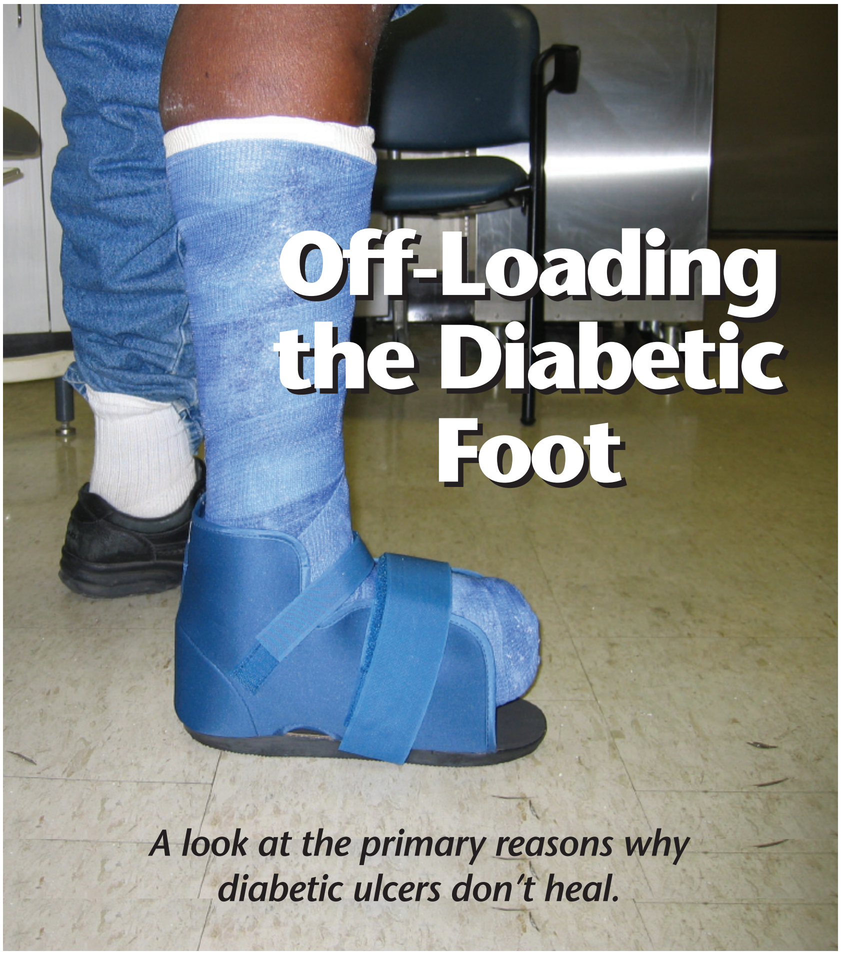

# Off-Loading the Diabetic Foot

*A look at the primary reasons why diabetic ulcers don't heal.*

## Goals/ Objectives

1) To understand the three mechanisms of ulcer etiology.

2) To better assess the role limited joint mobility plays in the biomechanics of the diabetic foot.

3) To understand the role of plantar pressure, pressure/time and repetitive loading.

4) To better evaluate and select an off-loading device for patients and understand their advantages and disadvantages.

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*Following this article, an answer sheet and full set of instructions are provided (p. 262).—**Editor***

**By Vincent Giacalone, DPM**

Plantar neuropathic diabetic foot ulcers are a leading cause of amputation on in the United States. Fourteen to twenty percent of patients with foot ulcers require an amputation, contributing to the $6 billion annual cost of amputations in the U.S. alone. Each year greater than 82,000 lower extremity amputation are performed on patients with diabetes, most of which are precipitated by a foot ulcer. Studies have demonstrated that most foot ulcers are caused by a combi-

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nation of peripheral sensory neuropathy and foot trauma, either major or minor. Peripheral arterial disease is often a complicating factor and usually not a major causative factor.

