The principles and practicalities of offloading diabetic foot ulcers

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Article points

1. Understanding the forces applied to the foot is essential if foot ulcer/pressure management is to be successful.
2. Total contact casts are the gold standard for off-loading.
3. The efficacy of a device depends on the ulcer's type, position, the presence of infection, exudate, spinal and balance problems, and patient compliance.

Key words

- Casts
- Forces
- Offloading
- Pressure

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'Offloading' in diabetic foot management is a term generally understood as relieving pressure from an ulcerated area. In truth, this term should more correctly be used to describe the reduction, redistribution or removal of detrimental forces applied to the foot. These forces may be a major contributing factor to ulcer occurrence, relapse, chronicity or deterioration. This article gives an overview of the types of force applied to the feet, the principles and types of offloading used in the management of diabetic foot ulceration and heel sores. The topic of offloading in ulcer prevention and relapse will not be covered, as it requires a dedicated article.

Foot ulceration is the most serious of all diabetes-related complications (Boulton et al, 2005; Young et al, 2008) and reportedly precedes lower-extremity amputations in up to 80% of cases (Pecararo et al, 1990). Sadly, due to limited resources, education, dedicated foot services and their accessibility, a lower-extremity amputation occurs every 20 seconds somewhere in the world (International Diabetes Federation, 2015). The morbidity and mortality associated with diabetic foot ulceration and amputation is devastating and has dramatic effects on the healthcare and social economies (Kerr et al, 2014).

Clearly, understanding the pathogenesis of diabetic foot ulceration is essential if prevention and effective treatment outcomes are to be achieved. While the presence of diabetes-related peripheral neuropathy cannot be reversed, other significant causal factors can be modified. Thus the successful management of diabetic foot ulceration relies upon effective control of infection, arterial supply and trauma avoidance. Management is only successful, however, when undertaken within a functional and cohesive multidisciplinary team. Significant success can be achieved when this approach is adopted, with one centre reporting up to a 62% reduction in lower-extremity amputations (Veves et al, 1992).

In patients with diabetes-related peripheral neuropathy, the most significant contributing factor to diabetic foot ulceration chronicity and deterioration is the application of injurious pressure or forces, i.e. trauma. This article examines some of the fundamental principles and practical aspects of pressure/force management or offloading.

Overview of forces applied to the foot

Diabetic foot ulceration occurring on the plantar aspect is predominately caused by a loss of protective sensation with a combination of excessive or sustained compressive, shear and frictional forces leading to tissue failure. The two major causes of foot ulceration that are widely reported and accepted are protective sensory loss and 'high or excessive pressure' (Veves et al, 1992; Shaw et al, 1998). It is the authors' opinion that although recognised, they are not always fully appreciated or effectively addressed in clinical practice. The reduction of either excessive or sustained forces to localised areas of the plantar surface is perhaps the most important clinical aspect of ulcer prevention and treatment. Sadly, offloading is

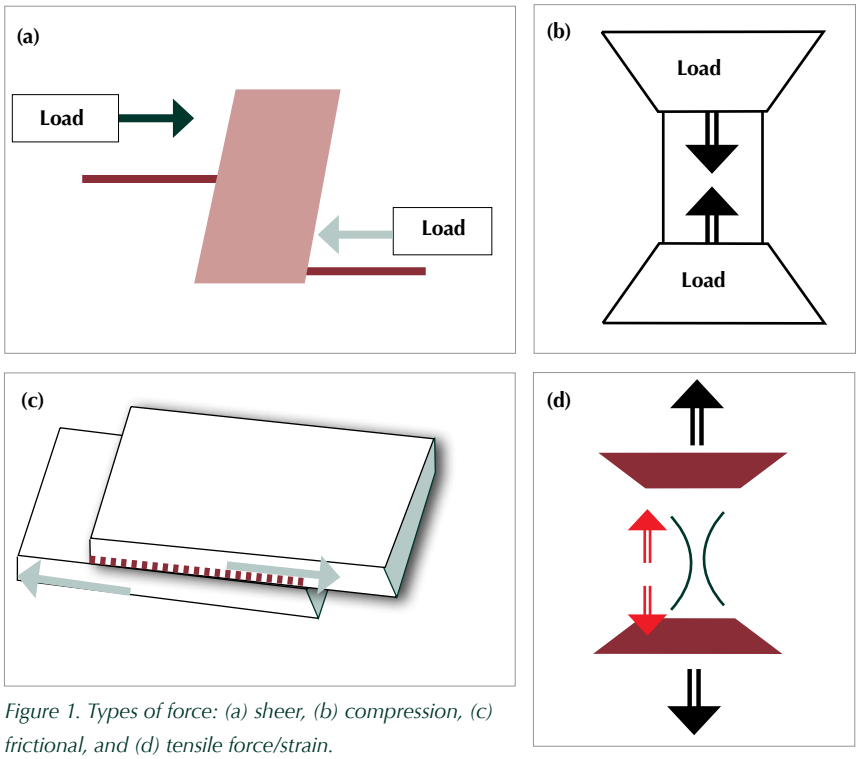

Figure 1. Types of force: (a) sheer, (b) compression, (c) frictional, and (d) tensile force/strain.

