Continuing medical education

Hair care: a medical overview (part 1)

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ABSTRACT

Doubts concerning the action of hair cosmetics and the health of both body and hair are very frequent in the dermatological visits. Dermatologists need no only to enrich the knowledge of scalp diseases but also of molecular interactions of cosmetics used in hair fiber, including the influence of such products when absorbed by the epithelium of the scalp. The amount of medical visits increases every day to find out which techniques and chemical products are best indicated to enable the desired changes in hair from its natural appearance and, at the same time, to keep the hair healthy and beautiful. In this article, divided in two parts, we discuss the hair physiology, structure and chemical nature, as well as the agents used for its smoothing, coloring, hygiene and cosmetic treatment, and the consequences that such procedures can have on overall health, including their use safety during pregnancy and lactation.

Keywords: hair preparations, hair, hair dyes.

INTRODUCTION

Changes in shape and color of the hair have been, since the beginning of civilizations, one indicator of beauty. The fashion is not limited to clothing, but extends to the hair, creating an incessant search for a different look. The smoothing of the hair had its peak recorded in mid-1900 with a technique for smoothing the african-ethnic hair using Vaseline and a hot metal comb at a temperature between 150 and 260 °C, called "hot comb". Over the following years, chemical substances which allowed hair straightening and curling on a permanent and more secure way have been developed. Currently, there is a tendency towards extremely straight hair in a definitive way. Questions about the action of capillary cosmetics over health of both body and hair are more often addressed in dermatological visits. Adding to this the already traditional use of agents that modify the hair natural color or hide the unwanted gray hair, we have a combination that can really be dangerous to the health of hair fiber. Increases every day the amount of medical visits to find out which techniques and chemical products are best indicated to enable the desired changes in hair from its natural appearance and, at the same time, to keep the hair healthy and beautiful. In this article, divided in two parts, we discuss the hair physiology, structure and chemical nature, as well as the agents used for its smoothing, coloring, hygiene and cosmetic treatment, and the consequences that such procedures can have on overall health, including their use safety during pregnancy and lactation.

Functional anatomy: the follicle that produces the hair fiber

The human skin contains approximately 5 million hair follicles, with about 100,000 follicles on the scalp; this number may vary according to the color of hair (Table 1). Most hair is located in visible places, with important psychosocial connotation.[1,2] Although the three main types of hair follicles (lanugo, vellus, and terminal) have differences in their structure and pigmentation, they all follow the same formation principle.

Every hair follicle in the anagen phase is fully formed and presents the format of a reversed cup of wine. In the cup, there is a structure similar to the onion bulb, named follicular dermal papilla, where stem cells are displaced in the center with a multi-cylindrical form, moving to the most external layer of the hair shaft. The presence of guide structures and cleavage plans make this an oriented growth. The inner sheath (IS) is a cylindrical and hard layer of differentiated

Table 1 – Number of hair follicles distributed by hair type[3,4]	
Hair type	Number
Caucasian (blond)	130,000
Caucasian (brown/black)	110,000
Caucasian (red)	90,000
African-American	90,000
Asian	90,000

keratinocytes, which guide and guard the hair shaft. The companion layer is an independent cell compartment between inner and outer sheaths and is a key part for anchoring the shaft in the hair follicle.[2,5,6] The epithelial compartments of the hair follicle are composed of 8 concentric cylinders: external sheath, companion layer, Henle's layer (IS), Huxley's layer (IS), cuticle (IS), as well as cuticle, cortex, and capillary hair shaft marrow. The lineage of epidermal differentiation is distinct in each of these cylinders. Three main populations of steam cells seem to originate both outer and inner sheaths, and the shaft. Bulge is the region where the epidermal steam cells are located, which originates the external sheath, while those which form IS and the shaft are placed in the secondary germ of the follicular papilla.[2,7,8]

The hair erector muscle gradually extends downwards to the bulge, the primary site of follicular stem cells.[2,7,8,9] The muscle is under adrenergic control, and involuntary contractions in cases of sudden stress, anxiety, or anger make the hair "to raise".

The hair follicle presents a system of autonomic innervations and numerous Merkel's cells around the isthmus, located between the insertion of the erector muscle of the hair and the sebaceous gland infundibulum. Blood vessels reach the entire follicle, through the sheath of connective tissue and penetrate the hair follicle dermal papilla of the terminal hair.[2,10,11]

Structures responsible for the shape of the hair shaft

It was believed that the shape of the IS was primarily responsible for the hair shape but, more recently, it is known that there are differences between the curvatures of straight and curly hair. Further studies were performed and showed that the shape of the hair shaft is programmed by the bulb, particularly by the axial degree of symmetry/asymmetry of the hair matrix. It has been shown that in the curly hair one side of the hair cuticle develops first, giving the appearance of a golf putter to this bulb, while the straight hair has an even and straight development.