The goal of the podiatrist treating a patient with a plantar foot ulcer is to heal the wound as quickly as possible without complication. There are four major reasons that plantar ulcers fail to heal:

1. Peripheral arterial disease resulting in poor wound perfusion.
2. Infection, in the form of critical wound bacterial contamination and colonization, acute soft tissue infection and/or underlying osteomyelitis.
3. Faulty wound healing, consisting of growth factor deficiency, abnormal matrix metaloproteases function or metabolic and nutritional abnormalities.
4. Pressure applied directly to the wound in the form of ground-reactive and weight-bearing forces, both vertical and shear friction. This is the greatest detriment to wound healing.

### Three Etiology Mechanisms

The late Dr. Paul Brand was the first to delineate the three mechanisms which are the etiologies for plantar foot ulcers in a neuropathic patient.[1] The first is low pressure sustained for a long period of time. It takes several pounds per square inch of pressure to blanch human skin. A patient with ill- fitting shoes will have pressure on bony prominences such as the dorsal interphalangeal joints, lateral 5th metatarsophalangeal joints (MPJ), or medial 1st MPJ. The shoe pressure will blanch the tissue, resulting in lack of perfusion and local ischemia, resulting in tissue breakdown within several hours. This is also the mechanism which causes heel and sacral decubiti. In the neuropathic patient, the pain resulting from the local ischemic process is not acted upon and the pressure continues.

*The greatest detriment to wound healing is pressure applied directly to the wound in the form of ground-reactive and weight-bearing forces, both vertical and shear friction.*

The second mechanism is that of high pressure over a short period of time, such as stepping on a sharp object. The third mechanism - by far the most common cause of plantar ulcerations – is moderate repetitive pressure, not high pressure, not low pressure, but rather some level of pressure in-between which is repeated with each step.

*There is no clearly documented threshold of plantar pressure for tissue breakdown.*

The third mechanism deserves a greater amount of discussion and detail. Typically, patients with diabetes develop sensory, autonomic and motor neuropathy together. Motor neuropathy leads to clawing of the digits which places a reverse buckling effect on the MPJ's. As the digits become dorsally dislocated on the metatarsal heads, a plantar force is placed on the metatarsal heads, increasing vertical pressure.

In addition, the digits contract, causing an anterior migration of the plantar fat pad distally into the sulcus. This leaves the plantar MPJ's without fat pad pressure attenuation, and only plantar skin. A combination of unprotected plantar skin (due to loss of the fat pad), increased plantar-force from the digits migrating on the dorsal MPJ's and peripheral sensory neuropathy, creates a negative scenario. Each step a patient takes results in some degree of tissue damage, depending on the amount of pressure. As the tissue is damaged with each progressive step, the lack of pain perception allows the patient to continue walking without guarding, until eventually the tissue breaks down and an ulceration develops.

### How Much Pressure is Too Much?

Studies demonstrate that the average patient takes approximately 15,000 steps per day. Many studies have highlighted a "threshold" for plantar pressure, from 500 kilopascals (kPa) to 900kPa using a variety of computerized gait and plantar pressure analysis systems. This, however, can provide a confusing picture. As an example, patient A places 400kPa sub 2nd MPJ and walks 6000 steps per day, and develops an ulcer. Patient B places 900kPa sub 2nd MPJ, however, only takes 2,000 steps per day, and does not develop an ulcer. Even though patient A had a lower pressure, he took more steps. So we know that it's not only pressure that causes plantar ulcers in the neuropathic patient. It's also the number of load cycles or amount of steps a patient is placing on the area.

In addition to plantar pressure and number of load cycles, an additional factor is what is known as the pressure time integral, the amount of time spent on a particular area during the gait cycle. For a variety of reasons, including limited joint mobility, foot structure, foot type and rigidity, as well as Achilles tendon contracture, many patients with long-standing diabetes will have an increased pressure-time integral. Duckworth and others have noted significantly higher pressure time integrals for patients with neuropathy and plantar ulcers compared to diabetic controls and those with neuropathy without an ulcer.[16] Patients spend more time during the gait cycle on the area of ulceration, which is a primary contributing factor in the ulcer formation, as well as a detriment to healing. Longitudinal studies have demonstrated that patients who demon-

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strate increased time in the area of higher pressure are more likely to develop an ulcer.

