Contents

CHAPTER

30 Systematics of pressure relief

Dirk Hochlenert, Gerald Engels, Jan Kottner

30.1 Pressure relief in diabetic foot syndrome

Dirk Hochlenert, Gerald Engels

Key notes

- The causal treatment of pressure related damage to areas of the foot is to offload them. Treatment can also include infection control and further treatment of causes, such as revascularisation.
- Offloading can be achieved by reducing steps and by redistributing load. The limitation of the number of steps is easy to prescribe and popular, but it is not beneficial to patients in the long run and is unsuitable outside of inpatient facilities. Load redistribution is achieved by performing operations (internal offloading) or by devices (external offloading). Standardisation is possible depending on the anatomical localisation (entity concept). External offloading is achieved by spacers, by tilting the foot (eversion/inversion) and by immobilising joints.
- Offloading is underestimated. Patients underestimate its importance and the practitioner underestimates it to the extent of omission. Any offloading devices which are seen as indispensable, must not be removable. Offloading must allow the patient's everyday mobility.
- Offloading should be absolutely dependable when treating ulcers whilst in prophylaxis, compromises are possible and often necessary.

30.1.1 Introduction

Loss of protective sensation (LOPS) is the main characteristic of diabetic foot syndrome (DFS). LOPS is irreversible and so, the diabetic foot persists for the entire life. It will switch back and forth between active phases (ulcers and active Charcot's foot) and inactive phases (prophylaxis). The basic measure is therefore to restore protection by offloading ulcers and immobilising the Charcot feet. In the prophylactic phase, the aim is to reduce the likelihood of overloading and to thereby make a renewed active phase less likely.

Overloaded areas of the foot are found on the sole, side areas of the foot, on toes, back of the heel and sometimes in other areas, such as amputation stumps. Areas which are not under pressure physiologically, but which become a contact or support area due to pathological changes in the biomechanics (plantarisation), occupy a unique position. These plantarisations often only occur when the foot is loaded and are therefore overlooked when at rest. A biomechanical examination is therefore necessary to achieve effective offloading. It helps to identify the causes of overloading and to determine which areas are suitable for increased loadbearing.

The immobilisation of joints and offloading are two different treatment concepts. Immobilisations are achieved by using cross-joint aids which also contribute to offloading. They are decisive in the treatment of the Charcot foot and are also highly effective in offloading ulcers and ulcer-endangered areas. However, they are also associated with disadvantages. For example, the muscles which should have been used to move the immobilised joints atrophy, and the risk of falling will increase with bulkier, heavier devices. A combination of different load redistribution methods can avoid the need for immobilisation.

30.1.2 No overloading without bone prominence

Overloading occurs above a bone protrusion area. The superficial tissue layers, including the skin, are pulled, stretched, and thinned out over these bony lumps or spurs. External pressure from the environment also squeezes these layers. The number of bony protrusions is limited. It is also not by accident that certain bony protrusions are overloaded, as the biomechanical characteristics of the individuals walking cycle determine the location. It is possible to determine its biomechanical background by looking at the wound location and to normalise the offloading accordingly. The lesion site characterises a subgroup of the DFS, the entity ➢ Fig. 30.1). According to the entity concept, each entity has a typical biomechanical relationship between overloading and possible offloading techniques.

It is easy for a therapist to recommend offloading by advising patients not to walk or reduce walking. However, this advice has many flaws. It limits mobility, independence and working ability. Reduced mobility also causes other health issues.

Fig. 30.1 The different entities on the foot (overview image). [P587]

Offloading measures should redistribute load instead, be nonremovable and allow everyday mobility without putting the ulcer under stress. Surgical procedures help to relieve pressure internally and have a decisive advantage over conservative procedures, as they cannot be forgotten or not complied with for any other reasons.

Since the offloading measures might have an impact on the patient's everyday life, they must be discussed extensively with the patients. Patients are the experts in their everyday lives and know best what they can and cannot do. The focus of offloading measures should be as effortless as possible and not require the patient to pay too much attention. The focus should also not be dependent on their pain perception from overloading as their nervous system can no longer detect any pain due to the impairment; this is called LOPS. Other sensations can remain unimpaired and neurological tests can appear normal, or sensations such as tickling can even be perceived as exaggerated, which makes diagnosis difficult. It is primarily based on the ease with which the patient uses his injured foot, rather than on neurological tests.

Communicating and selecting recommendations are also based on the patient's felt body (loss of sensation, ➢ Chap. 43.5). The patient becomes alienated from their foot, which is only perceived as part of the surrounding environment. The practitioner must be aware that removable devices will be disregarded, at least for parts of everyday life.

The goal is to combine the protection of the foot and everyday mobility. If this is successful, wound closure is secured and recurrence can be prevented.

30.1.3 Load redistribution through adhesive pads

There are materials available which can relieve the bony protrusion under the wound by supporting the associated bone at a certain distance from the wound itself. They are made of a semi-solid material and are positioned at least about 3 mm from the margin of the wound. Soft pads applied directly on the wound on the other hand have disadvantages. They increase the contact surface of the caved-in bone protrusion by including the immediate surroundings in loadbearing tasks. This pressure at the wound margin would be

counterproductive. Similarly, circular relief rings are harmful at the plantar surface and cause window oedema. The bone protrusion also sinks through the wound into this recess, stretching the wound and traumatising the wound margin. In most cases, the ring is not completely able to prevent the sinking bone projection colliding with the contact surface.

Spacer pads can not only support the foot in the area of the wound but can also tilt it so that the walking cycle uses the plantar surface distant from the wound. A raising of the outer margin thus relieves the outer margin because more of the load is placed on the inner margin during the walking cycle.

