

Hair Weathering, Part 1: Hair Structure and Pathogenesis

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Hair weathering is the deterioration of the hair shaft from root to tip resulting from a range of cosmetic and environmental factors. Cosmetic practices such as combing, brushing, braiding, weaving, hair extensions, straightening, waving, perming, and dyeing, as well as environmental factors such as exposure to UV light, can induce structural damage to the hair fiber. The cuticle becomes raised and porous, exposing the cortex to further damage. A decrease in hair shine, elasticity, and strength is observed, ultimately leading to hair breakage. Part 1 of this series reviews hair structure, including race and age variations, as well as the pathogenesis of hair weathering.

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Hair weathering is the manifestation of hair shaft defects due to cosmetic or environmental factors including physical or chemical trauma from hairstyling procedures and external factors such as UV radiation, wind, humidity, sea salt, chlorinated water, dust, pollution, and friction.¹ The condition usually affects scalp hair, but body hair also can be affected.²

After hair loss and thinning, hair weathering represents the most common concern among patients who present to dermatologists.³ Weathering can occur in normal hair, particularly in the distal part of long hair shafts, but minimal damage caused by certain practices or conditions predisposes hair to weathering.⁴⁻⁶

In part 1 of this series, we review the hair structure, including race and age variations, and the pathogenesis of hair weathering.

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The authors report no conflicts of interest in relation to this article. This article is the first of a 2-part series. The second part on the diagnosis and treatment of hair weathering will appear next month. Correspondence: Filipa Osório, MD (filipaosorio@gmail.com).

HAIR STRUCTURE

Hair is an epidermally derived structure that is comprised of a follicle and a shaft. The main constituents of the hair shaft are proteins, lipids, water, melanin, and trace elements. Hair is a dead structure with no nerve connections and thus does not cause a feeling of pain when damaged. Cross-sectionally, the hair shaft consists of 3 major parts (from the outside in): the cuticle, the cortex, and the medulla.⁷

The cuticle is a protective layer of keratinized scales that are arranged similar to roof shingles, providing 5 to 10 overlapping cell layers from root to tip. The free edges of the cuticle are directed outward with the proximal edges resting against the cortex.⁸ The cell structure of the cuticle includes 3 major layers: the cystine-rich A-layer, the exocuticle, and the endocuticle.⁹ The surface of the hair is covered in a covalently bound, monomolecular layer of a unique branched fatty acid, 18-methyl eicosanoic acid.² The normal cuticle has a smooth appearance, enabling light reflection and limiting friction between the hair shafts, and also is responsible for the luster and texture of the hair.⁷

At the root end, surface cuticle cells are closely apposed to the deeper cell layers. Within a few centimeters of the scalp, the free margin of these cells lifts up and irregularly breaks. Many fibers show complete loss of overlapping scales proximal to the tip, particularly on long hair shafts.

HAIR WEATHERING

Cortical cells become exposed and longitudinal fissures appear between them. Transverse fractures of the hair fibers also can occur and the altered shape increases the propensity for friction damage.⁹

The cortex makes up the bulk of the hair shaft and contributes most to the color and mechanical properties of the hair. The cortex consists of closely packed, elongated, polyhedral cortical cells filled with cysteine-rich keratin filaments that are orientated parallel to the longitudinal axis of the hair shaft as well as an amorphous matrix of high-sulfur proteins. Cysteine residues in adjacent keratin filaments form strong covalent disulfide bonds that contribute to the shape, stability, and texture of the hair. They remain intact when the hair is wet, enabling hair to resume its original shape. Other weaker bonds link the keratin polypeptide chains together, such as Van der Waals interactions, hydrogen bonds, and Coulombic interactions known as salt links, which can be overcome with water.⁷

In humans, a third component may be present in terminal hairs, known as the central medulla. Its function remains unknown.⁷

The tip of scalp hair contains substantially less cysteine (cuticle) and cysteine (cortex) than the root end; the converse applies for cysteic acid. The standard variation of cysteic acid content along the hair shaft is lower in bleached fibers than in untreated ones.¹⁰

Hair is porous; damaged hair is intensely porous. Water absorption causes the hair shaft to swell. Because wet hair produces more friction than dry hair when combed, brittle hair is more likely to be stretched to its breaking point when it is combed while wet.² When dry, however, hair shafts produce static electricity, which can cause hair shafts to repel, creating flyaway hair. Moisture reduces static and frizz.²

Hair weathering is the progressive deterioration of the hair shaft from root to tip in which the loss of cuticular protection leads to a reduction in the ability of the cortex to maintain moisture and a decrease in the hair's shine or luster. Further damage leads to loss of elasticity and strength, ultimately causing cortical degeneration, complete loss of structural integrity, and hair breakage.³

Race and Age Variations

The intimate structure of hair fibers as well as the constituent proteins and amino acids are similar in patients who are Asian, white, or black; however, important differences are observed in the associated geometry and mechanical properties of the hair (Table).¹¹