There is no clearly documented threshold of plantar pressure for tissue breakdown. The reason for this is differences in individual foot structure and function, plantar tissue thickness, pressure-time integrals, and number of load cycles for a particular patient. It is accepted that the greater the plantar pressure the higher the risk of breakdown. Armstrong, et al., identified a pressure of 700 kPa with 70% sensitivity as the dividing line between high risk and lower risk of ulcer development.[12] Patients below 700kPa were at lower risk, but not at no risk. Plantar pressure measurement, including peak pressure and pressure time integrals, is a significant clinical tool for evaluating and screening patients with diabetes in order to evaluate those who might be at higher risk of ulcer development. In addition, this research will assist us in a more complete understanding of diabetic foot function, as well as in the development of appropriate foot gear.

**Photo #1: A 62-year old patient with plantar hallux ulcer secondary to peripheral neuropathy, and limited first MPJ dorsi-flexion, resulting in tissue breakdown from moderate repetitive pressure**

### Testing for Plantar Pressure

The greatest problem with computerized plantar pressure gait technology is the fact that it is relatively expensive and not readily

*A simple hand-held skin thermometer is an extremely useful tool for patients and clinicians to determine areas of risk through increased skin temperatures.*

available to most podiatric physicians in their daily clinical practices. Many but not all areas of high pressure, however, may be identified by a simple clinical examination and the presence of plantar callus, as well as increased skin temperature in the area at risk. It is well understood that increased pressure results in increased callus and/or temperature. The inverse is also true that increased callus will result in increased pressure. As the cycle continues the area is more vulnerable to breakdown. Several plantar pressure studies have demonstrated pressure reductions between 24 to 32% in callus areas once callus tissue was debrided.[20,28] Callused tissue, however, will not provide information regarding pressure time or number of load cycles.

A simple hand-held skin thermometer is an extremely useful tool for patients and clinicians to determine areas of risk through increased skin temperatures. Patients or physicians who evaluate the skin temperatures at the plantar MPJ's and identify an area of sudden increase in temperature compared to adjacent areas or the same site on the contra-lateral foot can be alerted early as to potential breakdown. This information can then be used to have the patient curtail weight-bearing activity until skin temperatures normalize.

The physician must obtain information regarding the patient's daily activity level, shoe gear and occupation. Additionally, a high quality pedometer worn by the patient with neuropathy and a high risk foot will provide key information. This information can also be used to assist the patient in limiting his/her daily activity once a certain pre-determined daily number of load cycles or steps are reached.

### Limited Joint Mobility

Regarding pressure and time, there are several biomechanical scenarios which will cause a higher pressure time relationship, such as the condition of limited joint mobility. Limited joint mobility (LJM), also known by the name cheiroarthropathy, is a non-enzymatic glycosylation of the joint

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**Photo #2: A typical post-operative shoe flexing at the MPJ's as the patient goes through push-off, increasing plantar forefoot pressure.**

structural proteins secondary to elevations in blood glucose levels. This glycosylation results in an irreversible cross-linking of collagen and keratin, causing thickening of skin, tendons, ligaments and joint capsules, leading to a reduction in joint flexibility and a reduction of joint motion. This occurs most noticeably at the ankle joint, where it affects and reduces ankle joint dorsiflexion during gait, resulting in higher plantar forefoot pressures, as well as a longer pressure- time integral. This also affects the subtalar joint, limiting pronatory shock absorption. When LJM occurs at the first MPJ, it results in higher sub-hallux pressure.

*Patients with sub-hallux ulceration have limited joint mobility at the first MPJ, resulting in increased plantar pressure.*

The incidence of LJM varies widely from 8-42% of those with type I diabetes to 4–76% of those with type II. Greater than 66% of patients with diabetes of more than 5 years have some degree of LJM. This limitation is associated with higher plantar forefoot pressures, greater incidence of ulceration and reduced ankle joint dorsi-flexion. In 1991, Fernando found significantly higher peak plantar pressures in those with LJM with peripheral neuropathy (PN) compared to those without LJM.[19] Diabetic foot ulcers were noted in 65% of those with LJM and PN compared to only 5% in those with PN without LJM. After screening 1,666 patients in an out-patient diabetes clinic, Lavery in 2002 found that 10% of all patients demonstrated equinus at the ankle joint.[21] He also noted that patients with equinus had a three times greater risk of higher plantar pressures.