30.1.4 Insole

In the manufacture of an insole, the same principles apply as with adhesive pads. However, since the foot shifts on the insole, the support cannot be planned so precisely. The adhesive pads are constantly attached to the foot, while the patient can simply disregard the shoe with its insole. An advantage of the insole is that there is no need for a replacement after every dressing change. With an existing ulcer, the advantages of adhesive pads outweigh the advantages of the insole. On the other hand, if there is no existing wound, the insole is the preferred choice. Both can be combined.

30.1.5 Shoes

A shoe (➢ Fig. 30.2) not only protects against adverse environmental influences, but it can also change the pressure on the sole of the foot during the walking process. Most of all shoes are used for walking, and the patient must be able to walk well in them. For this purpose, the properties of the sole are decisive. The sole is slightly curved, with the tip of the sole curving upwards towards the toe. The heel area should be higher than the ball of the foot.

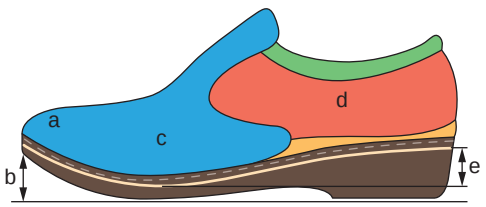

Fig. 30.2 Illustration of a shoe from the side with **a** toe box, **b** toe spring, **c** vamp, **d** quarter, **e** heel seat. The shoe has a ball roller and a sole stiffener (light yellow). The firm hold is generated between instep, sole and heel. The shoe has lacing or Velcro fasteners on the instep. [V864/L231]

This curved sole is also called 'roller' or 'rocker bottom sole'. The toes need to be extended less in the metatarsophalangeal joint, since the curvature of the sole already takes over part of this necessity imposed by the gait cycle. This reduces the pressure on the metatarsal heads. The foot can stand in a relaxed position on the curved sole by adjusting the thickness of the sole. The curvature is flatter on the surface in touch with the foot than on the outside. The extent of the curvature, its apex, position, and rotation are crucial for load redistribution and smooth walking. Since every person walks differently, the demands made are different. People with neuropathy can provide limited information which makes it challenging to design the shoe. Stiffening the sole can further increase the offloading effect of the rocker bottom sole. The toes can then no longer be dorsally extended in the metatarsophalangeal joints, and the function of this joint movement is taken over by the rolling sole. The shoe however becomes thicker, heavier, and clumsier which counteracts mobility. It should therefore be considered whether the affected person needs this stiffening.

If customised shoes are not based on the patient's individual needs, but according to the motto 'the more, the better', there will be a risk of non-compliance on wearing the shoe. In these cases, a patient may wear any shoe considered to fit. Objections made by patients such as 'But I can walk better with this' should therefore be taken seriously as they will point out that changes to the shoe are necessary. These compromises may also bring about an increase in comfort while reducing relieving properties.

In prophylactic therapy, these shoes are classified as comfort shoes (not covered by insurances in many countries), protective shoes or custom-made shoes. When treating ulcers, therapy shoes are used. They also accommodate thick layers of bandage. Many therapeutic shoes, so-called forefoot-offloading shoes or hindfoot-offloading shoes, are **not** endorsed by many including the authors, because it is possible that they can generate new high-pressure areas or reinforce existing overloading.

30.1.6 Knee-high, non-removable casts

These are given the highest recommendation in the international guidelines, according to current evidence as well as being the most traditionally used. With the introduction of wound treatment for diabetic feet as a continuation of the treatment of leprosy patients by Paul Brand at the end of the 1970s, the leg was plastered in Total Contact Cast (TCC) after wound care, and left until the next dressing change. Attempts at using 'windows' in the plaster were not successful.

With the introduction of plastic materials and the possibility of sawing the plaster into two shells or even using it as a prefabricated, ready-made orthoses, this practice was abandoned by many. Treatment of the wounds became possible, and the procedures could be used also by non-specialised clinics. However, the results are worse. Hidden pedometers prove that even under study conditions, 870 out of an average of 1,220 steps per day were taken without these aids. Attempts are being made to address this with disciplinary measures such as cable ties, which met with understandable resistance and failed to gain general acceptance. The superior standard method which has been used for centuries, is now broadly ignored. On the contrary, there are discussions about whether this standard should be adapted to current practices and to amend the guidelines, despite poor compliance from the patient. The authors support a TCC with two shells, of which the ventral, front part is divided again, and the proximal part is attached again so that the TCC becomes 'non-removable'. A large window is created in the ventral part of the TCC, through which the foot can be pulled out of the TCC and treated. This is a Ventral Windowed TCC or VW-TCC (➢ Fig. 30.3).

30.1.7 Further procedures

When discussing the individual lesion sites on the following pages, a concern is a particularly increased risk of peripheral arterial disease (PAD). In principle, a PAD can play a role in wounds in all locations. This circulatory disorder reduces the patient's defence against infection as well as the proliferation of new tissue layers for repair. It contributes to tissue destruction, which maybe later becomes an unavoidable indication for amputation. Therefore, the timely improvement of circulation is crucial. When a relevant PAD exists, and there is no progress in ulcer closure, improvement of blood circulation should be discussed. In the case of an indication of blood circulation-related disorder as the causal factor for a non-healing wound, actions

Fig. 30.3 VW-TCC (Ventral Windowed Total Contact Cast): **a** closed state, **b** open state. One advantage is the possibility of responding to individual needs. In this case, an additional flap was attached to the calf. [P587]

must take place without delay. Typically, neuropathy does not cause pain and other typical symptoms such as intermittent claudication. The widely used pain-based Fontaine-Classification must not be applied in DFS. Lack of pain should not be the reason for delayed follow-up or to delay revascularisation indications.