frequently overlooked due to lack of training, poor understanding, limited resources or over-familiarity.

This section gives a simple overview of the forces commonly applied to the foot when walking, standing or at rest. Recognising and understanding these different forces is absolutely essential if successful foot ulcer/pressure sore management is to be consistently achieved. Simply applying a cast walker, plaster cast or other pressure-relieving device maybe useful, but will be much more effective when the causative forces are understood, recognised and addressed.

There are four main types of force that are applied to the soft tissues of the foot, whether at rest or during activity:

- Shear force: when a material is moving in two or more directions at the same time due to single or multiple loads (*Figure 1a*)
- Compressive force: when a material is squashed or squeezed between two or more opposing loads (*Figure 1b*)
- Frictional force: when a force moves over the surface of a material while in contact with it, creating a 'drag' across the material's surfaces (*Figure 1c*)
- Tensile force/strain: when a material is stretched by two or more opposing forces (*Figure 1d*).

While looking at *Figure 1*, try to relate the diagrams to a localised area on the foot when walking or standing, for example, the plantar aspect of the big toe. During everyday activities, forces are repeatedly applied to the sole of the foot and/or any shoe contact area. The soft tissues are designed to accommodate and adapt to these forces without tissue damage. If the activity is more vigorous, as in sports, or is sustained while standing all day or lying ill in bed, then the magnitude of these applied forces is increased. The soft tissues are protected from these increased demands by a neural feedback mechanism, causing the body to make slight movements to offload and reload areas under excessive force. If the soft tissues are unable to accommodate these forces due to previous damage or glycation, or there is no neural feedback, damage is likely to occur. This is the case in neuropathic and neuroischaemic foot ulceration. Although the pathogenesis for these types of ulceration is slightly different, the causal pathway is similar.

Forces applied to soft tissues are very rarely singular. Thus, it is important to try to determine which are the most significant forces and find effective ways of addressing them. It is vitally important to remember that whenever force is reduced or removed from one area, it relocates to another. The aim is to reduce injurious forces at an ulcerated site, however, it would be disastrous to create a new lesion by overloading another area.

Other considerations

Successful offloading means that apart from recognising the detrimental forces applied to the foot, other essential factors must be considered, including:

- Magnitude: the size of the applied forces
- Direction: which way the forces are entering and exiting
- Velocity: the speed at which forces are applied and dissipated
- Duration: the amount of time any given force is in contact with the foot.

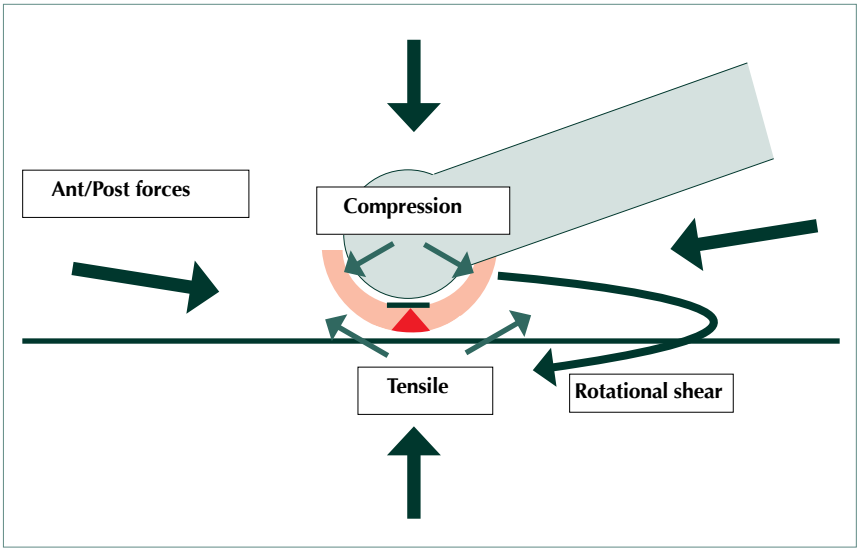

Figure 2. Some of the combined forces applied to an ulcer over a metatarsal head area. The triangle represents the ulcer. Ant/Post = anterior/posterior.

