problems to be addressed. First, we must address systemic aspects of diabetes, then vascular pathology of the patient, neuropathy, and bone deformities [4]. All soft-tissue reconstructive procedures must be delayed until the patient is medically optimized, and the infection is clinically eradicated [4,7].

The first step is to establish a clean wound base, which can be done with radical debridement of all necrotic and nonviable tissue and negative-wound pressure therapy (NWPT) or just debridement and covering [2-9]. NPWT cannot be used over untreated osteomyelitis, necrotic eschar, and exposed vasculature [9]. Once we have a clean wound base and reasonable vascular perfusion, reconstruction can be considered using a reconstructive ladder or pyramid [4-10]. The reconstructive ladder/ pyramid consists of primary closure/ NPWT, skin grafting/ bioengineered tissue alternatives (e.g., Integra, Matriderm, Alloderm)/ local random flaps, pedicle flaps/ local muscle flaps and free flaps [8,9].

Local Flaps

Local flaps can be divided into local random flaps, local muscle flaps and local pedicle flaps [7,11].

Local Random Flaps

Local random flaps are flaps that are vascularized by a random intradermal or subdermal vascular plexus, from a cutaneous, musculocutaneous or a septocutaneous perforating artery [6-12]. Colen et al. in 1988 concluded the first case series in using local random flaps for diabetic foot reconstruction [10,13]. They are useful for covering diabetic wounds with exposed bone, tendon, or other vital structures on the plantar or dorsal surfaces and replace like with like tissue without donor side morbidity [9-11]. We can divide them into rotational, advancement, transposition, bilobed, rhomboid and toe fillet flaps [7-14,15]. Epidermis, dermis, and subcutaneous tissue, sometimes also underlying fascia can be included in the flap [6,12]. When planning a local random flap, a length to width ratio should not exceed 1:1 or 1:1.5 ratio and can be used to cover defects up to 4 cm [2,16]. Wound dehiscence and scarring are the most common complications in treating diabetic wounds, based on Crystal et al [10]. Postoperative patients are advised in non-weight bearing, which can also be achieved by placing a cast or an Ilizarov external fixator [7,11].

The Rotation Flap is mostly used on the plantar side of the foot, especially midfoot wounds and can be subfascial or suprafascial [6,12,17]. It can also be used on the dorsum of the foot and on both malleoli [6].

The Advancement Flaps are a great option for closing wounds on the plantar aspect of the forefoot. 6,11,12,13,18 They are usually planned in a VY fashion, can be raised superficial with preservation of sensation and can be advanced 1–2 centimeters (cm) [6,11,12].

For covering larger defects on the plantar hindfoot **Transposition Flaps** can be used. They are based on rectangular design and require split – thickness skin graft to cover donor side defect [12].

For regions with more skin mobility, usually forefoot region under metatarsal bones, **Bilobed Flaps** can be used. Lobes are designed to be 90 degrees from the defect and each other and can cover defects from 1-3 square cm [12-19].

Forefoot defects can also be covered with **Rhomboid or Limberg type Flaps**. This type of flap can cover larger defects and should be raised within the relaxed skin tension lines [12].

Toe Fillet Flap is the last type of local random flap and usually used after digit amputation with preservation of the surrounding skin and soft tissue [9,14,15,18].

Local Muscle Flaps

Local muscle flaps are flaps that have axial blood supply and are especially good for plantar weight bearing wounds or osteomyelitic wounds [2]. They were first discovered by Ger et al. in the 1960s [20,21]. The most problematic site for wound covering is the plantar region, which consists of glabrous skin and an abundant amount of fat pads, fascia, tendons, and muscles. It is believed that muscle flaps have the best ability to absorb and distribute shearing forces along the foot [20]. Local muscle flaps in comparison with local fasciocutaneous flaps bring more revitalized tissue into defect, more bulkiness and usually do not leave any problematic donor site morbidity [9,12,20]. They can be harvested with just local anesthesia. The only disadvantage is their limited bulk and reach. Limited range of flap motion can be increased with ligating the feeding artery of the dominant pedicle, if there is a good collateral flow [22]. The intrinsic muscle flaps of the foot have one dominant pedicle entering or near the origin of the muscle and a minor pedicle entering the muscle more distant [7]. After inserting muscle flaps at the recipient site, we cover them with allogenic or autogenous skin grafts [23]. Postoperative treatment is the same as in local random flaps [7,24].