30.1.8 Entities in detail

➢ Table 30.1

Entity 1 – the tips of the hallux and Entity 2 – the 2nd to 4th toe The leading cause is a plantarisation

Table 30.1 The entities of the diabetic foot

Nr.	Entity	%	Special features
1	Tip D1	6.1	Before attributing the cause to shoes, clawing has to be excluded (push-up test, claw test and standing). Tenotomy of the FHL tendon is a low-complication permanent solution. Additional nail bed involvement is an indicator of revascularisation needs (18.1%) and high risk (4.9% major amputation).
2	Tip D2–D4	10.3	Tenotomy of the FDL tendon is low-complication and permanently effective, a spacer in the flexion fold is a short-term solution.
3	Torsional lesion D1 medial	6.1	Protracted, high risk of recurrence, provocation tests for functional plantarisation and good chance with tenotomy of the FHL tendon.
4	Medial 1st MTH	3.1	Rare opening of the joint, even if it appears so.
5	IP joint D1 plantar	2.9	High recurrence rate (50.5% in the subsequent year), hallux rigidus can be functional: test!
6	Nail bed	12.1	90% of D1, prognosis good, nail extractions usually not useful.
7	IP joint D1 dorsal	1	Frequent bone involvement. This is not a necessarily an indication for amputation! Combined tendon surgery to reduce zigzag deformity is a permanently effective alternative in many situations.
8	IP joint D2–D4 dorsal	6.5	Short-term: spacer pads, long-term: toe straightening through soft tissue intervention, effective and low risk of complication.
9	Interdigital	5.5	Often bone involvement, fewer relapses.
10	Small toe	3.5	Often bone involvement, rotation treatable with tenotomy.
11	MP-joint D5 lateral	2	High bone involvement, high revascularisation frequency (17.7%) and major amputation frequency (2.9%)
12	Base MT bone 5 lateral	0.9	High frequency of revascularisation and major amputation.
13	MTH1 plantar	6.7	Recurrences very frequent (over 50% in the subsequent year), many possibilities for internal relief.
14	MTH2–5 plantar	8.7	Internal offloading with high potential.
15	Ankle tip	1.9	Lesions with an exacerbation just above the bony prominence often caused by PAD with a high risk of major amputation.
16	Ankle area	2.1	Compression therapy concerning PAD and malleoli (perimalleolar pads), lengthy.
17	Calcaneal tuberosity	3.2	Prophylaxis is essential, also perioperative, high frequency of major amputations (4.3%) and long courses of treatment.
18	Heel: Sole and edge (rhagades)	5.6	PAD important, even a narrow necrosis margin is an alarm signal, major amputations.
19	Sole in unstressed areas	1.7	Prognosis generally good.
20	Back of the foot	2.2	Average forecast.
21	Rhagades on fore-/midfoot	1.3	Prognosis generally good.
22	Scars	5.7	Re-ulcerations in the scar area expand rapidly into the depths and often have serious consequences.

of the tip of the toe by a muscle imbalance that turns the toe into a claw. The force of the long flexor tendons predominates. They have their muscle in the calf and pull the toes towards the plantar side. The straight alignment of the proximal phalanx by muscles in the foot (Mm. interossei) is weakened by distal motor neuropathy to such an extent that each pull on the distal phalanx automatically leads to a zig-zag-deformity. It can also cause lesions on the back of the interphalangeal joints and under the metatarsal heads. Since the clawing movement may become apparent only under stress, it needs to be provoked. Without such a provocation, the cause may be seen erroneously in a shoe, since suspected shoes are common and can obscure the actual cause, the clawing of the toes, when viewed cursorily. These provocation tests are:

- Push-up test: in a patient lying down with a relaxed foot posture, by exerting pressure at the level of the metatarsal heads, the foot is brought into a 90° position in the ankle joint.
- Claw test: the patient is asked to turn their toes into a claw while lying down.
- Stand: observation of the patient getting up.

A second, rarer cause is the tip of the toe pressing against the inner lining of the toecap within the shoe.

Conservative measures can be: a pad in the flexion fold of the affected toe relieves the tip (➢ Fig. 30.4c). The materials used to make this pad vary and range from simple felt to orthosis individually made by podiatrists. In shoe manufacturing, the padding under the toes can be softened. But in the end, shoe design is relatively powerless in the long run against the strong muscular force that continues to turn the toe into a claw.

The surgical procedures include:

1. Cutting the long flexor tendon
2. Loosening the joint capsules of the proximal interphalangeal joint (PIP) and the metatarsophalangeal joint (MTP)
3. Lengthening or cutting the long extensor tendon

On this occasion, avital bones will also be removed. These procedures show excellent results with rare complications and are also possible with restricted blood circulation and anticoagulation or with platelet aggregation inhibition.

Entity 3: torsion of the hallux The medial side of the hallux can rotate in plantar direction (downwards), involving the joints of the metatarsal bone. As another factor allowing rotation, the foot can deviate into a pronated and outwardly turned (abducted) position. In the last phase of the gate cycle, the medial side of the distal phalanx takes much of the load and is not provided with sufficient protection for this effort. There, two bone protrusions dominate: the IP joint and the medial edge of the distal phalanx.

Conservatively, a condylar pad is used for offloading (➢ Fig. 30.5b). It relieves the medial condyle and puts

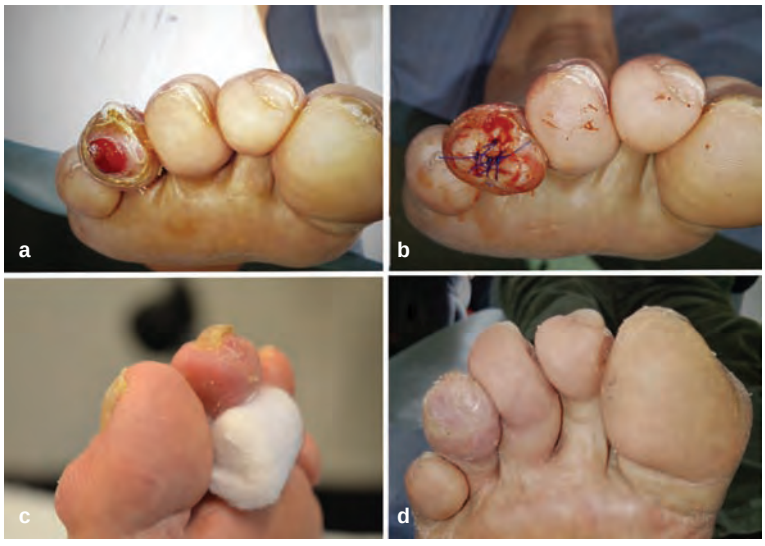

Fig. 30.4 Toe tip lesion: **a** ulcer on the tip of the 4th toe before debridement; **b** treated ulcer supplied, closed with a primary suture; **c** hollow moulded pad; **d** toe from **a** and **b** after wound closure, offloading here through tenotomy of the long flexor tendon. [P587]

