Text Atlas of Podiatric Dermatology
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Preface

For many years there has been a very positive link between podiatry and clinical dermatology, but unfortunately they largely remain apart in most medical cultures, both in training and in practice. Where they have begun to overlap in the clinical treatment of foot dermatological problems the benefits rapidly become obvious to those involved. Good examples include the often better management of ingrowing toenail by the podiatrist and the advantages of dermatological training in the correct use of cryosurgery. The podiatrist has the great advantage of always knowing that foot problems are moving all the time (I) and are constantly modified and compounded by this; many dermatologists only see foot disease in static pathogenetic terms. Sometimes a skin or nail problem may be helped more by alleviating the effects of friction and pressure than by complex pharmacological agents. In reality both should be able to work together.

Because of the different training, aptitudes and attitudes of the various specialists dealing with toenail pathology, the authors have allowed some overlap in description of subjects such as nail anatomy and foot function — in an attempt to show where in one context static structural considerations are appropriate whilst in another a more functional attitude is required.

In producing this Text Atlas the authors sincerely hope that it will be useful to those dealing with foot skin problems whatever their current formal speciality training may be — as traditional medical speciality barriers ‘break down’ it would be wonderful to think, as we evidently do, that podiatrist, dermatologist, nurse and primary care physician could directly share their skills in a practical way.

Rodney Dawber
Ivan Bristow
Warren Turner
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1 Anatomy and physiology of the skin

INTRODUCTION
ANATOMY
BLOOD SUPPLY
NERVE SUPPLY
APPENDAGES
THE NAIL
HAIR FOLLICLES AND ASSOCIATED STRUCTURES
INTRODUCTION

During a lifetime the average foot travels many thousands of miles. With each footstep it absorbs the impact of around twice the body weight. Typically our feet go unnoticed for the majority of our lives, remaining covered and out of sight. When foot problems do arise, embarrassment often prevents the individual from seeking attention. From a medical point of view, the feet are rarely examined as routine practice. In clinical medical practice the foot is rarely examined routinely; rarely is it seen as a 'unit' with specific functional problems in health and disease. The skin overlying the foot is the body's main interface with the ground and so has subtle adaptations to its structure at other sites in order to fulfil this role. Dermatological disease of the foot is not uncommon and in the last few hundred years in advanced societies the use of footwear has added an extra dimension to skin pathology.

The functions of the skin are summarized in Table 1.1. (Those in italics are of particular importance to the foot). Figure 1.1 shows the major components of the skin.

Table 1.1 Summary of skin function

<table>
<thead>
<tr>
<th>Barrier functions</th>
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<tbody>
<tr>
<td>Physical: thermal/mechanical/radiation</td>
</tr>
<tr>
<td>Chemical: irritants and allergens</td>
</tr>
<tr>
<td>Biological: viral/fungal/arthropod</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensory functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain/temperature/touch/vibration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoregulation</td>
</tr>
<tr>
<td>Vitamin D production</td>
</tr>
</tbody>
</table>
Figure 1.1
Anatomical features of the epidermis and dermis.
ANATOMY AND PHYSIOLOGY OF THE SKIN

Epidermis

- Stratum corneum
- Granular layer
- Desmosomes
- Spinous cell layer
- Basal cell layer
- Hemidesmosome
- Basement membrane zone
- Anchoring fibrils (and anchoring plaques)
- Fibronectin
- Blood vessels

Dermis

(a)

(b)

(c)
appearance, gradually ‘engulfing’ the tonofilaments. Lamellar granules are also synthesized by the cell at this level, and migrate to the cell membrane, expelling their contents into the inter-cellular spaces. It is thought these expelled lipid components are a major factor in skin permeability. This granular cell layer is the stage of ‘cell death’; intracellularly degrading organelles can be seen.

At the level of the stratum corneum (horny layer), which is about 15–20 layers thick, the cells are flat, anucleate and packed with keratin. Gradually the upper cells of the stratum corneum detach and flake away, the process of desquamation.

On the plantar surface of the foot, an extra layer is visible microscopically in the epidermis, between the granular and horny layer — this is the stratum lucidum and it is only found on thick, glabrous (non-hairy) skin.

The epidermis can be considered a very active ‘organ’, constantly generating keratinocytes from its basal layer which, over a period of 28–46 days, ascend outwards and undergo a process of maturation, keratinization and desquamation. This process produces a regular turnover of cells throughout life and has an important physiological role.

Trauma, desiccation and maceration can break down the stratum corneum providing a portal of entry for infective organisms. However, with certain organisms, particularly fungi, it has been shown that the response to invasion leads to an increased activity, causing faster maturation and desquamation of the epidermal cells, effectively shedding the invading organism.

