The effect of diabetes on the skin before and after ulceration

Lesley Weaving, Roy Rasalam

Diabetes affects the skin in many different ways at a microcirculatory level, making it more prone to injury and ulceration. These changes not only have an impact on healing but also on the resulting scar tissue, which is not as strong as the skin was prior to injury. Eight-five percent of amputations are preceded by ulceration, with re-ulceration rates reported to be as high as 70% after 5 years. This article looks at the changes that occur in the skin of people with diabetes and the importance of skin care before and after ulceration.

A history of ulceration is considered to be a significant risk factor for re-ulceration, and as such, people with diabetes are classed as high risk if they have a history of foot ulceration (National Institute for Health and Care Excellence, 2015). Australia's amputation rate as a result of diabetes appears to have increased in the last decade and is a major contributor to the national burden of condition (Lazzarini et al, 2012). Eighty-five per cent of amputations are preceded by ulcers (International Diabetes Federation, 2016); therefore, the prevention of re-ulceration is an important consideration in reducing amputation rates. Varying rates of re-ulceration have been reported in the literature, but the rate of re-ulceration is known to increase over time from initial ulceration; Miller et al (2014) reported 34% re-ulceration at 1 year, 61% at 3 years and 70% at 5 years.

A critical triad of neuropathy, minor foot trauma and foot deformity is present in >63% of patients' causal pathways to foot ulceration (Reiber et al, 1999). There are many reasons that determine whether people with diabetes develop ulcers, including their vascular status, nutritional status and compliance with preventative therapies, such as custom-made shoes or insoles (Miller et al, 2014). Despite these interventions, one study has reported a 30% re-ulceration rate over a 2-year period, during which individuals received regular podiatric review (Westphal et al, 2011). With this in mind, do we need to consider other factors, such as the health of the skin? What is the effect of ulceration on the skin during and after healing, and does it play a role in the risk of re-ulceration?

The skin

The skin is the largest organ of the body. Its main functions are to act as a barrier to substances entering the body and in the prevention of moisture loss. It helps to regulate temperature and provides sensory information (e.g. pain, touch and temperature). It has three layers: the epidermis, the dermis and a fat (subcutaneous) layer (see *Figure 1*). The epidermis is the thin outer layer, made of five layers. The outermost layer is the stratum corneum, which consists of dead cells and is the major barrier to chemical and bacterial transfer through the skin. The epidermis is thicker on the plantar aspect of the foot and is relatively waterproof. The second layer of the skin is the dermis, which contains nerve endings, sweat glands, oil (sebaceous) glands, hair follicles and blood vessels. It consists of a thick layer of fibrous and elastic tissue, giving the skin its flexibility and strength. Below the dermis is a

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Article points

1. People with diabetes are more prone to skin injury and ulceration.
2. Diabetes impairs the skin's ability to heal.
3. Scar tissue is not as strong as the tissue was before injury.
4. Skin should be kept in the best condition possible to prevent re-ulceration.

Key words

– Healing
– Re-ulceration
– Scar tissue
– Skin

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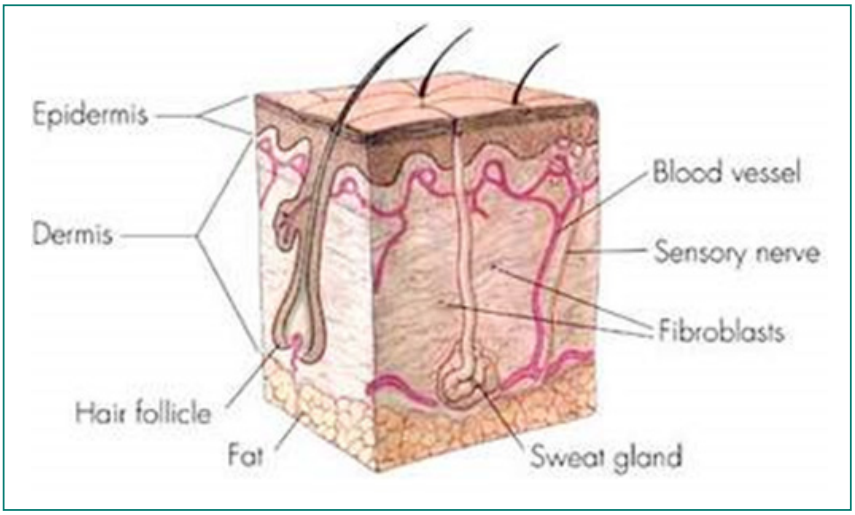

Figure 1. Cross-section through the skin.

