Adipose Reconstruction for Diabetic Foot Off-loading

Autogenous adipose transfers and allogenous adipose matrix injections are useful options.

BY ADAM R. JOHNSON, DPM

Many factors lead to the formation of a diabetic foot ulcer. The three most proliferate are local increases in pressure, peripheral neuropathy, and arterial disease. These manifestations occur at a higher rate in individuals with diabetes mellitus as elevated blood glucose leads to an increase of the malformation of proteins throughout the body. Blood glucose binds to proteins and leads to their structural change, creating advanced glycation end-products (AGEs).[1] The rate of AGE formation is proportional to the level of hyperglycemia. Connective tissue matrix components, including collagen and elastin, are affected by this process, affecting the elasticity and integrity of skin, ligaments, and tendons. These structures lead to a diabetic foot with poor shock absorption and higher peak pressures, and potential tissue breakdown and ulceration.

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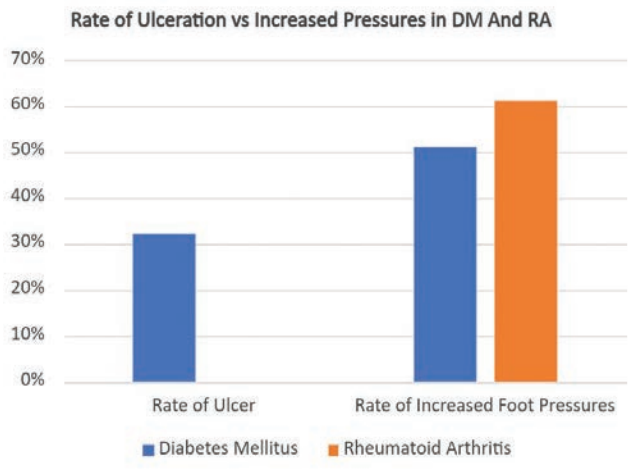
Standard care in wound healing demands off-loading of wounds when abnormal pressures exist, to mitigate these forces and aid in healing. Local, sustained high pressure may lead to a decrease in capillary blood flow or complete occlusion of blood vessels in the already AGE-compromised vascular supply and lead to tissue ischemia. As pressure increases, friction will also increase. Friction opposes the movement of one surface against another. Shear force is produced by the motion of bone and subcutaneous tissue in an opposing direction relative to the skin. The effects of these forces on the body may lead to the formation of blisters, hyperkeratosis, and skin erosions. Diabetic foot ulcerations commonly exist in the plantar forefoot due to abnormal pressures that develop as a result of these biochemical and biomechanical processes.



Masson, EA. et al. Found similar increases in foot pressures in patients with RA as in patients with DM; however, no patients with RA formed foot ulcerations.

While pressure management is important, it has been demonstrated that increased pressures alone may not lead to the formation of ulcerations.[2] Patients diagnosed with rheumatoid arthritis are often ulceration-free yet have elevated levels of foot pressure comparable to their counterparts with diabetes mellitus that do form ulcerations (see chart). The key difference between individuals with diabetes mellitus and rheu-

Continued on page 82

New Concepts and Studies

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matoid arthritis is AGE formation. AGE formation leads to the wide range of damage that occurs in individuals with diabetes mellitus, such as decreased cellular turnover,[3] diminished arterial and myocardial compliance and atherosclerotic plaques, and accumulations of debris and damage within the kidneys and retina.[4,5] The broad spectrum of damage, including damage to blood circulation and protective sensation, coupled with increased foot pressure, leads to the formation of ulceration. As a result of this, standard wound care should also include the addition of ongoing education on the importance of blood glucose control.

Figure 2: Collection of adipose cells.

Research utilizing magnetic resonance imaging has shown that qualitative structural changes are extensive in the diabetic neuropathic foot.

Standard off-loading techniques call for the use of knee-high ankle-immobilizing boots or the gold-standard total contact casts, when skin ulceration exists. When the diabetic foot is without active open ulceration, the use of diabetic shoes and pressure-shielding inlays may be employed. However, if these conservative measures fail, advanced measures should be considered. This may include surgical off-loading such as basic ostectomy procedures to remove bone prominences directly underlying the areas of increased pressure. A simple partial metatarsal head resection is one of the mostly commonly selected procedures for plantar forefoot ulceration as it may be performed with limited dissection and offers limited restrictions in the post-operative period. More advanced surgical off-loading options include indirect off-loading techniques. These indirect procedures are used to change the way the foot functions to reduce pressure.

Procedures of this category include bone osteotomies and tendon transfers and lengthening procedures. The Austin-Youngswick modified bunionectomy and Moberg osteotomy may reduce plantar hallux pressure by altering first metatarsophalangeal joint function and hallux position. Jones' tenosuspension, gastrocnemius recession, and tibialis anterior lengthening procedures may rebalance a foot with abnormal loading patterns. These procedures may reduce pressure across a broader area rather than only in the direct proximity of resected bone . While direct and indirect procedures can be used in isolation, they may be more powerful when used in conjunction with each other. However, occasionally a foot may present with limited options due to advanced deformity from previous ulcerations and infections, leading to loss of the plantar fat pad, or previous partial foot amputations leading to a limited remaining forefoot. In these situations, many surgical techniques fall short with their results, with continued ulceration due to lack of necessary pressure reduction or formation of a new ulceration in an adjacent location. To be successful, the lack of cushion and shock absorption quality in the foot may need to be addressed.

The obvious primary advantage of allogenous adipose matrix injections is the avoidance of an invasive harvesting procedure.

Figure 1: Adipose cells being harvested from the posterior calf.