As clinicians, it is imperative that when assessing foot ulceration or pressure sores we account for these essential factors. It is not always possible to remove all force applied to the foot, and thus clinicians must think in terms of reducing the duration, velocity, magnitude and direction of force or its redistribution.

Although there are many other principles that could be discussed, there is one that is very important when considering any offloading technique or device: the physical law that states 'the pressure under a curve is inversely proportional to the radius of that curve'. This means that the smaller the curve, the greater the pressure/force beneath it. The margins of the feet and tiny bony prominences are already under a high degree of intrinsic pressure. *Figure 2* illustrates the concept of forces and their direction when applied to an ulcer over the metatarsal head area on the sole of the foot. If we consider a loosely- or tightly-fitting shoe together with a compromised arterial blood supply, we can understand how and why neuroischaemic ulceration occurs. In the neuropathic foot, although the shoe rub may go unnoticed, it will take longer for tissue damage to occur due to good blood flow.

Clinical application

It is the authors' view that there are only three reasons a wound will not heal: inadequate blood supply, infection and trauma. Furthermore, it is well-recognised and accepted that offloading is one of the cornerstones of successful diabetic foot ulceration management and prevention (da Oliveria and Moore, 2015). Various types of cast are used for offloading pressure in practice. Plaster of Paris, which was traditionally used to make casts, has been replaced by fibre-glass or polyester resin cast bandages. These are easy to use, set quickly, are very rigid and lightweight. There are many different devices and techniques available, however, not just casts. The most common devices are briefly discussed in this article. The authors recommend reading the 2015 systematic review on behalf of the International Working Group on the Diabetic Foot as it gives a very clear, comprehensive and helpful overview of the topic (Bus et al, 2015). It is imperative to state that when considering offloading devices, 'one size does not fit all'. Thought must be given to several factors, some of which are discussed below.

Commonly used offloading methods

Cast devices

According to the reported data, non-removable cast devices are the most clinically effective for neuropathic forefoot and mid-foot ulceration. The overriding principle of all casts is to 'spread' the load from a small to a large area, reducing the unit of the load. Perhaps more important is the effect of immobilisation of the foot and ankle within the cast, which significantly reduces shear force. To date, few scientific data support this theory due to a paucity of appropriate shear transducers, but it appears to be a logical outcome.

Windows may be cut into cast devices but a very high-pressure area can occur at the window edges due to the compressing mass of the body and rigidity of the cast material. In some instances, this may be sufficient to cause the ulcerated area to protrude through the cast or cause tissue damage at the wound's margins. Careful consideration should thus be given to whether or not a window is appropriate.

There are a few contraindications for casts. These include infection, ischaemia, loss of sight and poor balance.

Total contact casts

The total contact cast (TCC) is a below-knee cast that incorporates the whole lower limb, encasing the whole foot. It is the accepted gold standard for the offloading of mid- and forefoot lesions (*Figure 3*) and there is a body of evidence to support its use (Bus et al, 2015). The TCC is also the gold standard form of offloading for neuropathic non-infected plantar ulcers, reportedly healing between 72 and 100% of ulcers within 5–8 weeks (Mueller et al, 1989; Armstrong et al, 2001). Despite this, the technique is not widely used in clinical practice, possibly due to a lack of education, training, and resources.

Total contact casts (TCCs) were traditionally made from plaster of Paris bandage intimately moulded to the lower leg and foot with padding only over the toes, malleoli and tibial crest. Nowadays, this intimate layer of plaster of Paris is covered by quickly-setting very rigid outer layer(s) of synthetic cast bandage. A piece of plywood is placed under the whole foot and is incorporated into the cast, with all of the hollows and cavities being filled with plaster of Paris bandage. Finally, a small rubber rocker is placed centrally under the cast to weight-bear upon.

Below-knee walking cast

The below-knee walking cast is the same type of cast used for setting lower-leg fractures, with some additions. Generally, accommodative padding is applied to the contours of the foot and some under-cast padding to the leg and bony prominences before the cast tape is applied. The ulcerated area can be left totally enclosed or a window cut for inspection and re-dressing. Below-knee casts are not considered to be as effective as a TCCs; however, they both immobilise the foot and ankle, thus reducing shear and activity levels (Caravaggi et al, 2000).