Throughout the basal layer are found specialist cells called melanocytes (Figure 1.3). These are dendritic cells which produce melanin in organelles called melanosomes. The melanin is evenly ‘donated’ as pigment granules to the surrounding keratinocytes, via the dendritic processes of the melanocytes. Melanin protects the skin against cell damage due to UV radiation. Exposure to such radiation causes the skin to darken and also stimulates further melanin production. The number of melanocytes in darker and lighter skinned individuals is similar; however, the melanin produced in dark skin is produced in much larger, more dense granules.

Changes in the level of pigmentation in skin can be induced by other factors. It has been postulated that the melanocyte has an important role in inflammation of the skin. Notably in darker skinned individuals, any form of inflammation in the skin can lead to hyperpigmentation or, less commonly, hypopigmentation. Pituitary hormones such as adrenocorticotrophic hormone and melanocyte stimulating hormone, other chemical mediators in the skin, can cause a similar effect. Melanocytes are distributed fairly evenly throughout the whole epidermis of the foot but as plantar skin is rarely exposed to UV radiation, it rarely shows any significant pigmentation.

The Langerhan’s cell is another dendritic cell of the epidermis (Figure 1.3). They make up about 2–6 per cent of the cells in the epidermis and are found particularly around the stratum spinosum. They are derived from the bone marrow and are important in skin immunity, having antigen presenting functions similar to those of the macrophage. Furthermore, they promote T-cell proliferation. It is thought that they play an important role in lymphocyte-mediated allergic reactions.

The interface between the dermis and the epidermis is known as the dermo-epidermal junction. This is a basement membrane divided into three layers, crossed by fibrils and filaments and forming an anchoring surface between the dermis and epidermis (Figures 1.2a, 1.3). Pathologically, the dermo-epidermal junction is a cleave plane for some blistering diseases.

Deep to the epidermis lies the dermis (Figure 1.1). This consists essentially of dense fibro-elastic tissues in a ‘gel-like’ base (ground substance) containing glycosaminoglycans. Tensile strength is provided by collagen
Melanin distribution and melanocytes in the epidermis: (a) Sites of melanocytes in basal and suprabasal areas; (b) migration of melanosomes along dendrites from where they are donated to adjacent keratinocytes (melanin granules).
strands, with elasticity afforded by interwoven elastic fibres.

At the dermo-epidermal junction, the dermis makes regular finger-like folds into the overlying epidermis called dermal papillae. These are complemented by ‘protrusions’ from the epidermis into the dermis known as rete or epidermal ridges/pegs. On the plantar surface, where there is increased mechanical stress, the dermal papillae and rete pegs reach much deeper hence a greater surface area is created between the two layers, forming a much stronger attachment.

The thin, upper layer of the dermis is known as the papillary dermis, while the deeper layer is the reticular dermis. The papillary layer contains most of the blood and lymphatic vessels, while the less vascular reticular layer possesses more dense collagen and elastic fibres. Cells of the immune system are present in the dermis, i.e. T-lymphocytes and mast cells.

The subcutaneous layer is a dense plane of primarily fat (adipose) and areolar tissue to which fibres from the dermis are firmly anchored. Over the sole of the foot the subcutis is thickened, particularly over the weight bearing areas of the heel and metatarsal heads (up to 18 mm). Fatty tissue in the heel areas is divided by numerous fibrous septa which attach the dermis to the periosteum of the calcaneus. Across the plantar surface of the metatarsal heads it is more loosely attached to

Figure 1.4
Early loss of fibro-fatty padding (FFP) across metatarsal heads.

Figure 1.5
Medial displacement of FFP in patient with rheumatoid arthritis.

Figure 1.6
Solitary piezogenic papule arising on the heel.
surrounding tissue. Fat across the sole of the foot has an important protective role. Not only does it serve as a good insulator but the fibrous septae effectively form sealed chambers of fat. When subject to mechanical forces, fat flows within these chambers and act collectively as a fluid cushion absorbing the stresses of locomotion. Abnormalities of this fatty layer may give significant problems (Figures 1.4–1.6).

Clinically, herniations of this fatty tissue into the dermis may occur, particularly on the medial side of the heel (visible when standing). This condition is most prevalent in middle age patients. Occasionally, these herniations may give rise to pain around the heel area and as such, are termed painful piezogenic papules. Generalized atrophy of the fat pad can also arise with ageing and diabetes. In the forefoot, anterior migration of the fat pad may occur in rheumatoid disease.