Page points

1. Skin conditions, such as infection, xerosis and psoriasis, are common in people with diabetes.
2. Regular moisturising of dry skin is recommended as part of a routine foot care regimen.
3. Scar tissue is not as strong as the original uninjured tissue and so is at increased risk of damage.

subcutaneous layer of fat that helps insulate the body from heat and cold, provides protective padding and serves as an energy store (Health and Safety Executive, 2016).

The healing process

When the skin is damaged, a complex healing process takes place that can be divided into four phases (*Box 1*). The final stage of healing, maturation, lasts from 21 days to 2 years. During this process, epithelial cells reduce the size of the wound. This is followed by re-organisation of the collagen by macrophages to form a scar (Brown, 2015). In healthy individuals, the resulting scar tissue formed after injury has approximately 80% of the tensile strength of normal skin (Ousey, 2009). Many factors play a role in how closely the healed skin resembles the original uninjured tissue, including the size, depth and location of the wound, as well as the nutritional status and overall health of the individual (Teller and White, 2009).

Box 1. The wound healing process.

- **Vascular response (haemostasis)**: injured vessels constrict, a clot forms consisting of a fibrin mesh that forms a scab, and vasodilation of the vessels commences.
- **Inflammation**: occurs in acute wounds 3–5 days after injury and is prolonged in chronic wounds.
- **Proliferation**: collagen fibres form to replace lost tissue.
- **Maturation**: in healthy individuals, this stage commences 21 days after injury. Scarring develops, and the new tissue is avascular and contains no hair, sebaceous or sweat glands.

The effect of diabetes on skin healing

Diabetes can affect the skin in different ways. Autonomic neuropathy is a common complication of diabetes leading to dry skin, loss of sweating and the subsequent development of fissures and cracks that break the skin barrier, allowing microorganisms to enter (Vinik et al, 2003).

It is now understood that a complex relationship exists between sensory nerve function and vascular response in type 2 diabetes. Dermal neurovascular function is regulated by peripheral C fibre neurons, which are damaged in diabetic neuropathy. This results in an imbalance between vasodilators (nitric oxide, substance P, and calcitonin gene-related peptide) and vasoconstrictors (angiotensin II and endothelin). This dysregulation leads to decreased pain and warm thermal perception, leaving skin vulnerable to heat and tissue injury (Vinik et al, 2001).

It has also been demonstrated that there is a reduced oxygen supply within the tissue of people with diabetes, which is accentuated in the presence of neuropathy (Greenman et al, 2005). Other skin conditions are also commonly seen in people with diabetes, the prevalences of which are reported to be between 30% and 91.2% (Demirseren et al, 2014). The most frequently reported skin condition in people with diabetes is cutaneous infection (mainly fungal), followed by xerosis (dry skin) and inflammatory skin diseases such as psoriasis (*Figure 2*). These conditions are more common in people with diabetes who have nephropathy than in those without nephropathy, and those who have an HbA_{1c} of >64 mmol/mol (8%) are at the greatest risk (Demirseren et al, 2014).

Figure 2. Psoriasis is one of the most common skin conditions experienced by people with diabetes.

Vascular endothelial cells line the entire circulatory system, from the heart to capillaries. These cells are important for vascular biology and become impaired not only with age but also as a result of hyperglycaemia, which results in the impairment of blood flow to the tissues (Petrofsky, 2011). When pressure is applied to healthy skin, the affected tissue can become hypoxic; once the pressure is released there is reactive hyperaemia (increase in blood flow) to oxygenate the tissue. Vascular endothelial dysfunction can diminish this response. It has also been demonstrated that in a standing position, the average person still has circulation in the skin but in people with diabetes (even those with normal weight) there is occlusion to the skin (McLellan et al, 2009). This occlusion, together with reduced or no post-occlusive hyperaemia, may be the reason that feet are so susceptible to wounds and skin injury, particularly in people with type 2 diabetes (Petrofsky, 2011).

Emollients

Regular moisturising of dry skin is recommended as part of a routine foot care regimen to reduce the risk of cracking and ulceration. What is not always clear is which emollient to use. There is little evidence available as to the most effective emollient, not only for the general population, but also for people with diabetes. A moisturiser that the patient is willing or happy to use that is supported by the available evidence is preferable. The clinician should also check that the patient likes the smell, texture and absorption of the cream before recommending or prescribing one. There is some evidence that high-concentration, urea-based emollients are beneficial, and these have been shown to improve dryness on the feet of people with diabetes (Bristow, 2013).