Scotchcast™/fibre-glass/polyester resin boots

This method was originally called the Scotchcast™ or Leicester boot. It was developed in the 1980s at Leicester Royal Infirmary in the UK (Burden et al, 1983; Jones et al, 1989). Reported data from trials show that these boots achieve healing in up to 80% of neuropathic foot ulcers (Knowles et al, 2002; Ha Van et al, 2003).

The boots are made from fibre-glass or polyester resin cast bandage and can be either removable or non-removable. Orthopaedic semi-compressed felt padding is incorporated into the cast, covering the sole of the foot, based on the principle of total contact. The boot may have a window cut into the cast to allow for inspection and dressing change if the device is non-removable. Although removable casts allow easy wound inspection and easy dressing changes, they can be left off and slippage often occurs within the cast. An over-cast sandal must be worn with Scotchcast™ boots, producing a discrepancy in limb length. The issue is that any casted or off-the-shelf device that causes a limb-length discrepancy can lead to worsening of ulcers or new spinal or hip problems; instability can pose a problem, especially if the patient has poor eyesight or one-sided weakness (cerebrovascular accident). A Scotchcast boot or equivalent without a cast sandal does not generally do this.

Removable cast walkers/ instant total contact casts

Removable cast walkers are 'off-the-shelf' below-knee cast walkers that generally have a

Figure 3 (above left). Total contact casts are the 'gold' standard treatment for mid- and forefoot lesions.

Figure 4 (above right). Removable cast walkers with a rigid rocker sole unit are held in place with Velcro straps.

Figure 4. Removable cast walkers with a rigid rocker sole unit are held in place with Velcro straps.

rigid rocker sole unit (*Figure 4)*. They have a soft fabric or inflatable lining. They are held in place by Velcro straps that are attached to the rigid outer shell and wrap around the leg area and across the dorsal aspect of the foot. These devices have been shown to be effective, but only when worn (Armstrong et al, 2005). They are expensive, but require little training to apply.

The instant total contact cast renders this type of device non-removable due to the application of a resin cast bandage around the leg section of the cast. This technique has been reported as being almost as effective as the TCC (Armstrong et al, 2005; Katz et al, 2005; Piaggesi et al, 2007).

Removable heel casts

The removable heel cast (*Figure 5)*, is a relatively recently developed technique that uses a flexible cast bandage. A study in the UK is currently under way to examine the efficacy of this device (Jeffcoate et al, 2014).

This device is quick and easy to make, requiring only scissors to cut the cast. It is applied over stockinette bandage and incorporates no under-cast padding. Extra localised layers of cast material are applied to the outer surface of the bandage over the ulcerated area. The authors prefer to make a cavity within this area to accommodate thin dressings and enable additional offloading. Removable heel casts can fit into ordinary footwear or cast sandals and should be replaced when soiled.

General patient advice for casts

All casts should be checked daily by the patient or his/her carer. Casts must be kept dry. Inspections should be carried out for any evidence of:

- Cast rub/sores
- Skin soreness
- Exudate strikethrough
- Swelling at the open ends of the cast
- Malodour
- Pain
- Skin discolouration (if the toes are exposed)
- The cast becoming loose.

If any of these occur, the cast MUST be removed immediately and the limb inspected.

Non-cast offloading devices

Half shoes (healing sandals)

Healing sandals are often called half shoes and need little expertise to fit. These commercially available sandals are designed to offload either the fore or rear foot. They have a thick wedge-shaped sole section that has a thin platform section at the area to be offloaded. They are removable and can allow for bulky dressings, however, they do create a limb-length discrepancy.

The wearer needs to be taught how to wear half shoes/healing sandals, however, and their correct use requires a constant conscious effort. Patient selection therefore requires considerable thought. With appropriate patient selection, these devices can be successful (Giacalone et al, 1997).

Crutches

These are simple, readily available and can be very effective when used correctly and fully. They are cheap and require very little expertise to supply. Their other advantage is that they allow daily wound inspection and dressing changes.

Wheelchair

This is another simple but effective method of offloading. Wheelchairs can be expensive,

however, and are not always practical for daily activity. It must also be considered that the offloading effect is negated when the ulcerated area is in constant contact with the ground or footplate.

Factors to consider when choosing an offloading device

Ulcer type

Neuropathic/neuroischaemic

It is widely believed that the use of cast devices is only suitable for neuropathic ulcers; however, this view is based on the fact that clinical research has almost entirely been undertaken on patients with neuropathy. It may be even more essential to offload those with arterially compromised skin, as even slightly elevated pressure on the skin occludes an already restricted nutritive flow. The design of offloading devices for these two types of ulcer is fairly similar, with slight variations to account for underlying pathologies and foot anatomy.