**BLOOD SUPPLY**

The main blood supply to the skin (Figure 1.1) arises from a network of vessels located in the subcutaneous layer. At this lowest level branches supply eccrine sweat glands and hair follicles located deep in the reticular dermis. Vessels ascend from this network and fan out to form a second plexus in the mid-dermis. Arterioles from this level supply smaller hair follicles and their associated structures. Other vessels ascend further to form a third plexus in the papillary dermis. From the papillary plexus, single capillaries loop upwards into the dermal papillae. These tiny vessels loop and descend to drain into venules within the papillary plexus and then descend further into the deeper dermis, eventually reconnecting with the subcutaneous blood vessels.

The advantages of a layered system of blood vessels become obvious when considering the role of the skin in thermo-regulation. The sympathetic nervous system is able to direct blood flow by controlling vessel diameter; when blood is diverted to the most superficial layer, heat loss is at its greatest and when there is constriction of the superficial vessels blood flow is redirected through the deeper dermis so that much less heat is lost through convection and radiation via the epidermis. The foot, owing to its small surface area, has a limited role in thermo-regulation. The foot arterial supply to the skin is shown in Figure 1.7.

Within the papillary dermis are the lymphatic vessels which act as ‘drains’ for intercellular fluid and small particles within the dermis. At

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**Figure 1.7**

Arterial supply of (a) the toe and (b) the foot.
the highest level in the dermis, lymphatic 'end bulbs' feed into larger lymphatic vessels which traverse deep into the dermis, connecting with the subcutaneous layer. The superficial vessels in their normal state are collapsed and highly permeable. Lymph drained from the lateral side of the foot flows up the leg into the popliteal lymph nodes behind the knee while the remainder of the lymph from the foot drains directly into the inguinal nodes of the thigh.

**NERVE SUPPLY**

Sensory perception is a vital component in maintaining skin integrity (see Chapter 3). The dermis is well supplied with nerves (both myelinated and unmyelinated fibres). In the foot, sensory nerves connect with the main pedal nerves. As with the rest of the body they are arranged in pattern of dermatomes (Figure 1.8).

The main sensations of the skin are tactile (touch, pressure and vibration), thermo-receptive (heat and cold) and nociception (pain and itch). Receptors in the skin vary in density according to their location, some being encapsulated, others being free (Figures 1.1, 1.9).

On the plantar surface where the papillary ridges are very dense and most organized (particularly on the heel, ball of the foot and volar surfaces of the toes) neural tissue is at its most orderly and dense. Numerous free nerve endings and Merkel’s discs are present. These discs are of unknown origin but are located in the dermal papillae and are linked to local keratinocytes in the epidermis. Their function is thought to be that of tactile perception.

Meissner's corpuscles are oval structures containing neural and connective tissues. These occur in large numbers on the soles of the feet, particularly within the volar pads of the digits, protruding into the basal lamina at the dermo-epidermal junction. Their function is thought to be that of touch perception. Deeper in the dermis are Pacinian corpuscles (pressure and vibratory receptors) close to the perios­teum of the phalanges and extensively across the plantar surface.

Pain and itch perception (nociception) arises from the activation of free nerve endings at the dermo-epidermal junction and throughout the dermis. Nociceptors respond to multiple noxious sensations such as mechanical, chemical, hot and cold.

As the skin changes, from thick plantar skin to thinner hairy dorsal skin, the neural network
becomes less organized. Tactile receptors exist in the root hair plexuses, any movement of the hair shaft on the dorsum of the skin is detected by these receptors. Table 1.2 shows the main functions of the sensory nerve supply.

### APPENDAGES

Hair follicles and their associated sebaceous and apocrine sweat glands are found on the dorsum of the foot (Figure 1.10). On the

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meissner’s corpuscle</td>
<td>Dermal papillae (particularly numerous in hands and feet)</td>
<td>Highly sensitive to light touch</td>
</tr>
<tr>
<td>Merkel’s receptor</td>
<td>Dermal papillae</td>
<td>Sustained light touch</td>
</tr>
<tr>
<td>Pacinian corpuscle</td>
<td>Deep dermis/subcutaneous layer border (particularly in fat pads)</td>
<td>Vibratory perception</td>
</tr>
<tr>
<td>Free nerve endings</td>
<td>Dermal papillae and throughout dermis</td>
<td>Nociception (pain) thermoreception chemoreception</td>
</tr>
</tbody>
</table>
plantar surface numerous eccrine (free) sweat glands are found (Figure 1.2b).

**THE NAIL**

The nail (Figure 1.11) has evolved as a tool to aid dexterity and the manipulation of small objects. However, in the foot the role of the toenail has lessened to that of offering protection of the underlying digital structure.

The hard keratinous nail plate arises from a group of specialist cells in the nail matrix, located at the base of the proximal nail fold, (effectively an infolding of the epidermis). Here the nail plate is strongly attached to the nail bed and underlying phalanx by vertically orientated connective tissue fibres. The nail fold covers about a quarter of the plate, whilst the lateral edges meet with the epidermis to form the lateral nail folds or sulci.