**Ankle Equinus and LJM**

A study by Lin highlights the effects of ankle equinus and LJM on plantar forefoot ulcer healing.[22] Linn treated 93 patients with total contact casting (TCC) for plantar forefoot ulcers. The patients broke into two groups, those who healed in 45 days in the TCC and those who failed to heal in the same time period. Those who healed had an ankle dorsi-flexion of + 2 degrees. Those who did not heal had an average ankle joint dorsi-flexion of –10 degrees. These patients then underwent a percutaneous tendo-Achilles lengthening (TAL) followed by TCC, and 94% went on to healing within 39 days. This study demonstrated the negative force of high plantar forefoot pressures due to ankle joint equinus. Armstrong in 1999 presented data which looked at 10 patients with a history of plantar forefoot ulcers and measured their ankle joint dorsi-flexion and plantar pressure pre and post-TAL. Pre-operatively, all 10 had a dorsiflexion of 0 degrees with a pressure of 860 kPa, and post-TAL increased the ankle joint dorsiflexion to +9 degrees and lowered the forefoot pressure to 630 kPa.

*The post-op shoe certainly has its advantages in that it is inexpensive, easily modified and available in various sizes, but it provides for no biomechanical support, allows for shear forces to take place, and there are significant fitting and slippage problems.*

Mueller, et al., reported on muscle strength post-TAL.[14] He noted that posterior plantarflexory muscle group strength was reduced 32% post-TAL and returned to pre-TAL strength within 7 months. It can be postulated that pressure reduction and ulcer healing is due in part to this reduction in plantar-flexory power. Of great concern, however, is the biomechanical alteration which occurs with a TAL. We know that over-lengthening of the Achilles can create a calcaneal gait, resulting in difficult-to-heal plantar calcaneal ulcers.

In addition, due to increased forces on the mid-foot, the risk of a mid-foot Charcot is increased. We do need long-term studies to follow the progression of TAL patients, as well as algorithms to allow for more appropriate planning of our surgical procedures based on foot type and structure, cavus vs. planus, etc. Different foot structures will function differently regarding plantar pressure and loading.

Studies by Ledoux have demonstrated what many would consider the obvious: that patients with diabetes and cavus feet will present with a greater tendency towards prominent metatarsal heads, bony prominences and claw toes, while planus feet with increased talometatarsal angles have increased lesser metatarsal pressure.[5]

**Diabetes and Peripheral Neuropathy**

We know very clearly that patients with diabetes and peripheral neuropathy are at a significantly greater risk of developing foot ulcers. This is due to multiple factors, including motor neuropathic changes to the forefoot leading to claw toes, anterior migration of the plantar fat pad and retrograde plantar pressure on the plantar metatarsal heads. Patients with sub-hallux ulceration have limited joint mobility at the first MPJ, resulting in increased plantar pressure. If you evaluate these patients clinically, they appear to have typical hallux limitus; however, many times absent are the radiographic changes typically seen in patients with hallux limi-

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tus. The reason for this is LJM, or soft tissue block or contracture rather than a bony block. Due to lack of 1st MPJ dorsi-flexion during gait, there is a significant increase in plantar hallux pressure. In addition, this causes the hallux to load early with an increase in the pressure time integral. These patients also have some level of LJM occurring at the AJ and STJ.

The plantar skin is traumatized with increased plantar pressure through repetition in the face of peripheral neuropathy, resulting in tissue breakdown and ulceration. The key for all podiatric physicians is to obtain complete ulcer healing, without complication, in the shortest period of time. In order to obtain this, three factors must be addressed. The wound must be free of infection and high levels of colonization and have a low bio-burden, the wound must have adequate vascularity for healing, and sufficient off-loading must be adhered to. It is often said, "It's not what you put on, it's what you take off," which is the most important factor in healing. We must select an off-loading method which meets our objective for pressure reduction or elimination, while working within the patient's limitations or parameters, as well as considering his or her risk of falling.

**Off-Loading Devices**

Some of the most commonly-used off-loading devices range from bed rest—which is not only impractical in many cases but is often unhealthy for most of our patients—to wheelchair use, to devices such as post-op shoes, roll-abouts, pneumatic walkers, to TCC. There are pro's and con's for each device.

