Hair and nail structure and function

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Summary

The hair and nail are skin appendages that share with the skin a common origin from the ectodermal layer. They fulfil important protective and cosmetic physiologic function. After intrauterine life, hairs are divided, by size in two major types: vellus and terminal. Terminal hair is described as being substantial or large in size with a diameter of about 60 mm. The scalp hair is a typical terminal hair. Vellus hairs are smaller, more lightly pigmented and the diameter is less than 30 mm. The hair has a growth cycle consisting in different phases: anagen, telogen, catagen.

The nail provides protection to the distal digit as well as aesthetic adornment and dexterity. Hair and nail disorders have a deep impact in the patient self-confidence and relation life. A vast spectrum of nail or hair alterations can be observed during the course of systemic disease although a causative association is seldom proved. A deep knowledge of the structure and physiology of the nail is necessary to correctly approach the pathogenesis of nail disorders.

Riassunto


Le unghie forniscono protezione alle falangi distali delle mani e dei piedi, sono un adornamento estetico e favoriscono l'esecuzione dei movimenti fini. Le malattie dei capelli e delle unghie hanno un considerevole impatto sulla vita sociale e di relazione del paziente. Un vasto spettro di alterazioni delle unghie e dei capelli può essere osservato in corso di malattie sistemiche sebbene il nesso causale sia raramente provato. Una approfondita conoscenza della struttura anatomica e della fisiologia dell'unghia consentirà un corretto approccio patogenetico.
**HAIR ANATOMY**

Two main types of hair are present after birth, although intermediate forms are also seen: vellus hair (fig.1), unmedullated, unpigmented or lightly pigmented, growing to a maximum of 2 cm, are usually located in body areas normally considered “hairless”, such as a child’s cheek; on the contrary, terminal hair (fig.2) are medullated and variously pigmented.

They can grow to considerable length and are best defined by their size relative to vellus hair (ca. 2x diameter). Terminal hair is the typical hair of the scalp throughout life in normal individuals. Each hair shaft is produced by an hair follicle, a mainly epithelial structure which protrudes down through the dermis, often into subcutaneous adipose tissue.

The hair follicle consists of a complex system of multiple tissue compartments that are clearly distinguishable by their morphology and type of differentiation. As hair follicle is associated with a sebaceous gland, arrector pili muscle and apocrine sweat gland, the conventional designation for the pilo-sebaceous unit fails to do justice to it, both linguistically and morphologically. In fact the unit is not a “hair-sebaceous” one, but it is a folliculo-sebaceous-apocrine smooth-muscled and nervous and vascular unit [1].

On average, the entire body surface of an adult contains 5,000,000 follicles [2] (Tab. I).

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<th>Table I. Hair follicles number.</th>
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<td>Total hair follicles</td>
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<td>Head</td>
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<td>Scalp</td>
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The maximum number of hair follicles is present at birth. Scalp biopsies have shown 700-800 follicles per cm² at birth, that decrease approximately to 300 per cm² in adult life. As seen in Tab. II, hair follicle morphology varies according with race. A wide range of variation is also present in hair colour. Depending on the presence of eumelanin, pheomelanin or oxy-melanin the hair can be black or brown, blond or red respectively.
Anatomically, each hair can be divided in two parts: an external one, named hair shaft and an inner one, named hair follicle. The major structure of the hair shaft is the cortex. It consists of elongated cells that run parallel to the fiber axis. Within these cells are located the tonofilaments and interfilamentous matrix material that are responsible for most of the physicochemical properties characteristic of whole hair. It is surrounded by a cuticle of overlapping flattened cells with their free margins pointing upwards to the hair tip. Thick hairs have a central zone of more loosely organized keratinised material, the medulla (figs. 3a-3b) [3].

In the hair follicle, the hair shaft is surrounded (from central to peripheral) by the inner root sheath, the outer root sheath, the basement membrane and the perifollicular sheath of connective tissue.

A mature follicle in anagen, as viewed in sections oriented vertically and by conventional microscopy, can be divided in two parts: an upper segment and a lower segment. This subdivision has a relevance even from a biological point of view. In fact, while the upper segment is permanent, the lower segment is the part of a follicle that undergoes changes during the hair cycle, marked by growing, involuting and resting. The upper segment extends from the ostium of the follicle to the attachment site of the arrector pili muscle. It is divided in two parts: the upper infundibulum, from the ostium of the follicle to the point at which the sebaceous duct enters the follicle, and the isthmus which extends from the inferior boundary of the infundibulum to the insertion of the arrector pili muscle (fig. 4).

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**Table I. Hair follicle morphology: racial variations.**

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<tr>
<td>Caucasoids</td>
<td>Variable from straight to helical</td>
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<tr>
<td>Negroids</td>
<td>Helical follicle</td>
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<tr>
<td>Mongolian</td>
<td>Straight follicle</td>
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This proliferation is more marked at the site of attachment of the arrector pili muscle. The bulge is probably the source of germinative cells that enables a follicle to be reconstituted at the end of telogen [4-6].

The lower segment extends from the insertion of the arrector pili muscle to the base of the follicle and is divided in the stem and the bulb.

The stem [1] is the upper part of the lower segment. It extends from the upper boundary of the bulb to the base of the isthmus.

The lowest part of the follicle is named the bulb (fig.6).

The bulge (fig.5) is a localized thickening of the outer sheath and it is a proliferation of cells of the outer sheath at isthmus.