Research utilizing magnetic resonance imaging has shown that qualitative structural changes are extensive in the diabetic neuropathic foot.[6] These changes cause fibrotic atrophy of the plantar fat pad and lead to the hypothesis that there is a lack of ability to dissipate the increased weight-bearing forces associated with the diabetic foot. Furthermore, the adipose atrophy process that is caused by diabetes mellitus may be locally accelerated in the presence of chronic wounds and infec-

Continued on page 83

Figure 3: Neuropathic ulceration located in area of high pressure with plantar fat pad atrophy.

Figure 4: Neuropathic ulceration decreased in size by over 50% in 2 weeks after adipose matrix injection.

Autogenous adipose tissue may be harvested from any site on the body. The simplest location is at the posterior calf.

tions, creating a self-feeding cycle and further diminishing the ability to absorb and transfer pressure at the locations where it is needed most. Autogenous adipose transfers and allogenous adipose matrix injections (Leneva, MTF Biologics) may be useful options to restore the lost cushion and shock absorption to the foot.

Allogenous Adipose Matrix Injections

Allogenous adipose matrix injections are newer to the market. Currently, a single supplier for this product exists (Leneva, MTF Biologics). Leneva is a shelf stable alternative to autogenous adipose harvesting. The obvious primary advantage of allogenous adipose matrix injections is the avoidance of an invasive harvesting procedure. A secondary advantage may also be the avoidance of a possible local panniculitis after placement of adipose tissue. Panniculitis is the local inflammatory process that occurs when adipocytes break down. Adipocytes are fragile cells and their disruption may lead to the leakage of pro-inflammatory intracellular lipids. Adipose matrix injections are processed to remove as much free lipid as possible.[7] While many products on the shelf act like a filler, providing cushion, allogenous adipose matrix works as more. While initially it does create a cushion to off-load, over time, it may lead to tissue remodeling and the formation of new adipose cells at the implantation site.[8]

Figure 5: Chronic plantar heel ulceration in patient with lack of plantar fat pad as the result of previous infections and I&D.

Autogenous Adipose Transfers

Autogenous adipose tissue may be harvested from any site on the body. The simplest location is at the posterior calf. Harvesting from this site is done at the same location where an incision is often made to perform a gastrocnemius recession. Most individuals with diabetic foot complications concurrently present with ankle equinus as a result of the damage occurring by AGE formation. Thus, this harvesting may be easily performed at the same time a gastrocnemius recession is performed for indirect surgical off-loading. The posterior calf often contains more than adequate amounts of adipose cells for collection and transfer. Clinically, one should be able to palpate the posterior calf to determine in advance if the tissue would provide the needed adipose cells. When making the skin incision for gastrocnemius recession, adipose will be seen immediately under the skin (Figure 1). These cells are loosened and teased out of the incision with freer elevator and atraumatic forceps, gently handled and removed, placed in a saline bath, and then held on the back table for later transfer to the desired location (Figure 2).

When implanting the adipose cells, an incision is made adjacent to the area of concern, dissection is tunneled deep directly underlying this area, and the adipose cells inserted, and tissues closed. Alternatively, if a direct off-loading procedure is being performed, after prominent bone is removed, the deficit created may be filled with the collected adipose cells. Post-operatively, an ankle immobilizing CAM boot and/or crutches are recommended to limit trauma to the newly implanted cells, which might lead to a higher rate of occurrence of panniculitis.

Case Scenarios

Case 1—Allogenous Adipose Matrix Injections for Plantar Forefoot Ulcer

A 67-year-old male with severe PAD presents with a new ulceration under the right 5th metatarsal head.

Continued on page 84

Figure 6: Status post adipose harvest from the calf with implantation into the heel.

The patient had a previous left foot 5th ray amputation which occurred after a non-healing ulceration and infection occurring three years prior under the left 5th metatarsal head. PAD in the right lower extremity was addressed with an invasive revascularization procedure. However, four weeks after revascularization and the onset of proper off-loading and local wound care, the ulceration failed to show any significant improvement (Figure 3). Advanced intervention was deemed necessary and the subcutaneous tissues underlying the ulceration were injected with adipose matrix. A small amount, approximately 1 cc of adipose matrix, was injected to limit stress on the local tissues. Two weeks later, the patient was evaluated in the clinic. The ulceration had healed over 50% and the surrounding tissues were significantly healthier appearing (Figure 4). In this situation, the patient will be monitored, and additional serial injections of adipose matrix may be employed.

Figure 7: Resolved ulceration and demonstrated robust padding as the result of adipose transfer.

Case 2—Autogenous Adipose Transfer for Plantar Heel Ulcer

A 52-year old male with Type 2 diabetes mellitus presented to the wound clinic with a non-healing plantar heel ulceration. Previously, the patient had a puncture wound to the heel which led to local abscess and tissue necrosis. After extensive debridement to resolve the infection and remove necrotic tissues, the heel was left without its inherent plantar fat pad. The lack of padding led to the development of a non-healing ulceration (Figure 5). The patient underwent surgery to harvest adipose tissue from the ipsilateral calf with implantation in the heel (Figure 6). A period of four weeks non-weight-bearing was completed with the patient healing both incisions and pre-existing ulceration during that time. The patient was evaluated at the three-month follow-up without signs of ulceration re-occurrence and with excellent take of the transferred adipose tissue (Figure 7).

Final Considerations

Adipose tissue reconstruction, autogenous or allogenous, should not be performed in the presence of active soft tissue and osseous infections. These procedures are not typically performed as a first line of therapy, but rather as an adjunct coupled with standard wound care, other surgical off-loading techniques, and patient education on diabetes control. As previously mentioned, diabetic foot ulcerations are the result of damages to multiple systems, all which may be better controlled with the reduction of AGE formation. Lack of blood glucose control will lead to ongoing damage to these systems and the resultant complications that follow. While adipose tissue reconstruction is an emerging tool in in wound healing, there remains limited research on its use. **PM**

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