The degree to which hair curls is directly related to the cross-sectional shape of the hair shaft and determines grooming ease. Hair in black individuals shows increased

friction when groomed, resulting in increased weathering and breakage (Figure 1).^{8,12} The cross-sectional shape of the hair fibers also influences the amount of shine and the ability of sebum to coat the hair shaft. Straight hair has a smooth surface, allowing maximum light reflection and ease of sebum movement from the scalp down the hair shaft. Although hair in black individuals tends to produce more sebum, the irregularly kinked hair shaft causes a dull appearance because of its rough surface, which makes the transport of sebum from the scalp more difficult.^{8,12} When placed in contact with water, hair in black individuals presents a lower radial swelling rate, which could be due to potential differences in fiber composition, particularly with regard to lipids.¹¹

Although the hair shaft in Asian individuals has a larger diameter and therefore higher tensile strength than white

Racial Variations of the Hair Shaft

Hair Shaft Attributes	Patient Populations		
	Asian	White	Black
Shape	Straight	Straight, wavy, or helical	Tightly coiled, helical, or spiraled
Cross-section	Round, larger in diameter	Round to oval	Elliptical or flattened, irregular
Pigment	Eumelanin rich	Mixture of eumelanin and pheomelanin	Eumelanin rich
Combing	Easy	Variable	Difficult
Sebum coating	High	Intermediate	Low
Moisture	High	Intermediate	Low
Water swelling rate	High	High	Low
Tensile strength	High	Intermediate	Low
Breaking stress	High	High	Low



Figure 1. Hair breakage caused by weathering in a black patient.

individuals, both hair types exhibit similar behavior when subjected to strain. Hair in black individuals differs from both whites and Asians because it breaks more quickly and requires less stress to reach its breaking point. This fragility could possibly be explained by natural constrictions along the fibers, twisted shape of the fibers, and presence of microcracks or fractures in the fibers.¹¹

A study comparing hair weathering in black, white, and Asian patients showed that black patients had an increased tendency to develop the condition, with more frequent longitudinal fissures and splits along the hair shafts and greater incidence of trichorrhexis nodosa, knots, fractured ends, breakage, irreversible matting, and short hair from breakage.¹³

Hair procedures such as straightening, braiding, and weaving, as well as wearing specific hairstyles, are common among black individuals; studies analyzing both adults and children have found a relationship between hair care practices and hair loss and breakage in these patients.^{14,15} In a study of 39 Nigerian adults, 7 participants (17.9%) reported hair breakage.¹⁶

The hair shaft in Asians is round in shape and is thick, robust, and straight. Hair in this population is difficult to perm or dye, and for these reasons, it often becomes damaged when subjected to cosmetic procedures because it requires higher concentrations of chemicals and longer amounts of exposure.¹⁷

Irrespective of race, gray hair seems to be coarser, stiffer, and dry faster than pigmented hair, though no chemical differences have been found between the fibers.¹⁸

PATHOGENESIS

Hair weathering can result from a range of cosmetic and environmental factors. The adverse effects of several

cosmetic procedures are described as well as the effects of UV light.

Cosmetic Weathering

Cosmetic weathering generally can be attributed to poor or incorrect cosmetic practices that are split into 3 main groups³: aggressive mechanical manipulation, exposure to excessive heat, and inexperienced use of chemical procedures.

Combing and Brushing—Combs made of metal or wood and those with irregular teeth tend to cause more damage to hair than those made of bendable plastic. Backcombing raises the cuticle layer, exposing the cortex and making the hair shaft more vulnerable to damage. Excessive brushing may induce premature telogen shedding (teloptosis). Hair clasps, pins, and rubber bands also can lead to hair fracturing.¹⁷

Braiding and Weaving—Natural hair can be braided in sections along the scalp to produce cornrows. The practice of adding color- and texture-matched synthetic or human exogenous hair fibers to natural hair is known as hair weaving. Acquired trichorrhexis nodosa is a potential side effect of this styling technique.¹⁹

Hair Extensions—Although they are scarcely reported, the side effects of hair extensions may be common. Traction alopecia is well-documented, and hair matting and breakage also are potential side effects that indicate hair weathering (Figure 2).²⁰

Straightening and Waving—Hair straightening may be accomplished by using hot combs or hair irons (temporary) as well as chemical relaxers or Brazilian hair keratin treatment (permanent).²¹

Hot combs and straightening irons form new hydrogen bonds at high temperatures that are broken as soon as the hair is exposed to moisture.¹⁹ The hot combing method utilizes a metal comb that may be heated electronically or over a hot plate, reaching temperatures as high as 300°F to 500°F. A heat protector spray should be applied to dry hair before the procedure is started.²² Adverse events include hair breakage, bubble hair, hot comb alopecia, and thermal burns of the skin.¹⁹ Using a hot comb on wet hair or applying a wet spray prior to use results in greater structural damage than if used on dry hair.^{23,24}