It is composed by the matrix, the supramatrical zone and the keratogenous zone.

The matrical zone extends from the base of the bulb to the site where the bulb has the widest diameter which is called the critical line of Auber.

The supramatrical zone spans from the critical line of Auber to the B-Fringe which defines the area where keratinization in the Henle’s layer of the inner root sheath begins and where the outer root sheath becomes stratified.

The keratogenous zone boundaries are defined by the B-fringe proximally and the A-Fringe (Adamson’s fringe) distally. The A-fringe is the site where the cornification of the cortical keratinocytes is first observed and where Huxley’s layer loses its trichohyalin granules (fig.7).
The matrix contains the proliferating pool of undifferentiated cells that give rise to the three components of the inner sheath and to the hair shaft. Although the matrix has been assumed to be the source of the outer root sheath, that has not yet been demonstrated. Above the matrix, in the supramatrical zone, begins the differentiation of the progenitor cells. In the keratogenous zone the cells begin to die and cornify.

The anagen hair follicle contains an assembly of specialized fibroblasts, the dermal papilla (fig. 8), which is located in the center of the hair bulb and surrounded by the epidermally derived germative epithelium.

The dermal papilla is composed by various cellular types (fibroblasts, Langherans cells, lymphocytes, mast cells), extracellular matrix, blood vessels and nervous fibres and is probably responsible for inducing differentiation of the hair bulb matrix [7-8]. This parallels embryologic events, where development of the epithelial component is dependent upon inductive stimuli from the mesenchyme [9]. There is also evidence that the size of the hair follicle and the volume of the hair fibre are determined by the volume of the dermal papilla [10-11]. In the hair follicle, hair shaft is surrounded by the inner root sheath, which is composed, moving inward, of Henle’s layer, Huxley’s layer and the cuticle of the inner root sheath. The inner root sheath stretches from the base of the bulb to the isthmus, where the cornified cells desquamate. The outer root sheath is located from the inner root sheath and extends from the base of the follicle to the lower boundary of the infundibulum. It is composed by epithelial cells that changes gradually in width and colour, through the follicle length. At last, the dermal sheath is a connective tissue that surrounds the outside of the hair follicle (fig. 9).
Hair and nail structure and function

**Fig. 9** Histological aspect of the root sheaths: 1) inner root sheath, 2) outer root sheath, 3) dermal sheath, the basement membrane (arrow).

**HUMAN HAIR FUNCTIONS**

Hair is an important element of human appearance that is commonly used for recognition and is one determinant of physical attractiveness [12]. Across the centuries, the decoration of scalp hair has been a medium of social communication and a display of social identity or status. Several studies have shown the negative psychological impact of various conditions associated with hair loss [13-15]. For many years hair has been regarded as important only for these aesthetic functions, but recently hair follicle epithelial cells and their contribution to healing skin have attracted particular attention [16]. It is believed that epithelial outer root sheath cells provide replacement cells for the epidermis in response to wounding. Moreover, the dermal sheath probably contains progenitor cells that become important in the wound healing process [17]. Hair plays an important role even in skin repigmentation. In adult follicle, melanocytes are found in the bulb epithelium, and in the epithelial outer root sheath cells at the infundibulum and at the lower part of the follicle. While only active (DOPA-positive) melanocytes exist in the epidermis of normal skin, there are some inactive (DOPA-negative) melanocytes in the outer root sheath of the lower part of a normal hair follicle. These latter cells appear to form a melanocyte reservoir in the skin. Under certain circumstances, for example during repigmentation of vitiligo, outer root melanocytes proliferate and migrate to the epidermis [18]. At last hair offers a valid UV protection of the scalp skin.

**NAIL ANATOMY**

Like hair, the nail unit forms by invagination of the epidermis into the dermis. It consists of the nail plate and the tissues that surround it. The nail plate is a fully keratinized structure that covers the dorsal distal phalanges of the fingers and toes. It results from maturation and differentiation of the epithelial nail matrix cells and is firmly attached to the nail bed, which partially contributes to its formation. The nail bed is the structure upon which the nail rests. It extends from the distal margin of the lunula to the epidermis of the hyponychium and, normally, appears pink because of a blood-filled vascular network that is visible through the translucent plate. The nail bed keratinization produces one fifth of the total mass of the nail plate which consists of a thin, horny layer that forms the ventral nail plate. The nail matrix is a specialized epithelial structure that lies underneath the proximal nail fold. The epithelium of the nail matrix consists of basal cells that differentiate into spinous cells and subsequently into the orthokeratotic cells that compose the nail plate. The matrix appears as a convex crescent and consists of a proximal or dorsal portion and a distal or ventral portion. The proximal portion of the matrix is the predominant supplier of cornified cells that constitute the dorsal nail plate, whereas the distal matrix (lunula) contributes the intermediate nail plate. Proximally and laterally the nail plate is surrounded by the nail folds, which cover its lateral and proximal margins. The hyponychium is the anatomic limit between the nail bed and the free margin of the nail plate.
HUMAN NAIL FUNCTIONS

Probably, the most important function of the fingernails consist in enhancing tactile discrimination and fine movements. Furthermore, fingernails are utilized for scratching and grooming and are an efficient natural weapon [19]. Toenails protect the distal toes and contribute to pedal biomechanics. The nails also contribute to the aesthetic appearance of the hand and foot.
References


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