Hair cycle

The hair cycle is traditionally recognized by three phases: growth (anagen I-VI), regression (catagen I-VIII) and rest (telogen).[2, 4,5,13-15] There is a sequence of repetitive rhythmic changes in the morphology of the follicle features that follow a sequential organization genetically encoded.[2,5,14,15]

Anagen

At the anagen phase, the hair is actively growing, and materials are deposited in its shaft by follicular papilla cells. The duration of the anagen phase is genetically determined and varies according to the anatomic site studied. In the scalp, it has a duration of 2 to 6 years[4,16] (Table 2), with a growth rate of approximately 0.03 to 0.045 mm per day, with a faster growth rate in women.[17] Approximately 85-90% of all hairs are in this phase of growth (Table 3). Some people may have much longer hair because they have an anagen phase of long duration. However, individuals who have a short anagen phase cannot have hair that reaches a long length. Although popular culture teaches several formulas and recipes to make the hair grow longer, the maximum length of the hair of each individual is genetically determined and is not influenced by vitamin supplementation or topical treatments.

Catagen

The catagen phase is very controlled, and the terminal differentiation and apoptosis make a rapid involution of the follicle while the actual hair shaft factory, the bulb, is removed almost completely.[2,5,18] The follicular dermal papilla does not undergo apoptosis. However, it gets condensed and moves upwards, and there is a decline in the number of fibroblasts nuclei, probably by the migration of fibroblasts from the papilla to the proximal sheath of connective tissue.

The earliest signs of the end of the anagen phase and the induction of catagen are retraction of melanocyte dendrites in the follicle and enzymatic evidence that melanogenesis is becoming to an end.[2,19] Most of the follicle melanocytes also suffer apoptosis.[2,19,20] Melanocytes destroyed in the follicle are restored during the next anagen phase from the reservoir of melanocytic stem cells in bulge and/or the outer sheath melanocytes.[2,19,21,22] The gray hair, then, would be a largely insufficient maintenance of the hair follicle from melanocytic stem cells.[2, 21.22]

During the catagen phase, the follicular papilla shrinks,[5] and the hair in "club" shape leaves the epithelial sac. It characteristically presents a brush tip and proximal end depigmented, since it is generated only after the end of melanogenesis and the transfer of melanosomes. Less than 1% of hair is in this phase of involution (Table 3), which can last between 2 and 3 weeks (Table 2).

Table 2 – Duration of terminal hair on the scalp according to hair cycle[2]	
Hair cycle fase	Duration
Anagen	2-6 years
Catagen	2-3 weeks
Telogen	3 3 months

Table 3 – Percentage distribution of terminal hair on the scalp according to hair cycle[2]

Hair cycle phase	Terminal hair
Anagen	85-90%
Catagen	< 1%
Telogen	10-15%

Telogen

At the end of this process of involution, the follicle enters into its "rest stage", the telogen stage, because the proliferative activity and biochemistry of the follicle reaches its lowest level during the hair cycle at this phase. However, the telogen can present a much greater importance to the regulatory follicle than the simply "rest" implies, since it may serve as a "brake" to the anagen phase.[5] The hair is in telogen phase for 3 months (Table 2), and approximately 10-15% of the hair shaft are at rest (Table 3), reflecting a hair loss of 100-120 strands per day.

Exogen and kenogen

There are two other phases recently described in literature:[4,23,24] the exogen and the kenogen. In the exogen phase it was demonstrated that the exclusion of the hair shaft is active, highly controlled, which differs from the telogen phase that is normally quiescent. The kenogen phase is a new phenomenon in the hair cycle, which represents the empty follicle between the end of telogen phase and the new anagen phase. It can be found in normal people, but seems to be more common in individuals with androgenetic alopecia.