The most common local muscle flaps are the abductor hallucis, the abductor digiti minimi, the flexor digitorum brevis and the extensor digitorum brevis We use these muscles because they tend to be atrophic in patients with diabetic neuropathy [2,7,9,12,23].

• **Abductor Hallucis Flap** is used for covering plantar or medial midfoot and forefoot, heel, and ankle defects [9,22,23]. It is supplied by muscular branches of the medial plantar artery, with the dominant pedicle at the take-off of the medial plantar artery. It has a very thin distal muscular bulk, so it can be difficult to dissect from flexor hallucis brevis muscle [6,9].

• **Abductor Digiti Minimi (ADM) Flap** is the major workhorse flap for small to moderate size defects in the hindfoot, lateral plantar midfoot, lateral ankle and calcaneal region [6,9,12,20-22]. Its dominant pedicle of the lateral plantar artery is distal and medial to its origin on the calcaneus. ADM flap can also be used in patients without any pedal pulses, which was described by Altindas et al [6,20]. In some cases, the recipient site can be closed primary. The flap can also be tunnelled from donor to the recipient site [24]. The only disadvantage of this flap is, that it has a limited size [21].

• **Flexor Digitorum Brevis (FDB) Flap** is used for covering plantar heel defects and midfoot. Its vascular supply comes from two major pedicles from medial and lateral plantar artery. FDB muscle can cover deep defects because of its significant bulkiness [6,9,12,22,23].

• **Extensor Digitorum Brevis (EDB) Flap** is based on lateral tarsal artery, branch of the dorsalis pedis artery. Flap is used to cover sinus tarsi and lateral calcaneus but can also cover Achilles tendon and malleoli [6,9,12]. We can also use this flap as a rotating flap on dominant pedicle or lateral tarsal artery or on dorsalis pedis artery. Unfortunately, it has a limited bulkiness. However, because the flap consists of 4 muscle bellies, it can be used to fill out bone cavities in osteomyelitic foot [12,25].

Local Pedicle Flaps

When we must cover larger wounds, more than 4 cm2, we must think about pedicle flaps [16]. Pedicle flaps can be fasciocutaneous, adipofascial or musculocutaneous and are defined as areas of tissue with a well neurovascular supply. The most common ones used in diabetic foot are the digital artery island flap, medial plantar artery flap and reverse - flow sural artery flap. One of the advantages of pedicle flaps versus local random or muscle flaps is that they can be harvested outside the weight-bearing zone, so if the flap fails, the original defect is not larger than before [7,12].

• **Digital Artery Island Flap** is an adipofasciocutaneous flap based on the digital artery, vein, and nerve. The flap is typically raised from the lateral aspect of the great toe or the medial aspect of the fifth toe, because the metatarsal arteries here are the longest and provide a larger arc of rotation. The donor site is usually covered with STSG. Digital artery island flap is used to cover defects of the plantar forefoot [6,7,12].

• **Medial Plantar Artery (MPA) Flap** is a workhorse flap for patients with a soft tissue defect together with Charcot neuroarthropathy. MPA flap consists of deep or superficial medial plantar artery and cutaneous branch of a medial plantar nerve. By carrying the cutaneous branch of a medial plantar nerve, we

can repair sensation. It's a fasciocutaneous flap that can cover defects up to 6x10 cm, mostly used around the dorsal – medial or lateral – plantar midfoot and heel. Defects on the donor site are covered with split – thickness skin graft [5-7].