For twice-a-day application, it is recommended that an emollient is applied just before getting into bed. Covering the foot with a damp undersock and then a dry oversock may enhance the effect of the emollient (Bristow, 2013). For once-a-day application, the cream should form part of a patient's daily regimen of washing, drying and checking their feet thoroughly. It is recommended that emollients be used to lubricate the skin, but not between the toes (International Working Group on the Diabetic Foot, 2015). A pump dispenser is considered by some clinicians a more user-friendly way of delivering the right amount of emollient than a tub and also decreases the risk of contamination (Carr et al, 2008), although tubes are also commonly used.

Silicones

Once skin has healed, silicone gel has been proven to be effective in scar-tissue management on non-weight-bearing areas; however there is little evidence to support its use on weight-bearing areas (Westphal et al, 2011). *Figure 3* and *Figure 4* demonstrate that silicone gel may be useful in protecting newly healed skin during the maturation process. A person with type 2 diabetes who suffered from psoriasis had developed ulceration and subsequent osteomyelitis at the base of the fifth metatarsal

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3. Further research is required on the most-effective way to care for the skin of people with diabetes.

head, which had healed well with the use of a removable cast device. However, once they returned to wearing their bespoke shoes with total contact insole, the skin re-ulcerated (*Figure 3*). Silicone sheeting was used to protect the area once epithelisation was achieved and for 8 weeks afterwards, and no further ulceration occurred during this time (*Figure 4*). This suggests that the silicone sheeting provided some protection to the newly healed skin during the early stages of the maturation process (Weaving, 2014). However, a pilot study of 30 people with diabetes found that silicone gel sheeting did not reduce the risk of ulceration (Westphal, 2011).

Why it's important to keep the skin healthy

There are many factors affecting a person's skin when they have diabetes. These factors can lead to ulceration and contribute to delayed healing. Poor glycaemic control of diabetes has been shown to affect the microcirculation, along with poor oxygen supply, occlusion in the skin during weight bearing, changes to the vascular endothelial cells, dry skin and reduction in elasticity all putting the skin at greater risk of injury. This is further complicated by the reduced strength of the scar tissue that forms after the ulcer has healed.

Eighty per cent of ulcers are caused by some form of trauma and are, therefore, considered to be preventable (Healy et al, 2013). While custom-made footwear is used to prevent re-ulceration, it appears to be most effective for those with foot deformity (Reiber et al, 2002). Not every insole or shoe is a perfect fit to each patient's foot (Miller et al, 2014). It is therefore important that the skin on the foot is kept in the best condition it can be to cope with the stresses placed upon it, whether it is from shoe wear or simple day-to-day weight-bearing activities.

Conclusion

There is little evidence on how best to look after the skin of people with diabetes. From the available evidence, the healing of a diabetic foot ulcer should not be considered the end result of a patient's journey, but the beginning of a process to remain "healed". We want patients to be active and keep mobile to help with their overall health and wellbeing; however, the impact of diabetes on their skin makes them vulnerable to skin breakdown, particularly where there is scar tissue from previous ulceration. Further research is required on the most-effective way to care for the skin of people with diabetes not just when dry, but also post-healing during the maturation process when the stresses and strains of simple weight bearing could lead to re-ulceration and, subsequently, potential

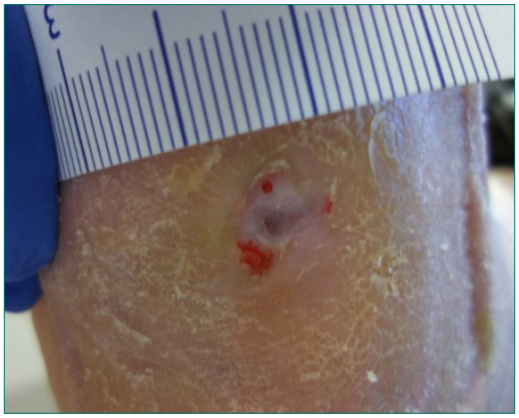

Figure 3. A patient with type 2 diabetes and psoriasis experienced re-ulceration after changing from a removable cast device back to their bespoke shoes.