Hair composition

The hair shaft is essentially a lipoprotein structure without life.[25,26] The terminal hair is composed of 3 layers: cuticle, cortex and medulla. The most external layer is the cuticle of flattened dead cells, overlapping each other like a roof tiles. These cells are named scales and form 5 to 10 layers, each with a thickness of 350-450 nm. Each cell is coated with an outer membrane named epicuticular, rich in cystine (sulfur-rich amino acid) and fatty acids. The cuticle cellular structure is composed of three main layers: the outer layer A, which contains the largest amount of cystine (sulfur) and, therefore, is the most resistant; the exocuticle, which also contains cystine, and the internal endocuticle, which is virtually without sulfur.[25,27] The entire cuticular unit has the property to protect the cortex from regular traumas, such as the act of hair combing and washing, which is responsible for some degree of cuticular damage, especially in the more distal end of the hair strand, causing trichoptilosis (lengthwise slit of hair shaft with the appearance of "split ends").

The cortex is an inward area with the greatest mass of hair fiber. Cells in the cortex have elongated structures in its interior named macro- and microfibrils of keratin. The macrofibrils contain microfibrils, which in turn contain the protofibrils. The latter are composed of polypeptide chains in α-helix format whose chemical shape and structure are maintained by links between the atoms of different chains. These links may have varying strengths: weak as the hydrogen bridges or strong as the ionic links or disulfide bridges. Such chemical bonds when permanently or temporarily broken allow the change in the hair physical form.[28,29]

Hair shaft cells have a helical arrangement in its structure separated by a narrow space that contains an intercellular protein material which keeps them together.[25,30] They are divided into 3 layers: orthocortex, mesocortex and paracortex, where the polypeptides of keratin are arranged 2 by 2, an acid with a base, forming the protophyll which are responsible for the ability of keratin to be extended and stretched. The endocuticle is the innermost layer of each cuticle cell and consists of amorphous protein. It is the most vulnerable area to the attack of shampoos, to waste repository, friction and fractures by traction, act of combing, or chemical treatment.[29]

Keratin

Keratin is composed of filamentous proteins that have a central α-helix structure. Four long α-helixes separated by three non-helical regions form a tetramer with identical dimmers antiparallelly arranged. These tetramers form a protophyll which pairs form a protofibril. The lateral association of four protofibrils forms a cylindrical filament of keratin. The cylinders of keratin are dispersed in a lipoprotein matrix.[29]

In conclusion, hair structures are formed by α-helical protein units with spiral format whose amino acids bind through bridges of disulfide, hydrogen, and ionic binding, giving it firmness and flexibility at the same time.

Hairs are more flexible and elastic than nails because they have fewer disulfide bridges present in keratin, which are the main responsible for its rigid helical form. Keratin, with its typical spatial conformation and chemical bonds, is primarily responsible for the fiber stiffness, strength and insolubility. Each disulfide bridge is formed by two molecules of sulfur linked to one another.

Keratin is colorless. The scalp hair color is given by the melanin in the cortex and medulla, possibly from the hair bulb melanocytes, which comprise only 3% of the hair strand mass. There are two types of melanin that will determine the hair natural color: gray, blond, brown, red and black, according to the amount and rate of eumelanin (brown and black) and pheomelanin (yellow and red). The melanin present in granules is linked to a protein referred to as melanoprotein. Both melanins are dependent on the amount of cysteine present in the melanocyte.[29]

Hair pigmentation occurs during the anagen phase and is promoted by the transference of eumelanosomes or pheomelanosomes from melanocytes present in the follicular dermal papilla. These melanocytes are different from those present in the epidermis, have longer dendrites and a lower melanocyte/keratinocyte ratio (1:1 - 1:4) than that of the epidermis (1:25 - 1:40).

In the center of the hair shaft there is a marrow formed by a protein known as trichohyalin.[25] The function of the marrow has been the object of study, but this region has no known involvement in aesthetic procedures. It is known, however, that in older patients the cells appear more dehydrated and with marrow spaces filled with air, which replace the marrow site.

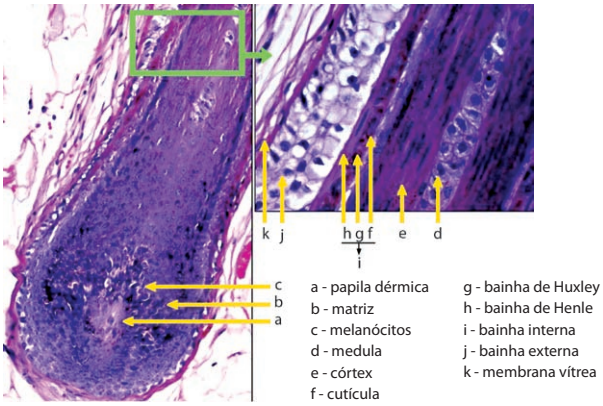

Figura 1 – Hair composition.

