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Environmental and Cosmetic Factors in Hair Loss and Destruction

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Abstract

Acquired hair loss may be a manifestation of various internal diseases, hormonal and nutritional conditions, systemic intoxications and genetic traits. However, exogenous exposures may be major contributors to hair thinning and decline of texture, color, luster, elasticity and manageability. In this review, we describe the effects of various exogenous agents on hair, including hair cosmetics, traction, heat, water, solar radiation and X-irradiation.

Hair loss affects a large part of the population. It is usually categorized into five pathogenetic mechanisms: hair shaft defects, telogen effluvium, anagen arrest, destruction of hair follicles or miniaturization of the follicle. Hair loss often occurs due to various internal diseases, hormonal and nutritional conditions, intoxications and genetic traits. In addition, hair loss also occurs as a manifestation of external stimuli. This chapter describes the various exogenous factors that promote hair loss by the first four mechanisms (table 1), and downgrade hair's physical properties such as strength, shine, and tactile characteristics.

Hair Structure, Elasticity, Water Permeability and Hair Cycle

The hair fiber is an extremely stable structure that can resist breakdown thousands of years after a person's death. About 50–100 μm in diameter, it consists of a cuticle, cortex and medulla. The cortex provides the majority of hair fiber mass and is responsible for its strength. It is made of elongated cells, tightly packed together. These cells are composed of long filaments, or microfibrils, which contain organized α-helical rods of keratin embedded in an amorphous matrix. These

Table 1. Exogenous environmental and cosmetic insults and resultant mechanisms of hair loss

	Hair shaft defects (including hair breakage)	Telogen effluvium	Anagen arrest	Cicatricial alopecia
Environmental				
Scalp injury				
Avulsion				+
Thermal, electric or chemical burn				+
Sunburn		+		
Contact dermatitis		+		
Pressure		+		+
Sunlight	+			
X-irradiation		+	+	+
Swimming (water, chlorine)	+			
Self-inflicted				
Trichotillomania		+		+
Trichoteiromania	+			
Scraching associated with scalp dermatoses	+			
Hair care and cosmesis				
Shampooing	+			
Combing, brushing, back combing, towel drying	+			
Ponytails, multibraiding, hair meshing		+		+
Heat drying	+			
Chemical processing				
Permanent curling	+			
Relaxing	+			+
Bleaching	+			
Permanent coloring	+			
Minoxidil		+		
Hair transplantation		+		
Rhytidectomy (facelift)		+		

proteins are remarkable for a proportionately high level of the intermolecular cross-linked amino acid, cystine, the disulfide bonds of which give hair its great tensile strength. Other protein-protein intermolecular bonds, such as salt bonds and hydrogen bonds also exist in keratins [1]. The hair cortex is covered by an external cuticle, which accounts for 10% of the hair fiber's weight. The cuticle consists of overlapping layers of scales, each about 0.5 μm thick. In a newly formed human hair, up to 10 scales can overlap in one cross-section. The cuticular scales protect the underlying cortex and act as a barrier. When the scales are intact, their smooth surface reflects light, so the hair looks shiny and healthy. Finally, the medulla consists of specialized cells that contain air spaces. Only thick terminal hairs have a medulla, which may be discontinuous [1].

Aside of the main proteinaceous component, dry hair weight is composed of 1–9% of lipids. Hair lipids are composed of squalene, wax esters, triglycerides, free fatty acids, cholesterol, ceramides, cholesterol sulphate and 18-methyl-eicosanoic acid. 18-methyl-eicosanoic acid binds chemically to the cuticle surface, and seems to contribute to various physical properties of hair fibers, such as shine and manageability [2].

The elasticity of healthy hair enables the fibers to resist forces that would otherwise change their shape and length and regain their original form when the force is removed. The tensile strength of hair, which allows its elasticity, depends on a healthy cortex. Normal wet hair can be stretched up to 30% of its original length, without damage, but further stretching of the hair is associated with partially irreversible damage and breakage. The extensibility of hair increases in high degree of humidity. It decreases with increasing diameter of the shafts, in lower temperatures and following bleaching and permanent waving. Sunlight exposure impairs elasticity, as bleaching does, but to a lesser degree [3].