Infection

The use of offloading is absolutely paramount in the fight against spreading infection. It is the authors' clinical observation, in conjunction with consensus views with other expert clinicians, that the use of offloading techniques may improve the initial response to the laboratory-guided antibiotics prescribed for acute infection.

It is important for clinicians and patients alike to understand that walking, standing on or compressing infected tissue can cause a localised infection to quickly become more widespread. This is because infected exudate is pushed deeper into the tissues and necrosis occurs quickly in devitalised tissues when they are stood or walked upon.

It is essential that an acutely infected wound is not placed into a non-removable cast device. Casts can be used with caution when infection is under control, but very regular wound inspection is vital.

Location

There are certain devices that are more effective in some locations than others.

Rear foot

The heel region is perhaps the most difficult area to offload, heal and prevent relapse. The approach to offloading the heel is one of total pressure relief, particularly when the patient is at rest — either with the foot on the floor or lying in bed. It must be remembered that a combination of low pressure and time will lead to tissue ischaemia and destruction. The devices that are commonly used are:

- For weight-bearing: crutches with or without a below-knee cast, a half shoe (with thin heel section and thick forefoot section) or a flexible heel cast.
- For non-weight-bearing: commercially-available leg trough, pressure-relieving mattress, flexible heel cast or pillows. Using crutches to prevent heel strike is very effective when walking and standing. At night, a pillow or rolled-up blanket placed under the calf can be used. This site proves a challenge for effective offloading, especially during prolonged spells in bed.

Mid-foot

This area is best served by the use of a non-removable cast, e.g. a TCC, below-knee cast or fibre-glass boot. Felt padding can be shaped to cover the sole of the foot with a cavity at the ulcer site. It should be built up until a flat surface is obtained. Where casting is not available, a piece of rolled up firm-density foam secured either side of the mid-foot ulcer may be effective.

Forefoot

Any device that does not allow the foot to move into full loading during the propulsive and toe-off phase of gait, whereby preventing forefoot loading should be should be used for this ulcer site. A half shoe may be useful, but a leg- or boot-type cast is the most effective method for offloading (Bus et al, 2015). A customised sandal with a foam-filled sink in the sole unit located over the ulcer site may also be useful.

Toe area

Here the predominant reason for foot ulceration is shoe rub. To protect ulcerated toes in

footwear, the uppers should not touch the toes; however the shoe fastenings must be sufficient to prevent the foot from moving. Arguably the most effective method is to cut a hole in the part of the shoe overlying the ulcer site or to remove the whole toe section of the shoe. Patient permission must be obtained before doing this. Uncontrolled pressure relief in this area frequently leads to osteomyelitis and resultant amputations.

Amount of exudate

During the acute stages of ulceration or in the presence of oedema and infection, there is frequently a large volume of exudate produced daily. This can leak into the cast and become malodorous or a source of infection. In these situations, therefore, cast changes must be frequent. Anecdotally, we have observed that when offloading is effective, the levels of exudate reduce quite quickly.

Spinal and balance problems

Great care must be taken to consider the effects different offloading devices may have on other conditions such as the load applied to a scoliosis or osteoarthritis in the knee, hip or spine. Consideration must also be given to an individual who has poor balance, has had a cerebrovascular accident, or is blind, etc.

Fixed or removable cast?

Whether a patient should be given a removable or non-removable cast should be carefully considered. Non-removable casts are ideal — if a cast can be removed, it probably will be, and will only be worn when attending clinic appointments.

Some individuals suffer from what we term 'cast phobia'. This is like claustrophobia, where a patient feels they must be free of the cast. It induces similar symptoms to a panic attack. In these uncommon cases, a removable device or crutches are the only viable options.

Skills/competencies

The acquisition of knowledge is easy now, as the internet and YouTube video clips show people how to do just about anything. The application of acquired knowledge is a different matter altogether, however, and generally requires some degree of training and then mentorship with a governance system in place. Adopting a reflective practice attitude and discussing practice with experienced clinicians is a good model to help clinicians develop skills.

Education

Despite all the aforementioned factors, one of the most effective and perhaps most frequently overlooked factors in offloading is education. Facilitating patients to clearly understand the impact of standing on an open wound and helping them to discover ways that they can offload their ulcer is far more efficacious than simply saying: 'Keep off your feet.'

Conclusion

Offloading techniques and devices can be effective in the management of diabetic foot ulceration and the prevention of lower-extremity amputations. The secret to success is in determining the types of injurious forces and relating these to the application of offloading modalities and reassessing their effects at each patient visit. ■

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