• **Reverse flow Sural Artery Flap** is a neurofasciocutaneous flap based on the vascular axis of the sural nerve. The flap receives its vascular supply through retrograde flow from communication with the perforating branches of the peroneal artery. The most distal pivot point of the flap is approximately 5 cm proximal from the lateral malleolus [6,12,26]. The flap can be raised supra or subfascially and covers larger defects around the heel, ankle, and lower leg. The donor site is closed primary or using the STSG [7,12]. Because peroneal artery usually occludes later than anterior or posterior tibial artery, this flap is ideal for patients with diabetic foot ulcers [5]. Based on Yammine et al. venous insufficiency and increasing age are the risk factors for the development of complications and not diabetes [26].

Discusion

Limb amputation in comparison with limb salving procedures, like local flap coverage and other modalities, leads to higher economic costs and a higher 5-year mortality rate [16]. A proactive, multidisciplinary approach is there for essential for lon–lasting, soft–tissue cover for diabetic wounds. Every diabetic wound needs debridement and well vascularized coverage.

Split thickness skin-grafting (STSG) is a simple and effective procedure to cover wounds with healthy granulation tissue without exposed tendons, bones, vessel, or joints [2-12]. It also cannot be placed on weight-bearing surface or subject of shearing forces [9,12,16]. Mostly dorsal and some plantar soft-tissue defects can be effectively managed with STSG as recommended by Ignatiadis et al. and confirmed by Anderson et al [2]. If all the above is not included, we must think about bioengineered tissue or flap coverage.

Regarding the size, we can use local flaps, pedicle flaps or free flaps. Surgeons must also bear in mind that cover of a soft tissue defect must be based on the safer flap according to the vascularity of the limb. Local random flaps are beneficial for covering small to medium size defects because they can replace soft tissue with adjacent tissue without sacrificing structure and function. Based on Ramanujam et al. local random flaps have an almost 76% successful rate of coverage but have a much higher complication rate compared to local pedicle flaps or free flaps as was displayed by Kim et al. Wound dehiscence and skin slough are the most common complications, which are usually treated conservatively [2,10,16].

People still think that flap reconstruction in diabetic patients will not work because of the arterial vessel disease. This statement was dismissed by subsequent studies (for example: JP Hong et al., Colen et al. and Ozkan et al.), which showed that arterial occlusive disease occurs mainly in the leg and that the system in the foot is less involved. That is why microsurgical approach in diabetic foot showed similar success comparable to that of a non-diabetic patient. Nevertheless, when thinking of covering the defect with a free flap, a revascularization of at least the tibial arteries must be done in patient with peripheral arterial disease [9]. For free flap anastomosis a small vessel with a pulsatile flow is enough. Free flaps are mainly indicated for extensive and complex wounds, where local tissue is nonviable or inadequate [2,4].

Hong et al. in his study stated that local flaps have not been as successful as free flaps, especially in diabetic foot with reduced perfusion, because of breaching the distal flow of small collateral vessels [4]. While Crystal et al. agreed that diabetic foot ulcers can be closed with local flaps [10]. This was confirmed by Attinger et al. in his study, where he concluded that local muscle flaps provide a simpler, less expensive, and successful alternative to free flaps for small foot and ankle defects with exposed bone (with or without osteomyelitis), tendon or joint [2].

While pedicle fasciocutaneous flaps can cover larger wounds, they are inferior to local muscle flaps in treating osteomyelitis, usually leave a problematic donor site and does not provide enough bulk [22]. Hong et al. found them even inferior to free flaps, because of their less successful rate [4].

Despite all that controversy still exist as to which flap, whether local muscle flap with skin graft, fasciocutaneous perforator flap or free flap, offers the optimal reconstruction method for diabetic foot ulcer. Nevertheless, we can agree that as long as the defect is covered with a well vascularized tissue, it will provide an optimal cover.

Conclusion

Treating diabetic foot ulcers remains a challenging task. If limb amputation was the main treatment in the past, nowadays multidisciplinary approach with limb sparing reconstructive techniques dominates. There are many available options for soft tissue reconstruction in the diabetic foot based on the size, comorbidities, and the complexity of the defect.

Conflicts of Interest

There are no conflicts of interest.

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