Hair physical properties

The strength of the hair comes from the cortex, but an intact cuticle is necessary for the hair shaft inner protection. The hair in the water, by undergoing hydrolysis, can be stretched up to 30% of its size without suffering any damage.[17] The hair shaft porosity is approximately 20%, and the weight may increase by 12-18% when wet. Water absorption is very rapid, with a rate of 75% of absorption within the first 4 minutes.[25]

Static electricity affects mainly the dry hair because it is a bad conductor. It may be an aesthetic problem because hair shafts repel one another "raising" the hair. This problem can be minimized by combing the hair under conditions of low temperature or by increasing the hair moisture.[25]

Caucasian, Asian and African-ethnic hairs have the same chemical composition but with some structural differences that make the visual characteristics so peculiar to each type. The African-ethnic hair has the sulfur amino acids molecules arranged differently, given its spiral aspect with constriction points along the hair shaft, various diameters along the hair, and ellipsoid shape. This type of hair offers lower resistance to fracture when combed, have less lubrication along the hair, and greater cuticle/cortex proportion, which gives them less weight. Hair shaft is ribbon flat, growing parallel to the scalp. For all that, it is a hair more difficult to untangle and comb. The Asian hair is the most straight, keeping a steady diameter along the hair strand. Have a greater resistance to fracture when combed, better lubrication throughout the length of the hair and larger cuticle/cortex proportion. In cross section of the hair, the strands are cylindrical and grow perpendicular to the scalp, being easily disentangled. Caucasian hairs are intermediaries in relation to the Asian and African-ethnic hair characteristics, with large variation between individuals.[28,31,32,33]

Hair coloring techniques[28,29]

The chemical depends on the type of agent used for coloring. Agents are generally classified by the color durability: gradual, temporary, semi-permanent and permanent. There are natural and synthetic pigments. Among the natural, the best known is henna, which gives the hair a red-orange hue. Most people prefer to use synthetic pigments which give more predictable results. It is interesting to perform a contact test before using certain products, mainly those based on coal tar-based ingredients.[34] Several studies try to determine the carcinogenic potential of the use of hair coloring products, especially in relation to bladder and hematological cancers.[35,36] However, these studies did not confirm this relationship and, until now, products are considered safe for the health by agencies such as Food and Drug Administration (FDA) and *Agência Nacional de Vigilância Sanitária* (Anvisa).

Gradual coloring: obtained by metallic dyes such as salts of lead, bismuth or silver. The objective is only to darken the natural hair hue in limited shades of black, brown or dark gray, being sought mostly by men, especially because of its fast use (5 minutes). The metal particles seem to react with the cuticle cysteine residue to form sulfide metals which are slowly deposited in the hair, and the pigmentation is gradual. Drawbacks are the smell of the chemical reaction (sulfur) and the irreversibility of the process. Treated hair cannot be colored with other techniques, since it will break apart.

Temporary coloring: provided by water-soluble dyes with high molecular weight, which prevents penetration beyond the cuticle. The color usually comes out in the first wash, unless the hair is damaged (porous) by previous chemical treatments, which causes a more prolonged effect due to its deeper penetration. Application on previously colored hair may cause unexpected and unwanted hues. They are available in shampoos, gels, mousse and sprays, rarely causing contact dermatitis.

Semi-permanent coloring: in general, obtained by synthetic hennas. They are substances of low molecular weight derived from coal tar (diamines, aminophenol, phenols),

and may cause contact dermatitis. These substances spread across the cortex, remaining in the hair by 4 to 6 weeks, or up to 8 shampoos. Little damage to the hair shaft is caused, but the effect on chemically treated hair can be unpredictable. Semi-permanent colors can darken the hair up to 3 tones, and are available as lotions and mousse. The application is made on humid hair just after the shampoo, and should be left on hair for 40 minutes before rinsed. Damaged hair, or retouches of new roots, needs different molecular weight molecules in order to maintain a uniform color.