Figure 4. The patient continued to use silicone sheeting for 8 weeks after the ulcer had healed, which prevented re-ulceration.

loss of a limb. This is a worthwhile endeavour when we consider that every 30 seconds a lower limb is lost somewhere in the world as a consequence of diabetes (Boulton et al, 2005). ■

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Boulton AJ, Vilikyte L, Ragnarson-Tennvall G et al (2005) The global burden of diabetic foot disease. *Lancet* **366**: 1719–24

Bristow I (2013) Emollients in the care of the diabetic foot. *The Diabetic Foot Journal* **16**: 61–6

Brown A (2015) Wound management 1: Phases of the wound healing process. *Nursing Times* **111**: 12–3

Carr J, Akram M, Sultan A et al (2008) Contamination of emollient creams and ointments with Staphylococcus aureus in children with atopic dermatitis. *Dermatitis* **19**: 282

Demirseren DD, Emre S, Akoglu G et al (2014) Relationship between skin diseases and extracutaneous complications of diabetes mellitus: clinical analysis of 750 patients. *Am J Dermatol* **15**: 65–70

Greenman RL, Panasyuk S, Wang X et al (2005) Early changes in the microcirculation and muscle metabolism of the diabetic foot. *Lancet* **366**: 1711–5

Healy A, Naemi R, Chockalingam N (2013) The effectiveness of footwear as an intervention to prevent or to reduce biomechanical risk factors associated with diabetic foot ulceration: a systematic review. *J Diabetes Complications* **27**: 391–400

Health and Safety Executive (2016) *Structure and functions of the skin*. HSE, London, UK. Available at: http://bit.ly/ZIW36y (accessed 02.09.16)

International Diabetes Federation (2016) *Diabetes and the Foot*. IDF, Brussels, Belgium. Available at: http://bit.ly/2cUTPJB (accessed 13.09.16)

International Working Group on the Diabetic Foot (2015) *Prevention and management of foot problems in diabetes: a Summary Guidance for daily practice 2015. IWGDF Guidance documents*. IDF, Brussels, Belgium. Available at: http://bit.ly/2kLpS69 (accessed 22.02.16)

Lazzarini PA, Gurr JM, Rogers JR et al (2012) Diabetes foot disease: the Cinderella of Australian diabetes management? *J Foot Ankle Res* **5**: 24

McLellan K, Petrofsky JS, Zimmerman G et al (2009) The influence of environmental temperature on the response of the skin to local pressure: the impact of aging and diabetes. *Diabetes Technol Ther* **11**: 791–8

Miller JD, Salloum M, Button A et al (2014) How can I maintain my patient with diabetes and history of foot ulcer in remission? *Int J Low Extrem Wounds* **13**: 371–7

National Institute for Health and Care Excellence (2015) *NICE guideline 19. Diabetic foot problems: prevention and management*. NICE, London, UK. Available at: *www.nice.org.uk*/guidance/ng19 (accessed 02.09.2016)

Ousey K (2009) Chronic wounds – an overview. *J Commun Nursing* **21**: 4–9

Petrofsky JS (2011) The effect of type-2-diabetes-related vascular endothelial dysfunction on skin physiology and activities of daily living. *J Diabetes Sci Technol* **5**: 657–67

Reiber GE, Vileikyte L, Boyko EJ et al (1999) Causal pathways for incident lower-extremity ulcers in patients with diabetes from two settings. *Diabetes Care* **22**: 157–62

Reiber GE, Smith DG, Wallace C et al (2002) Effect of therapeutic footwear on foot reulceration in patients with diabetes. A randomised controlled trial. *JAMA* **287**: 2552–8

Teller P, White TK (2009) The physiology of wound healing: injury through maturation. *Surg Clin North Am* **89**: 599–610

Vinik AI, Erbas T, Park TS (2001) Dermal neurovascular dysfunction in type 2 diabetes. *Diabetes Care* **24**: 1468–75

Vinik AI, Maser RE, Mitchell BD, Freeman R (2003) Diabetic autonomic neuropathy. *Diabetes Care* **26**: 1553–66

Weaving L (2014) KerraPro pressure reducing pads in preventing pressure ulceration. Harrogate 2014 Conference Posters. Harrogate, *Wounds UK*, UK. Available at: http://bit.ly/2m75Rab (accessed 02.09.16)

Westphal C, Neame IM, Harrison JC, et al (2011) A diabetic foot ulcer pilot study: does silicone gel shee ting reduce the incidence of reulceration? *J Am Podiatr Med Assoc* **101**: 116–23

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