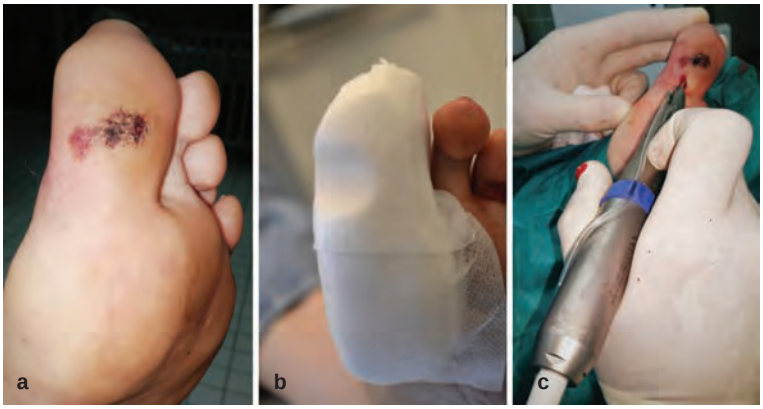

Fig. 30.5 Ulcer of the 1st toe due to torsion and overstretching in hallux rigidus: **a** visual appearance, **b** with condylar pad, **c** medial condylectomy in minimally invasive technique. [P587]

the stress on the tip and metatarsal head (MTH) 1 and 2. This is more difficult to reproduce in an insole than with adhesive felt in the acute phase, but still possible. The shoe can also help to offload a little with a sole stiffener and a rocker-bottom sole.

With a tenotomy, the surgeon can sever the tendons causing the rotation.

Entity 4: hallux valgus Hallux valgus is described as the combination of a medially deviating metatarsal head with a laterally pointing 1st toe. In this deformity, there is an exposure of the head of the 1st metatarsal bone to medial pressure. An injury here does not lead to bone contact as frequently as might be assumed since fibrous structures such as the tendon of the abductor hallucis muscle between the skin and the MTH provide a certain degree of protection.

Offloading is the domain of conservative treatment with sufficiently broad footwear and padding in front of and behind the metatarsal head. A reduction of the wound surface can be achieved by minimally invasive surgery with a transcutaneous 'lateral release'. This is not one of the established procedures of hallux valgus surgery. These procedures should be considered after wound closure because of the need to introduce foreign material such as screws.

Entity 5: IP joint of the hallux The plantar side of the hallux's IP joint, centrally or slightly medially, comes under pressure due to a hallux limitus or rigidus (➢ Fig. 30.5). In these two deformities, the 1st toe's metatarsophalangeal (MTP) joint is partially (limitus) or completely (rigidus) stiffened. However, the dorsal extension of the 1st toe is necessary during the gate cycle. If this dorsal extension in the MTP joint is no longer possible, there will be overstretching of the IP joint instead. This joint is physiologically not intended for a dorsal extension, and the skin on the plantar side of the joint is not prepared to be subjected to pressure. In case of stress from overstretching, the plantarised skin may express an ulcer under the medial condyle of the joint.

Conservatively, offloading with condylar padding is possible. In the shoe, the stiffening of the sole prevents further overstretching when attempting dorsal extension in the IP joint. Slipping in the heel area should be prevented to avoid increased pressure under the hallux.

The surgical procedures range from resection of the medial condyle, which is the least invasive procedure (➢ Fig. 30.5c), to the Valenti procedure with a dorsal V-shaped partial resection of the metatarsophalangeal joint of the hallux.

Entity 6: nail bed injuries Nail bed injuries are frequent. Causes vary from structural changes of the nail in nail pathologies such as onychomycoses or psoriasis to traumatic injuries and ingrown toenails. An appearance like an ingrown toenail needs a meticulous analysis of the underlying cause of inflammation. Repeated lingering traumas in the nail fold (sulcus) lead to a state of irritation as well as infections and errors in care resulting in an ingrown nail. The causes are trauma from extrinsic factors (footwear or neighbouring toe) or pressure of the soft tissue against the nail as a consequence of malpositioning of the toes.

Conservative treatment consists in podological care and therapy of nail problems. Nail mycosis can be eradicated with medication but tends to recur. Nails

which were previously damaged by pressure are predisposed to fungal infection. Selecting broader shoes, especially at the toe box, avoids pressure on the nail. The toe box should not contain any stiffening materials.

Ingrown toenails are also treated surgically, e. g. by phenolisation (partial nail avulsion), or other destruction of the nail matrix of the nail part close to the sulcus. The cause of the situation is particularly well treatable when repeated pressure from the side or plantar causes irritation of the sulcus, which can easily be misinterpreted as an 'ingrown nail'. The pressure can be removed permanently by a tenotomy.

Entity 7 and 8: dorsum of the 1st toe (7) and the lesser toes (8) at the IP joints These are affected by the typical zigzag malposition. At the hallux (entity 7) and the proximal interphalangeal joints (PIP joints) of the toes 2–4 (entity 8), bony tips are formed by overbending and pressing against the inner lining of the toes box.

Pyramid-shaped spacers, which are attached to the back of the foot above the MP joint, i. e. as distally as possible, have proven successful in ulcers (➢ Fig. 30.6). After the wound has closed, a spacious toe box without stiffening material is recommended.