**Felted-Foam Dressings**

Felted-foam dressings were popularized by the Deaconess program for the treatment of plantar ulcers and are used by many centers throughout the country. They consist of a multi-layered felted foam dressing applied to the foot with a cut-out around the ulcer area, and are fixed to the foot with adhesive and a secondary dressing. The patient wears a rigid sole post-operative shoe, and the dressing is changed at least weekly. Of concern is the aperture or cut-out area, which may cause an edge effect at the ulcer's periphery, and increase vertical and shear forces, impeding healing. They cannot be utilized in patients with friable skin, dermatological disorders or adhesive allergies.

Fleishli & Lavery evaluated side-by-side the off-loading potential of the felted-foam dressing with a variety of other modalities, including TCC's, pneumatic long-leg walkers, half shoes, post-op shoes, and simple canvas sneakers.[27] They found that the felted-foam performed slightly better than the post-op shoe alone in reducing plantar pressures, however not nearly as well as the TCC or long-leg walkers. In a 2003 study by Zimny, et al., a felted-foam dressing was evaluated against the use of a half shoe in 54 patients in a prospective randomized trial.[6] The felted-foam group's healing rate was 0.5mm/week vs. 0.4mm/week in the half shoe group with a 75-day healing time vs. 85-day healing time in the half shoe group. Compared to an average healing time of 42 days in several studies on the TCC, the felted-foam does not fare well.

*The total contact cast remains the gold standard for off-loading a plantar diabetic foot ulcer.*

Due to the fact that the padding, in combination with a post-op shoe, does not lock the ankle joint and prevent ankle joint plantar-flexion during push-off, its beneficial off-loading effect is limited. It does, however, have benefits, such as in the patient who will not accept a cast or walking boot, or any other modality, or in a patient where another device is simply too dangerous and poses a high fall risk. I personally use the felted-foam concept with success on these types of patients with the "something is better than nothing" philosophy. When practical, I will often add a half shoe or long-leg walking boot to augment the pressure reduction. Additionally, older patients with reduced push-off forces during gait tend to gain greater benefit from the felted foam dressing.

**Post-Op Shoes**

The post-op shoe certainly has its advantages in that it is inexpensive, easily modified and available in various sizes. The downside, in my opinion, outweighs the advantages. The shoe provides for no biomechanical support, allows for shear forces to take place, and there are significant fitting and slippage problems. Additionally, compliance with these shoes is less than ideal, with most patients admitting they do not wear the shoe as directed. The greatest deficit to healing plantar forefoot ulcers is that the outsole is flexible and bends when the patient goes through the push-off phase of gait. When the shoe bends during gait, it concentrates and increases the pressure and focuses it under the forefoot during push-off. In order for the shoe to become useful, you must create a rigid roller sole with the apex of the rocker beginning just proximal to the metatarsal heads.

The Darco® diabetic shoe is of slightly greater value, with a more, but not completely, rigid sole. Similarly, the DH® pressure relief shoe, with removable hexagonal plugs, has a pressure relief insole and works fairly well. The greatest disadvantage any shoe-type device has is its inability to prevent the ankle joint from plantar-flexing during gait. If the ankle is not locked and is allowed to plantar-flex during gait, the forefoot loads, and pressure is increased. The DH shoe, however, does have a more rigid roller outsole.

A rigid roller sole also limits

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dorsi-flexion of the hallux and toes, and therefore the involvement of the forefoot rocker mechanism reduces forefoot pressure up to 30%, independent of walking speed. The Darco® Orthowedge healing shoe allows for less forefoot pressure, with a 10 degree dorsi-flexion angle; however, the negative heel can and often does result in Achilles tendonitis and can be somewhat clumsy for many patients to wear. The integrated prosthetic & Orthotic System (IPOS)® half shoe also has a negative heel, which is elevated 4 cm., and has a narrower base of support, which can be very difficult for older patients to ambulate with. Gait lab evaluations have demonstrated that the pressure reduction ability of this shoe are significant; however, this must be balanced with the patient's compliance, comfort levels and stability, as well as fall risk.