Permanent coloring (oxidation): provided by alkaline solutions (pH 9 to 10) based on ammonia that penetrates through the cuticle. They can lighten or darken the hair, and are more effective for gray or white hairs. Pigmentation is permanent and is never removed by washing. Roots should be colored every 4 or 6 weeks. Use of a new color on hair already colored can damage hair strands. Permanent color results from an oxidation reaction between para-aminophenol, metaminophenol, phenylenediamine and hydrogen peroxide. If the hair is very dark and a lighter tone is desired, a prior depigmentation with ammonium persulphate, potassium and hydrogen peroxide is required. Final pigment is applied on discolored hair. It is recommended that relaxing and perm procedures should be done at least 2 weeks before coloring. The difference between permanent and semi-permanent (hair toner) hair coloring is only the presence of ammonia in the first one. Ammonia acts by increasing the pH of the hair, causing its swelling. Therefore, the product can penetrate deeply through the cuticle and may reach the cortex. Some degree of hair toxicity is credited to ammonia, which is not true, because ammonia is not toxic, only increases the penetration of substances that are common to both types of coloring. Hair toners also contain resorcine, resorcinol, paraphenylenediamine and paraminophenol, such as the permanent colors. Both differ by the presence or absence of ammonia; that is, higher or lower pH action.

Discoloration (highlights, to dye hair lock): it means partial or total removal of the hair's natural melanin. Depigmentation of red hair is more difficult than brown hair. The most common method involves the use of hydrogen peroxide 12% in alkaline base (ammonia). Initially, the granules of melanin are dissolved and the hair tends to a reddish brown color. Then there is a stage of slow fading. The mechanism of action is not fully explained, but it is believed that the first stage involves the destruction of several chemical bonds holding pigment particles, while the second stage seems to involve the rupture of the melanin polymeric structure. It is time dependent and difficult to control. Long periods of residence (1 to 2 hours) can intensely damage the hair strands. The process also destroys some keratin disulfide bridges, which leads to a weakening of the hair. Damage also occurs to the cuticle, which makes the hair become porous.

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Questions for Continuing Medical Education - CME

1 - Regarding the format of hair strands, which of these structures has a major role:
a) inner sheath
b) outer sheath
c) bulb
d) companion sheath
e) epidermis

2 - What is the kenogen phase?
a) the phase of further growth of hair
b) seems to be more common in patients with alopecia areata
c) represents the empty follicle between the end of the catagen phase and the new telogen phase
d) the exclusion phase of active hair shaft
e) represents the empty follicle between the end of telogen phase and the new anagen phase

3 - What is(are) the melanocytic stem cells reservoir(s)?
a) inner and outer sheath
b) bulge and outer sheath
c) inner sheath
d) bulge
e) outer sheath

4 - What is the duration of each phase of the hair cycle: anagen, catagen and telogen, respectively:
a) 6 months, 3 years and 3 months
b) 3 months, 3 weeks and 6 years
c) 6 years, 3 months and 3 weeks
d) 6 months, 3 days and 3 weeks
e) 6 years, 3 days and 3 weeks

5 - Trichoptilosis is:
a) several hair strands coming out of a single hair follicular unit
b) the sudden change of the anagen phase of growth to telogen phase
c) hair in "bamboo"
d) the same as gray hair
e) lengthwise slit of hair shaft with the appearance of "split ends"

6 - About the outer layer of the hair shaft, we can state that:
a) it is named cuticle and is composed of cells named scales overlaping like shingles
b) it is named cuticle and consists of a single layer of dead cells without sulfur
c) it is named cortex and is composed of macro- and microfibrils of keratin with longitudinal arrangement
d) it is named cortex and is composed of 5 to 10 layers of dead cells rich in sulfur
e) it is named cortex and is the most mass of hair and divided into ortho- and paracortex

7 - Hair color has as a characteristic:
a) it is given by keratin found in the cortex
b) it is given by the melanin in the cortex and cuticle keratin
c) it is given by keratin and melanin located in cuticle and cortex
d) it is given by melanin located in cortex and medulla
e) it is given by the melanocytes of epidermis

8 - The complex of cell membrane and the endocuticle form the region:
a) more subject to residue deposit of cosmetics and chemical attack
b) rich in cystine
c) rich in keratin
d) more resistant to the action of permanent color or toners
e) rich in lanthionine

9 - Hair is more malleable than the nails because:
a) it has a greater number of disulfide bridges
b) it has fewer disulfide bridges
c) it has more ionic connections
d) it has less ionic connections
e) there is no relationship of this feature with the chemical bonds of keratin, but with a different composition of its amino acids

10 - The main difference between permanent and toner hair coloring is:
a) the presence of ammonia only in hair toners
b) the presence of paraphenylenediamine only in permanent colors
c) the presence of diaminophenol only in toners
d) the presence of ammonia only in permanent color
e) the presence of resorcin and resorcinol only in permanent color