Severing or lengthening both the tendons of the plantar flexors and those of the dorsal extensors can permanently reduce the zigzag deformity. The capsules of the MTP joint and PIP joint have often shrunk if the deformity has existed for many years; it makes sense to perform a capsule release. In the context of the wound situation, the joint can be removed if it has been opened widely. Since the wound surface will be reduced with the removal of the overbending in the context of tendon-surgical procedures, the wound can often be closed (sutured) in one or two steps.

Entity 9: interdigital lesions Interdigital lesions occur when toes are pressed against each other. The IP joints are enlargements of the toe's diameter that can cause pressure on the skin above the joint itself and on the opposite side. The shoe must be broad enough so that the front portion does not exert pressure on the sides of the toes. The width is expressed in letters and describes the height and broadness of the ball of the foot. Broadness alone describes only one dimension and is less suitable. A certain degree of tightness is necessary for the shoe to give the foot a firm hold. However, the shoe must not be so tight that the toes are crushed against each other. It is difficult to find the correct measure if the patient can no longer provide meaningful information, due to reduced sensitivity. Therefore, it makes sense to fix the foot within the shoe between the instep, sole and heel cap, and to be broad in the area at the front.

Spacers between the toes are problematic because they further restrict the available space. In any case, the authors use a distally doubled-up wound dressing made of flexible foam. Additionally, a small plantar support in the zone between the metatarsal heads can be helpful, reducing the load, slightly distancing the toes from each other.

Surgically, a lateral release in the hallux valgus or removal of the IP joint can be helpful. Resection of the

Fig. 30.6 Ulcer on the back of the PIP joint: **a** visual appearance, **b** spacer pads, **c** after sparing joint resection, **d** after combination intervention with tenotomies of the tendons and capsule-splitting. [P587]

Fig. 30.7 Lateral side of the foot: **a** Quadratus plantae insufficiency with a rotation of the small toe, **b** ulcer at the head of MTH 5 lateral and **c** ulcer at the base of MTH 5. [P587]

joint is simple and should not be confused with the indication of amputation.

Entity 10–12: foot The foot shows five bone protrusions **laterally:** three at the small toe (entity 10) which are very close to each other, at the 5th MTP joint laterally (entity 11), and at the base of the 5th metatarsal bone (entity 12).

The bone protrusions on the 5th toe are very close to each other and are practically impossible to differentiate. They are put under pressure if the small toe twists so that its lateral side becomes the contact surface with the ground (➢ Fig. 30.7a). This rotation, caused by a muscle imbalance, is called 'quadratus plantae insufficiency'. It is corrected by a tenotomy of the long flexor tendon of the small toe. Conservative treatment is possible using spacers on the metatarsal bones. If the cause of pressure against the lateral side of the foot is a deviation of the foot within the shoe, raising the outer edge might limit this deviation.

If the lesion on the 5th metatarsophalangeal joint is strictly lateral, limited blood supply is often involved. Spacers, wide shoes and a resection of the head are possible treatments.

Strictly separated from this is a position at the limit between the lateral and the plantar face of the joint. Tilting of the foot with its lateral margin in plantar direction (inversion/supination), and overloading of the lateral side causes these lesions. The lateral condyle of the 5th metatarsal head is the internal pressure point and can be removed with relatively little effort. Increased tension on the Achilles tendon can maintain this inversion/supination. If this is the case the cause can be corrected with a lengthening of the tendon. Additionally, the 1st ray can be lowered by a diagonal elevation of the outer edge. This is discussed in detail with the overloading on the 5th MTH's plantar tissue.

There is a protrusion at the base of the 5th MT bone at which the tendon of the fibularis brevis muscle (also known as peroneus brevis muscle) is attached. Lateral pressure will damage the skin and soft tissue above it. Removal of the prominence is not possible because then the whole foot supinates as a sickle foot, through the loss of the function of the fibularis brevis muscle. Surgical measures aim at restoring pronation by transferring the tendon of the tibialis anterior muscle to the lateral fibularis-tertius tendon. However, conservative measures and in particular spacer pads and recesses in the shoe are predominantly used. At this lesion site, too, circulatory disorders are described as clinically relevant with above-average frequency.

Entity 13 and 14: metatarsal heads These can exert pressure in **plantar** direction and cause skin damage. Usually, ulcers at this site are considered the typical lesions of the diabetic foot, although they occur far less frequently than toe lesions. Various mechanisms are involved in the high pressure under MTH:

1. These lesions are predominantly purely neuropathic. Vascular problems can also occur, but revascularisation is only performed in 5–8% of cases in specialised care.
2. Besides causing LOPS, neuropathy also causes muscle imbalance with the result of the typical zigzag deformity (see entity 1, 2 as well as 7 and 8). The constantly overextended MT-joint over-

stretches the protective padding structures under the MTH. These protective pads thin out and can even tear. The MTHs become palpable directly under the skin.