**Photo #3: The use of felted foam dressing for a plantar ulcer.**

### Removable Long-Leg Walking Boots

Removable long-leg walking boots have several distinct advantages. They are removable for wound inspection and greater sleeping comfort, reusable, cost-effective, may provide for edema control, have a built-in rigid rocker sole, lock the ankle joint and lower plantar forefoot push-off, and are available in a variety of sizes. There are several particular brands which appear to provide for better control than others, such as the DH® walker, Air Cast® walker, and the Bledsoe® diabetic conformer boot. These are available in up to extra-large; however, you may have difficulty fitting a patient with a widened midfoot Charcot foot.

The Bledsoe boot provides several advantages. One is the fact that it is available in particular sizes, such as men's or women's, 8-9 or 10-11, etc., and specifically left and right, in order to obtain a more appropriate fit. Additionally, the boot contains an auto-molding insole base, as well as a liner, to allow for a total contact insole. This will provide for pressure uptake in the arch and heel area, limit rear-foot movement and shear forces, and allow for greater reduction in forefoot pressure and shear.

**Photo #4: A patient begins to ambulate with the use of a total contact cast.**

Patient concerns with the walking boots are the fact that they are relatively heavy and hot, somewhat difficult to walk in, and may require a contra-lateral shoe to provide for greater balance.

### Total Contact Cast

There is no question that the total contact cast remains the gold standard for off-loading a plantar diabetic foot ulcer. In physics we learn that Pressure = force/area.(p=f/a). The mechanism for the TCC's effectiveness is the fact that the pressure is reduced because the same amount of force is distributed over a much larger area, P = f / a. Additionally, the cast is very effective at edema control and most importantly, locking the ankle and completely preventing ankle plantar flexion and forefoot push-off. The TCC also forces patients' compliance as they cannot remove it. It also decreases cadence and shortens patients' stride length, and eliminates shear forces.

*There are some plantar lesions, which despite the best and most appropriate off-loading, simply will not heal.*

I am often asked about the effects to the contra-lateral foot. Interestingly enough, studies looking at this have demonstrated that most patients have pressure reduction on the contra-lateral foot, as well. The reason is the shortened stride length and decreased cadence. By adding a cane for the contra-lateral side, you can further reduce pressure on the contra-lateral side, as well as improve patient stability and comfort. A study by Drerup demonstrated a peak plantar pressure reduction of 14.5% when stride length was reduced by only 23%.[4]

The disadvantage to the TCC is that it has a steep learning curve for the physician. It requires a significant amount of experience for learning how to apply and remove it, and requires frequent removals and reapplications. Is costly due

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to multiple applications, is relatively time-consuming, and has a high potential for iatrogenic lesions. I usually recommend attending a TCC workshop and then working with a podiatrist in your area who utilizes the cast frequently, and becoming very familiar and comfortable with it prior to utilizing the TCC on your patients. Typically, I will debride the wound and apply the appropriate dressing, keeping it as thin as possible. I apply the cast and have the patient back in three days to check for fit and possible pistoning in the cast due to edema reduction. Once all edema is removed, I generally have patients back once a week to once every two weeks depending on compliance and wound drainage. The TCC is, however, contraindicated in patients with peripheral arterial disease, wound infection, osteomyelitis and wounds which are deeper than they are wide.

The TCC has the shortest documented healing time of all the off-loading modalities. In several studies, as well as the one by Linn mentioned earlier, the average non-infected plantar forefoot ulcer will close within 45 days in a TCC. This is compared to 70 days for a half shoe, 90 days for felted-foam, 108 days for a custom-molded shoe, and 300 days for custom splints. A study by Lavery, et al., compared the mean peak pressure under the 1st and 2nd metatarsal heads as well as the plantar hallux, while patients wore a TCC, DH Pressure Relief walker®, Aircast pneumatic walker®, 3D® Dura Stepper, CAM walker, added-depth shoe, and a canvas sneaker.[8]

*The rule of thumb in wound care is that the wound should reduce by 50% within four weeks.*

Studies of all the locations found that the TCC and the walkers were very effective at off-loading the plantar forefoot. Pressure reduction for both devices was essentially equal. Healing times for TCC, however, are significantly better than for the walkers. The reason for this, most hypothesize, is the fact of forced compliance with the TCC. Although the pressure reduction is similar with the walker and the TCC, ulcers heal faster in the TCC simply because patients cannot remove it. Most patients are not as compliant with the walkers and remove them at home.