Despite the close-fitting scales of the cuticle and the sebum, which naturally coats it, hair is permeable to water, so when soaked, rapid water absorption takes place and its weight increases by 12–18% [4]. Water penetration is restricted by the normal barrier functioning of the cuticle, so damaged cuticles allow higher water absorbance. The hair water content is an important factor in its physical and cosmetic properties.

The degree of the hair's curl is determined by the cross sectional shape of its fibers. Caucasoid hair has an elliptic cross section and tends to be wavy. Mongoloid hair has a circular cross section and is typically straight. Negroid hair has an asymmetric flattened cross section that accounts for its irregular kinky appearance.

A hair cycle has a succession of three phases. Hairs can be in an actively growing state called the anagen phase, which lasts around 3 years, or in a resting or preshedding phase termed the telogen phase (3 months). A very brief

transitional phase between anagen and telogen is called the catagen phase (2–3 weeks). Telogen follicles account for the hairs that are normally shed from the scalp every day. At any given time, about 5–20% (on average, about 10%) of the hairs are in the telogen phase. However, the precise percentage of telogen hairs varies from person to person and even between parts of the scalp [5]. At the end of the telogen phase, a cluster of stem cells, located in the midportion of the follicle at the insertion of the arrector pili muscle, known as the bulge zone, begin to proliferate rapidly downward to form a new anagen hair. At about the same time, the telogen hair is shed.

Hair Shaft Defects That Are Caused by Exogenous Factors

Weathering

Acquired hair shaft defects are associated with breakage, which may appear as hair loss, or with a decline of hair quality. The hair follicle is usually not affected and later growth is not disturbed.

In the degeneration of hair fibers, several mechanisms such as friction, cosmetics, wetting, heating and ultraviolet irradiation operate simultaneously. In everyday life, all hair fibers undergo some degree of cuticular and secondary cortical breakdown before they are shed. These changes, referred to as 'weathering', are most prevalent in the tips of long hair, which are exposed to external noxious stimuli for longer time. The progressive microscopic changes in weathering include lift up and irregular breaks of the cuticular cells, until some surface areas become totally denuded of cuticle. With further damage, longitudinal fissures appear between exposed cortical cells followed by transverse breakage (trichoschisis), trichorrhexis nodosa like nodes, and trichoptilosis (split ends), a longitudinal splitting of the distal end of the hair [6]. In fact, the main cause of trichorrhexis nodosa, also described as an inherited weakness of the hair shaft, is a mechanical or chemical trauma. Weathered hair is of abnormal texture, fullness and shine, and difficult to manage.

Daily practices such as shampooing, combing, brushing and styling enhance weathering. Frequent shampooing, which efficiently cleanses hair of its natural sebum, can leave the hair dry, statically charged and more exposed to friction and thus to weathering. Medicated shampoos that contain antiseborrheic compounds such as tar, selenium sulfide, zinc pyrithione, salicylic acid and ketoconazole may alter hair shafts' physical properties, negatively affect hair-combing ease and smoothness, and again promote weathering, though some new formulations leave the hair in good condition. Some harsh detergents can even remove proteinaceous material from the hair shaft [7]. Most modern shampoos, however, are designed by the manufacturers in an intention to fulfill

customers' expectations, and leave the hair clean and yet shiny, full of volume and easy to manage. If the cuticle is already injured by repeated chemical processing and the hair is overporous, repeated wetting by itself may negatively affect hair shaft condition. When the protecting affect of the cuticle is diminished, the shafts swell with water when the hair is washed and its repeated expansion and contraction gradually weakens it. Shampooing is also associated with matting of hair, nowadays a rare phenomenon, but not with increased hair shedding, both to be discussed later.

Over-indulgent brushing and combing, especially of wet hair, is probably the most damaging in applying mechanical stress to the hair. As such, repetitive combing of a hair tress is a common laboratory method for producing fractured hairs and split ends. The fractures created by repetitive combing cannot be explained only by stretching tension, because the force needed to break an undamaged hair exceeds the force needed to extract the same hair from the scalp. Instead, it was shown that the fractures are due to bending and twisting of the hair fibers and hair-hair interactions are even more damaging than those between the hair and the comb [8]. Repetitive combing induces trichorrhexis nodosa and trichoschisis. The form of trichorrhexis nodosa induced by combing is distal, usually localized, and not associated with hair loss, but with weathered dull hair. Back combing (from tip to root) is even more damaging.