The nail plate usually has a pale lunula (half-moon) visible at the proximal end. The lunula represents the most distal portion of the nail matrix, its colour being lighter than the more distal nail bed. proximally, the eponychium (which arises as an outgrowth of the ventral surface of the proximal nail fold) and the cuticle act as effective seals to prevent infiltration by infection or irritants. More distally along the nail plate, prior to the nail separating from the nail bed at the hyponychium, is the onychodermal band (not always visible); this runs transversely across the nail bed. It is thought to be the most distal anchor for the nail plate.

The nail plate is a three layered structure composed of hard keratin, most of the plate being generated by the proximal and distal matrix. The deepest layer being added to the underside of the plate by the nail bed, distal to the lunula. Microscopically, the nail plate and nail bed fit together in a tongue-in-groove arrangement (Figure 1.11d).

Nail formation follows a similar sequence of events to that of the epidermis. Basal layer keratinocytes divide, differentiate and die, adding to the nail structure as it grows towards the end of the digit. Melanocytes are also found in small numbers in this matrix basal layer but normally their pigment is not visible in the nail plate.

The nail apparatus has a double blood supply (Figure 1.7). Lateral digital arteries run up the margins of the digits on the volar surface, close to the bone. Branches of these supply the phalanx and give rise to a superficial arcade which serves the proximal nail fold and matrix. Arteries then course dorsally, winding around the distal phalanx to just below the nail plate.

**Figure 1.10**

Hair follicle and associated structures.
Figure 1.11
(a, b) Nail apparatus structures.
(c) Longitudinal nail biopsy, orientated to equate with (b).
(d) Microscopic 'tongue in groove' nail bed and nail plate relationship.
giving rise to a proximal and distal arcade which serve the nail bed and matrix. Numerous muscular arterio-venous shunts (glomus bodies) exist in great numbers in the nail bed, their main role being to maintain an adequate blood supply to the nail apparatus in cold temperatures. Owing to its intricate neuro-vascular arrangement, changes in the general circulation and health are often reflected in the nail.

HAIR FOLLICLES AND ASSOCIATED STRUCTURES

Hair follicles are located over most of the body surface (Figures 1.1, 1.2c, 1.10). On the foot, they are restricted to the dorsum. Hair diseases which specifically affect the foot are rare.

Associated with the hair follicle is the sebaceous gland (Figure 1.10) which produces lipid rich sebum. Owing to their association with hairs, sebaceous glands are restricted to the dorsum of the foot and when compared to sebaceous glands in other areas of the body they are fairly inactive. Sebum production is stimulated by androgens, but inhibited by oestrogen.

Two types of sweat gland exist in the skin — eccrine and apocrine (Figures 1.1, 1.10). Eccrine glands are coiled structures located in the reticular dermis with a single duct ascending to an opening to the epidermis. They are most numerous on the sole of the foot. Apocrine glands are the larger of the two glands and are exclusively associated with hair follicles mainly in the inguinal and axilla areas and the areola of the breasts; they appear to have little significance on the foot. Sweat is a mixture of water, sodium chloride, urea, ammonia and other chemicals. Its release is controlled by sympathetic branches of the autonomic nervous system. Over the whole body, sweating acts as a cooling mechanism by its evaporation and could also be seen as an excretory function. Sweat glands in the foot, however, play little part in thermo-regulation; they produce a steady flow of sweat across the plantar surface, which serves to enhance grip. Sweat also helps to moisten the skin and when mixed with skin squames and the natural epidermal flora, a cocktail is formed which presents an inhospitable environment for most pathogenic organisms!

Across the sole of the foot, congenital flexure lines or skin creases are evident as a result of the arrangement of the collagenous fibres within the dermis. This pattern of dermatoglyphics is unique to each individual and remain unchanged throughout life. Dermatoglyphics are most prominent as a network of ridges over the main weight bearing surfaces — the heel, across the ball and the plantar aspects of the toes. Interestingly, as dermatoglyphics become exaggerated over the weight bearing areas of the plantar surface, clinically one is able to gauge where most of the weight is being borne by examination. It is thought that their function in the foot is twofold. Firstly, they enhance tactile sense across the skin. This theory is backed up by the fact that cutaneous sensory nerve endings are more densely congregated in areas of prominent dermatoglyphics. Secondly, the pattern of ridges is somewhat analogous to that of the tread of a tyre. This in conjunction with moderate amounts of sweat, serves to enhance the grip of the toes and sole by increasing the friction co-efficient.
References

3 3: Skin disorders

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5.5: Aspects of skin therapeutics

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