*Consider not only peak plantar pressure, but also load cycles and the mechanics resulting in increased time the load is applied.*

In a study in Diabetes Care in 2003, patients with foot ulcers were given a waist-worn pedometer and were provided with a CAM walker with a computerized pedometer imbedded, which was not accessible to the patient.[7] The study showed that patients logged significantly more steps with the walking boot off than on, using the cam walker only 28% of the day. A small subset of patients, only 30%, wore the device for 60% of their activity. I have utilized the concept of the "Instant TCC" whereby the pneumatic walking boot is applied, then wrapped with a roll of plaster as a deterrent so the patient does not remove the walker. If he or she does, I will easily know.

Both the TCC and the removable walkers should slow the patient down. One study has demonstrated when walking speed is reduced from 1.19 m/s to 0.83 m/s, peak plantar pressures are reduced 10% at the forefoot and 5-18% in the heel.[2]

### Rule of Thumb

The rule of thumb which is quickly emerging in wound care is that the wound should reduce by 50% within four weeks. If it fails to do so, you should reconsider your treatment plan or re-evaluate the patient's vascular status, consider bacterial wound colonization or re-visit the current off-loading. There are, however, some plantar lesions, which, despite the best and most appropriate off-loading, simply will not heal. The most common locations for these lesions are the lateral and central midfoot. When presented with an open lesion at the plantar midfoot secondary to a chronic but plantar grade and stable Charcot, off-loading is biomechanically difficult. The walkers are rarely effective due to the rocker nature of the Charcot foot. The TCC is the best device in this situation; however, obtaining healing can be difficult. After a course of unsuccessful TCC, surgical intervention may be necessary. Rosenblum published a study in which he evaluated 32 feet on 31 patients with chronic non-healing diabetic foot ulcers at the plantar lateral midfoot, all of whom had failed conservative care.[25] All underwent plantar exostectomy with an overall success rate of 89%. Catanzariti also reported on 27 procedures on 20 patients, 18 medial and 9 lateral.[26] 20 of the 27 patients healed primarily with 6 of the 7 being lateral column, requiring revisional surgery.

### Summary

In summary, there are several important considerations when off-loading the diabetic foot. Consider not only peak plantar pressure, but also load cycles and the mechanics resulting in increased time the load is applied. Evaluate the foot and ankle for limited joint mobility at the 1st MPJ as well as the ankle joint. Consider a percutaneous TAL in patients with ankle joint equines, which is inhibiting the off-loading efforts and preventing healing. Select the best off- loading device for the patient; provide information on

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wound size and location, the foot structure, the patient's job, home environment, and other medical or ambulatory conditions.

If the wound fails to progress despite lack of infection and osteomyelitis and the presence of adequate vascular status, consider inadequate off-loading as a major issue. This can be due to the selection of an inappropriate device or the patient's non-compliance with the selected device. Most non-complicated plantar ulcers will respond quickly with appropriate off-loading. ■

*If the wound fails to progress despite lack of infection and osteomyelitis and the presence of adequate vascular status, consider inadequate off-loading as a major issue.*

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Continuing Medical Education

# E X A M I N A T I O N

***See answer sheet on page 263.***

1) The total contact cast (TCC) and removable walking boots have similar off-loading profiles when tested, yet clinically the TCC heals ulcers in a shorter period of time due to:
A) The walking boot caused edema
B) The walking boot causes patients to limp due to a height difference
C) Patients have an increased stride length while in the TCC
D) Forced patient compliance while in the TCC

2) In order to determine tissue breakdown threshold, plantar peak pressure must be evaluated with the following:
A) Number of load cycles or steps the patient takes per day
B) The amount of times the ulcer is debrided
C) The patient's vascular status
D) The patient's age and weight

3) Plantar forefoot ulcers which fail to heal may be due to which of the following:
A) Inappropriate dressing
B) Ulcer of over 3 months duration
C) Limited ankle joint dorsiflexion / ankle equinus
D) Prior use of broad spectrum antibiotics