3. The fat padding of the sole, typically 1 cm thick beneath the MTHs and even 2 cm under the heel, decreases in people with neuropathy. It is not a direct consequence of overuse and also affects people with neuropathy but without diabetes mellitus. How exactly neuropathy is linked to the degradation of the fat cushion has not yet been clarified.
4. Repeated borderline pressure excess leads to a thickening of the skin (callous), which at the same time becomes less elastic. Due to autonomous neuropathy, the compromised nerves address sweat glands less effectively, which makes the skin drier. This thick, brittle horn plate is bent back and forth with every step and then tears. At the interface to the subcutaneous tissue, spot bleeding occurs. Patients with normal ability to sense pain will notice considerable pain before bleeding occurs, which leads to the interruption of the load. These spot bleedings are the first clear evidence of a limited pain sensation and an urgent warning signal in a patient with neuropathy. A blood-filled blister may develop underneath skin if left unattended, and bacteria will migrate when there are cracks on the surface which come into contact with them. A callous abscess will develop. The liquids will no longer be drained when the cracks become encrusted. If the patient continues to walk, the pus is pushed deeper into the abscess and a defect develops, creating an opening which resembles a borehole, also known in some countries as malum perforans.
5. Additional overloading of the entire forefoot occurs if the Achilles tendon pulls too early and too strongly. It is often referred to as Achilles tendon shortening, even though not the tendon but the muscles (triceps surae) usually constitute the shrinking structure. Sometimes it is only shortened to a certain extent, which on its own would still make walking possible, but together with an increased muscle tone, it works just like a shortening. During the examination, it is essential that the examiner holds the heel with one hand and aligns it just below the lower leg before testing the dorsal extension of the foot.
6. At the 1st metatarsal head, it is usually the medial sesamoid bone that represents the inner pressure point. The 1st metatarsal bone of the hallux valgus deviates medially from the straight alignment. The sesamoid bones are attached to the other metatarsal heads by ligaments and cannot participate in this movement. While the lateral sesamoid bone slips between the 1st and 2nd metatarsal heads and is harmless, the medial sesamoid bone slips out of its mould in the head of the 1st metatarsal bone, and ends up on top of a ridge between both moulds exerting an excessive pressure. At the same time, the oblique metatarsal bone also turns towards plantar with its medial side.
7. While walking, mostly one foot only is loaded at a time. Thus, balancing can be achieved by ensuring that the 1st and 5th metatarsal bones are mobile and operated with muscle power, and not fixed firmly in the tarsal bones. This mobility can be very pronounced, and the muscles can get exhausted. In this case, the two outer metatarsal bones carry less of a load. In contrast, the central metatarsal bones 2, 3 and 4, which are anchored firmly in the tarsus, cannot move. They end up being situated at a lower level with respect to the outer metatarsals and exposed to excessive pressure.
8. Overloading of the 5th MTH occurs when the foot rolls mainly over to the outside. There can be various reasons for this. For targeted therapy, it is essential to recognise when a low 1st metatarsal tilts the forefoot outwards. The Coleman block test serves this purpose: if the heel is viewed from behind while standing, the longitudinal axis is turned inwards through the heel (varus). If the 1st metatarsal is tilted downwards by placing the foot on a block, the edge of which supports the heel and the 5th ray and the 1st metatarsal drops. If this is the case, insoles are effective to reproduce this correction in the shoe. If the heel does not straighten in this position, other – usually operative – measures must be considered. If, however, the heel can basically be aligned with the lower leg and is not aligned in the block test, a shortening of the triceps surae can be the trigger. An extension of the Achilles tendon is then often helpful.

For lesions below the 1st MTH, offloading devices can be attached underneath the foot to ensure full offloading (➢ Fig. 30.8). Retrocapital support, a recess

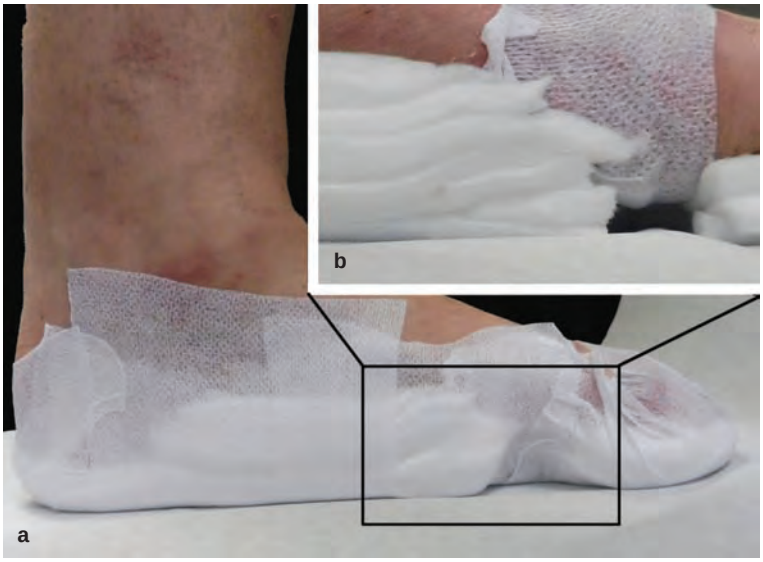

Fig. 30.8 Offloading of an ulcer under MTH 1: **a** seen from medial side with fixation, **b** detail without fixation. Seven layers of felt can be observed retrocapitally. [P587]

under the 1st MTH, a toe balcony, and support of the medial arch with the redistribution of the load to the lateral part of the foot are used. A similar approach can be applied to the insole. The shoe can also be equipped with a curved sole and maybe a sole stiffener.

Surgically, there are many possibilities to achieve permanent offloading, which is also useful during remission (➢ Fig. 30.9). It largely eliminates the zigzag deformity with tendon interventions and capsule release. Additionally, a wedge can be removed from the metatarsal

Fig. 30.9 Straightening of various toe deformities and thus relieving a plantar wound. [P587]

bone immediately retrocapitally, which allows the head to be tilted slightly upwards. Alternatively, a few millimetres are removed from the shaft, after which the head adjusts slightly further dorsally and proximally. A resection of the entire head is only necessary if parts of the bone or cartilage are necrotic or if the joint is exposed within the wound. It often leads to a bacterial invasion and destruction of the joint surface. However, toe amputation, which is performed in about 10% of cases, can often be avoided if alternative concepts are used consistently and in good time.

For lesions below the 2nd MTH, a toe balcony and support of the neighbouring MTHs, as well as retrocapital support and local recess, also help. The adhesive supports are usually less bulky than for the 1st metatarsal bone. Rocker-bottom soles and maybe sole stiffeners in the shoe additionally relieve pressure. Among the surgical measures, the straightening of the zigzag deformity by needle tenotomy and percutaneous capsule release is often and surprisingly useful for first-time users.