Using hair dryers or curling irons is also associated with structural changes in the hair. Heat generates formation of splitting spaces between the cuticle layers and disturbs their smooth surface which allows reflection of light and thus suppresses hair shine [9]. Friction is increased. Heat-dried hair has a lower moisture content and a higher propensity to flyaway than room temperature-dried hair [10]. Normally, heat drying does not produce tensile damage, but exposure to higher temperature is associated with hair breakage, as discussed below.

Permanent waving, relaxing, bleaching and permanent coloring of the fully formed hair, necessitate chemical products that induce significant damage to the hair fibers. Permanent hair waving requires reduction of disulfide bonds in the cuticle and cortex with alkaline thioglycollate, manipulation of the hair into a new shape and reformation of some of the bonds with hydrogen peroxide. In hair relaxing, sodium hydroxide or guanidine hydroxide – both at high pH 12 – are used. A variety of bonds are broken throughout the hair and the hair is pulled into a straight form. In hair bleaching, melanin pigment in the hair cortex is bleached by using alkaline hydrogen peroxide or persulfate. In order to access the pigment, the bleach must cross the cuticle, causing irreversible oxidation of disulfide bonds to cysteic acid (–SS– groups are converted to SO3H) [11]. Permanent color involves hydrogen peroxide and ammonia (pH 9–10). Again,

the product must bleach pigment from the cortex before forming permanent colors throughout the fibers.

Permanent coloring induces cuticular damage that can be clearly shown by ultramicroscopy and is most evident in the first day after coloring. After 8 weeks, the hair shows complete restoration and return to the precoloring state [12]. Permanent waving and bleaching cause significant hair shaft damage, even when properly applied. Perming weakens the hair because the S–S bonds reformation in the waved form is always incomplete. The hair typically shows increased water permeability, less extensibility, rough surface and rapid weathering. Repetitive bleaching also results in overporous brittle fibers, low in shine, which weather rapidly. The altered shape and surface damage of chemically treated fibers increase the propensity to friction, so if permanent changes are undertaken, the hair will be more vulnerable to everyday practices of washing, combing and drying and the normal weathering process will be increased greatly. If the chemistries involved in perms, bleaches and relaxers are left on for too long, at too high concentration, or with heat, the hair fiber is likely to be broken or dissolved. For example, over-reduction of the hair or under-neutralization of a perm-reducing agent may be associated with significant hair loss 2–5 days following a perm. The cause is breakage of hair fibers very close to the scalp. Similarly, chemical relaxers often cause hair breakage, the degree of which depends on the exact chemical, the exposure time and prior hair condition. Hair breakage is most common in the nape area, a location first to be treated by the hair stylist and hence exposed for longer period of time. Hair treated repeatedly is also prone to irreparable damage and breakage.

Exposure to sun causes dryness, rough surface texture, decreased luster, stiffness and brittleness of hair, as well as change of color [13]. Transmission electron microscopy of hair exposed to sunlight shows rupture and detachment of the external layers of the cuticle or even full cuticular layer disintegration and splitting of the ends. Chemically, the oxidation of keratin that is induced by light occurs at the cystine C–S bond to yield 1 mol of cysteic acid, and the mechanism is thought to be free radical in nature [14]. The cuticle is altered to a greater extent than the cortex because it is free of melanin granules, which are photoprotective, and exposed to higher intensities of radiation. Damage to protein and lipids in the cuticle of the hair fiber are caused by UVA and UVB and only marginally by visible light [14]. The detrimental changes caused by exposure to sunlight are enhanced by humidity and moisture, so ‘surfer’s hair’, subjected to sun and salty water soaking, is notoriously frazzled, damaged and bleached. Loss of hair color is caused by damage to the melanin granules, mainly by visible light [15]. Color change is seen more often in red-headed and blond persons because pheomelanin is more sensitive to degeneration than