4) Biomechanically, the most successful devices for off-loading the plantar forefoot accelerate healing due to their ability to:
A) Lock the ankle joint and prevent plantar-flexion during push-off
B) Increase weight-bearing in the heel
C) Limit patients' activity
D) Prevent edema

5) The typical post-operative shoe is not efficient at off-loading a plantar forefoot ulcer due to:
A) There is little to no shock absorption
B) The fact that the sole is flexible and it does not lock the ankle joint
C) Inability to tighten the Velcro closures
D) The rigid sole of the shoe

6) Which of the following is not one of the three mechanisms of injury resulting in a plantar ulceration?
A) Low pressure over a short period of time
B) High pressure over a short period of time
C) Moderate repetitive pressure
D) Low pressure over a long period of time

7) The following are the most common reasons for wound healing failure except;
A) Peripheral arterial disease
B) Infection
C) Elevated blood glucose
D) Inadequate off-loading

8) In order to evaluate a patient's potential for ulcer development all of the following should be considered except:
A) Amount of pressure placed on the area
B) Number of load cycles or steps
C) Amount of time the area is loaded
D) Patient's age

9) Pressure in a callused area may be reduced by what percentage after callus debridement?
A) 15-22%
B) 24 – 32%
C) 16-29%
D) 44-68%

10) Limited joint mobility may affect all of the following joints except:
A) Subtalar joint
B) Ankle joint
C) Fist MPJ
D) Affects all of the above

11) Limited joint mobility occurs in the joints due to:
A) Muscle fiber stenosis
B) Muscle denervation
C) Glycosolation of collagen fibers
D) Auto tenodesis

12) A patient with diabetes and a sub hallux ulcer and limited first MPJ motion without radiographic evidence of first ray elevatus or first MPJ bony block may have:
A) Osteomyelitis
B) Pseudo-limitus
C) Limited joint mobility at the first MPJ
D) Limb length discrepancy

13) Felted foam dressing may be best used to off-load an ulcer in:
A) Young active patients
B) Older patients with reduced push-off
C) Patients with a midfoot charcot
D) Patient with underlying osteomyelitis

14) The following are disadvantages in using a post op shoe for a plantar ulcer except:
A) Lack of biomechanical stability
B) Allows for shear and friction
C) Problems with fitting and slippage
D) Easily modified

*Continued on page 262*

Continuing Medical Education

# EXAMINATION

(cont'd)

15) In the lab removable walking boots have pressure reduction similar to a total contact cast. Clinically, however, the cast has superior wound healing rates. This is most likely due to:

A) The fact that most patients remove the walking boot sometime during the day
B) The inability of the boot to lock the ankle joint
C) The fact that the walking boot has a roller sole
D) The fact that the cast is heavier than the walking boot

16) One of the reasons a total contact cast is effective is due to its ability to reduce pressure by:

A) Decreasing the area the force is applied to
B) Increasing the area the force is applied to
C) Increasing the force under the foot
D) Reducing edema in the foot

17) By asking a patient to reduce his/her stride length by approximately 25%, plantar pressure can be reduced by:

A) 90%
B) 45%
C) 14.5%
D) 39%

18) All of the following are contraindications to the use of a total contact cast except:

A) An ulcer which is deeper than it is wide
B) Acute infection
C) Peripheral arterial disease
D) Edema

19) When using a total contact cast or walking boot, pressure on the contra-lateral foot is often reduced due to:

A) Reduced cadence and stride length
B) Weight of the walker or cast
C) Bulkiness of the dressing
D) Height of the walker or cast

20) Most foot ulcers are caused by a combination of the following:

A) Trauma and peripheral arterial disease
B) Peripheral neuropathy and trauma
C) Peripheral neuropathy and peripheral arterial disease
D) Peripheral arterial disease and tight shoes

***See answer sheet on page 263.***

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| 3. | A | B | C | D | 13. | A | B | C | D |
| 4. | A | B | C | D | 14. | A | B | C | D |
| 5. | A | B | C | D | 15. | A | B | C | D |
| 6. | A | B | C | D | 16. | A | B | C | D |
| 7. | A | B | C | D | 17. | A | B | C | D |
| 8. | A | B | C | D | 18. | A | B | C | D |
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