The conservative relief of ulcers under the 5th MTH depends on the simultaneous influence of the 1st MTH. If the 1st MTH is lowered and the inversion of the heel resulting from this can be corrected, the principal offloading technique is to lower the first metatarsal in relation to the entire foot. If not, a simple raising of the outer edge together with a retrocapital support is sufficient.

Removing the lateral condyle of the metatarsal head, a wedge resection or microsurgically removing a small part of the metatarsal bone can correct the internal pressure and relieve stress.

Offloading of the 4th MTH is similar to the 5th MTH.

Beneath the 3rd MTH, involvement of neighbouring MTHs, retrocapital support, as well as a curved sole and maybe sole stiffening are useful. Zigzag deformity can be surgically corrected by needle tenotomy and capsule release. The head can be moved dorsally after a wedge resection, or a piece of the distal, subcapital metatarsal bone can be removed by minimally invasive surgery to achieve dorsal displacement.

Entity 15: ankle and Entity 16: area of the ankle These are therapeutically compressed in chronic congestion conditions. The compression of the ankle area is desired, but not that of the malleolae. Pads are lined in order not to overdo the compression on the tips and to allow it to become effective as much as possible in the depressions. Ankle tips are also susceptible to acute trauma. Accordingly, critical PAD can usually be found in wounds on the tips and not in wounds in the area.

Conservative offloading consists of perimalleolar pads, which fill out the depressed area between the malleolae, Achilles heel and the sole. Surgical procedures to relieve the pressure are not useful here, but plastic surgery procedures to close the wound can be useful, just as with other foot ulcers.

Entity 17 and 18: heel The heel has three areas where ulcers can occur: the tuberosity, the sole and the transition area between them (➢ Fig. 30.10). On the tuberosity, pressure ulcers occur in people who have difficulty in spontaneously changing their contact area with the supporting surface. These are not only people in nursing homes; often these ulcers develop postoperatively. Therefore, prophylaxis must be well organised and not limited to the operating theatre itself. Until the patients have overcome possible somnolence and general postoperative weakness, prophylaxis of the heel must be ensured uninterruptedly in patients with neuropathy, especially in patients with accompanying PAD. The transition area often shows considerable hyperkeratosis and rhagades. In contrast, plantar ulcers rarely develop because of permanent pressure, as can occur in heel runners when the Achilles tendon function has failed. More often, an ulcer occurs after trauma and it is important to remove any foreign bodies which may have entered the ulcer.

Relieving pressure on the heel can be achieved with conservative measures. In ulcers at the tuberosity, these are mainly devices that offload the heel. Pressure on the sole of the heel can be relieved most effectively with orthoses or a TCC, which allow epicondylar support in the area of the tibial head. If the Achilles tendon is functioning, a slight dorsal extension of the foot can help to relieve the heel.

Entity 19–22: atypical areas Atypical areas are areas without a typical bone protrusion and include the sole apart from the heel and the metatarsal heads, the back of the foot, rhagades outside the heel and scars after previous procedures. There is no standardised relief from pressure here. Lesions on scars have a particularly poor prognosis as re-ulceration in previously damaged areas.

Fig. 30.10 Heel lesions: **a** plantar heel, **b** rhagade in a marginal area, **c** pressure of tuberosity, **d** relief of pressure in a flex-cast, **e** tape dressing of a rhagade. [P587]

REFERENCES

Brand P, Yancey P. The gift of pain. Grand Rapids: Zondervan; 1994.

Bus SA, Armstrong DG, van Deursen RW, et al. IWGDF guidance on footwear and offloading interventions to prevent and heal foot ulcers in patients with diabetes. Diabetes Metab Res Rev 2016; 32 (Suppl. 1): 25–36.

Hochlenert D, Engels G, Morbach S, Schliewa Sgame FL. Diabetic foot syndrome – from entity to therapy. Basel: Springer International Publishing; 2018.

Risse A. Phänomenologische und psychopathologische Aspekte in der Diabetologie. Berlin, New York: Walter de Gruyter; 1997.

30.2 Pressure relief for pressure ulcers

Jan Kottner

Key notes

- Existing pressure ulcers must be offloaded.
- If permanent offloading is not possible, the wound must be relieved regularly.
- Specialised mattresses and overlays should be used, rather than standard mattresses.

30.2.1 Introduction

Consistent relief and off-loading of existing pressure ulcers are the cornerstones of any successful pressure treatment. This concerns both early clinical signs such as persistent erythema or dark livid discolourations with intact skin as well as existing wounds (Section 13). Patients should not be positioned on areas of existing or suspected pressure ulcers.

In the case of several pressure ulcers, other health restrictions, or competing therapy priorities, achieving prolonged or even temporary offloading may not be possible. Soft positioning on special mattresses should be an additional consideration. Putting pressure on the ulcers must be kept to a minimum. In the case of device-related ulcers, e. g. through cannulae or wires, the wound must also not be exposed to any

further mechanical influences, i. e. the devices must be removed or arranged differently.

30.2.2 Proper positioning

Pressure ulcers located at typical predilection sites such as the sacral area, trochanter, back of the head or heels can be relieved by traditional positioning techniques which includes 30° to 40° lateral positioning and 135° (abdominal) positioning. Sufficiently large and soft positioning aids such as cushions and rollers should be used. Positioning pads can keep pressure ulcers contact- and pressure free. Patients with pressure ulcers in the buttock area should never directly sit on that area at any time. It is important to do positioning professionally so that the wound is truly and sustainably relieved.

The presence of a pressure ulcer is the strongest predictor that further pressure ulcers can develop. It is therefore imperative that patients do not develop new pressure ulcers, both during the positioning procedure and during the positioning period. All principles of evidence-based pressure prevention must be followed during pressure ulcer treatment, which includes close inspection of all pressure predilection sites.

30.2.3 Special devices for proper positioning

There are several special devices for the positioning or offloading of certain parts of the body.

Heels

For pressure ulcers on the heels, there are many products available on the market for heel off-loading. They are designed so that the lower leg and foot are in a kind of shoe or splint, and the heels are free (➢ Fig. 30.11, ➢ Fig. 30.12, ➢ Fig. 30.13). The type of materials used, the construction, the cost and also the user-friendliness vary greatly. In principle, the aids must ensure that the contact area of the lower leg is considerable and that the Achilles tendon does not rest directly on the support, as this, in turn, represents a risk of a pressure ulcer. Also, the heels must be free,

Fig. 30.11 Auxiliary aid for heel-free positioning I. [V860]

Fig. 30.12 Auxiliary aid for heel-free positioning II. [V861]

Fig. 30.13 Auxiliary aid for heel-free positioning III. [U349]

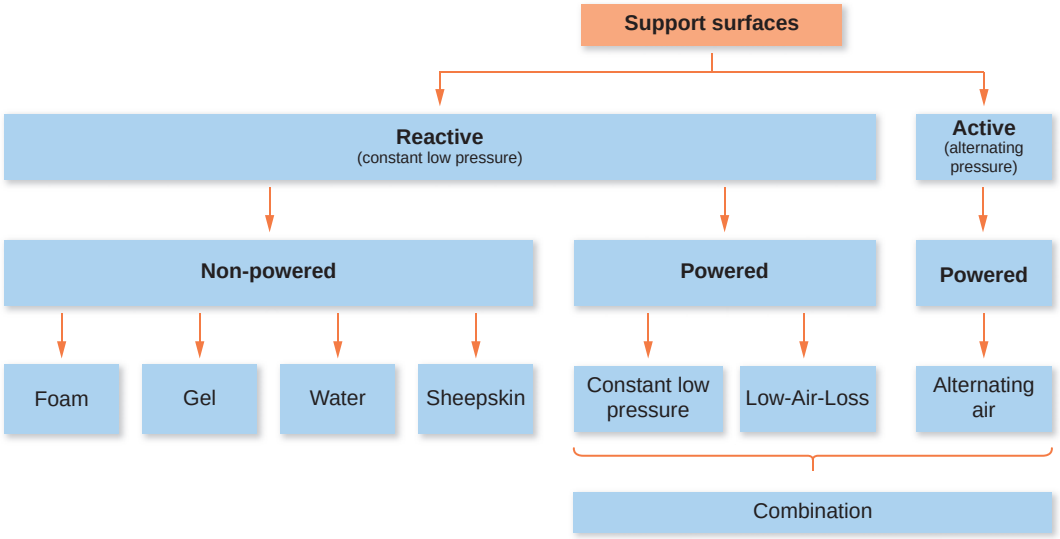

Fig. 30.14 Classification of mattresses and overlays. [P576/L231]

Fig. 30.15 Sinking of the body into a soft positioning mattress. [V863]

and the knees should bend slightly at 5–10°. Finally, the choice of materials and construction should cause as little occlusion as possible. There is currently no evidence to suggest that one device is superior to another for the treatment of heel ulcers. The heels (and feet) must be carefully observed when using aids for heel-free positioning.

Foams and gels

For the optimal positioning of particular body parts, there are numerous other aids such as air-filled cushions, or aids which can be individually shaped and adapted from suitable materials such as cuttable foams or formable gels. These can be useful for certain unique pressure points presenting challenges such as pressure ulcers at the back of the head or the ear or at the buttocks. However, specialised experience and expertise are essential to ensure that this procedure is effective and does not produce undesirable effects, e. g. new pressure ulcers as a result of the use of the device. So-called ring pillows, water-filled bags or gloves should never be used.

Specialised mattresses, overlays and pillows

Pressure-relieving systems are classified into two groups: active and reactive systems (➢ Fig. 30.14). Active systems are effective in alternately aerating and ventilating mattress elements, whereby alternating aeration and relief of skin and tissues can be achieved. Reactive systems allow the body to sink into and become enclosed by the support (soft positioning), which reduces the surface pressure and thus the deformation of the underlying tissue (➢ Fig. 30.15). Many specialised mattresses consist of combinations of both elements.

Pressure-relieiving systems are particularly suitable for the prevention of pressure ulcers. Whenever possible, pressure ulcers should not be in direct contact with these specialised support surfaces. Additionally, guidelines recommend that patients with grades 1 or 2 pressure injuries should at least lie on a reactive system, and patients with grades 3 or 4 pressure in-

juries on an active system. Although the scientific evidence is heterogeneous, it is assumed that healing of existing pressure ulcers on these specialised mattresses is promoted, in comparison to standard mattresses. Air fluidised beds enable maximum soft positioning and do not impede the healing of pressure ulcers.

The selection of special support surfaces should not only be dependent on its effect but also on its practical criteria. Motor-driven and alternating pressure systems can be very stressful for patients, due to the constant noise and movement. Structural conditions such as the size and weight of the system must be correct, and the operating and maintenance costs must be affordable, e. g. for informal caregivers.

REFERENCES

Haesler E (ed.); National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel, Pan Pacific Pressure Injury Alliance. Prevention and treatment of pressure ulcers: Clinical practice guideline. Osborne Park, Western Australia: Cambridge Media; 2014.

McGinnis E, Stubbs N. Pressure-relieving devices for treating heel pressure ulcers. Cochrane Database Syst Rev 2014; 2: CD005485.

McInnes E, Dumville JC, Jammali-Blasi A, Bell-Syer SE. Support surfaces for treating pressure ulcers. Cochrane Database Syst Rev 2011; 12: CD009490.

McNichol L, Watts C, Mackey D, Beitz JM, Gray M. Identifying the right surface for the right patient at the right time: generation and content validation of an algorithm for support surface selection. J Wound Ostomy Continence Nurs 2015 42; 1: 19–37.