Straightening irons have 2 juxtaposed flattened plates that press on either side of a section of hair and straighten the hair when heated. Typically the plates are made of Teflon, ceramic, tourmaline, metal, or titanium.²⁵

In contrast, curling irons or tongs create temporary waves or curls in the hair. There are many different models that vary by diameter, material, barrel shape, and handle type. The barrel's shape can either be a cylinder, cone, or reverse cone, and curling irons often have brush attachments or double and triple barrels. The curling iron



Figure 2. Hair extensions from a macroscopic view (A) and a dermoscopic view (B). The telogen hair roots are evident as the telogen hair cannot be shed due to matting.

also can have a spring-loaded, Marcel, or clipless handle. Spring-loaded handles are the most popular and utilize a spring to control the barrel's clamp. Devices that utilize a Marcel handle, named after Marcel Grateau, allow the user to manually apply pressure to operate the clamp. Clipless wands have no clamp and the user simply wraps hair around a rod. Most clipless curling irons come with a Kevlar glove to avoid burns. Some curling irons are charged with ionic energy that prevents frizziness and static. Negative ions are believed to shrink water droplets in the hair, helping to dry hair faster with less heat damage while also eliminating static electricity and neutralizing odors.²⁵

Crimping irons work by styling hair with a sawtooth crimping effect. The look is similar to the crimps left after taking out small braids; however, unlike braids, crimping

irons use heat and may damage the hair, similar to straightening or curling irons.²⁵

Perming—Perming solutions such as thioglycollates and bisulphites produce permanent hair waves by cleaving a certain number of disulfide bonds between hairs. As these bonds are broken, the hair shaft is vulnerable and can be easily damaged by sudden temperature changes or mechanical trauma. The perming solution is then washed off and a neutralizing oxidative agent such as hydrogen peroxide or sodium bromate is applied to the hair. New disulfide bonds form in the new shape of the hair. It has been reported that the neutralization process (oxidation) may be more damaging than thiol reduction, and free radicals may cause some of this damage. Internal hair lipids in cell membranes also are lost during permanent waving. The process must be repeated every 2 to 3 months, and after many procedures, few remaining disulfide linkages are left, with permanent reduction of the hair strength.⁷

Hair damage usually is caused by overperming or poor neutralization, or by formation of new incomplete bonds due to shampooing the night of or a few days after the procedure. Hair breakage occurs close to the scalp and usually happens a few days after perming.⁷

Chemical Straightening—The chemical process involved in relaxation is similar to perming. Breakage of the disulfide bonds allows the hair to be mechanically straightened. Relaxing agents can be lye or nonlye based. Lye relaxers use sodium hydroxide as the alkaline agent, while nonlye relaxers use either lithium hydroxide or guanidine hydroxide.⁷ The latter agents probably are less irritating to the scalp but are more drying to the hair and thus can cause more hair breakage.¹⁹ Chemical hair straightening needs to be repeated every 4 to 6 weeks and only areas of regrowth need to be straightened, otherwise damage to the hair can occur.⁷

Complications are more common with chemical straightening procedures than with perming because the hair is manipulated when the bonds are broken. Hair breakage is the most common side effect of this procedure and it is most common in the nape area, followed by the anterior scalp margin (Figure 3). The location is related to where the relaxer is first applied.¹²

In 1994 and 1995, there was a nationwide outbreak of alopecia associated with an all-natural hair-straightening formulation.²⁶ Despite claims that the relaxer was safe and natural, it contained copper, ammonium, and chloride salts and had a pH of less than the listed level of 3.95%. Of 464 patients, 95% reported hair breakage and/or hair loss after using this product.²⁶

Brazilian hair straightening, also called Brazilian keratin treatment, is a newer method to temporarily straighten hair by sealing the hair with a liquid keratin and a

preservative solution using a flatiron.²⁷ Although we know of no case series or case reports in the medical literature regarding this practice, it was the experience of one of the authors that the procedure may result in hair breakage and hair loss (Figure 4). In fact, Health Canada has received multiple complaints from stylists and consumers who have reported hair loss following the use of this technique, among other adverse effects.²⁸

Dyeing—Several different cosmetic hair dyes have been formulated including temporary, gradual, semipermanent, and permanent dyes.²⁹ All hair dyes may induce contact allergic reactions in the skin, but resulting hair shaft defects vary according to the type of dye.

Temporary hair coloring agents are removed after 1 shampooing. The particle size is too large to penetrate through the cuticle and they do not damage the hair shaft. The dye also can run and stain clothing if the treated hair gets wet from rain or perspiration.²⁹



Figure 3. Hair breakage caused by chemical straightening in a black patient (macroscopic view)(A). Broken hair showed evidence of trichorrhexis nodosa (B).

Gradual dyes, also known as metallic or progressive hair dyes, are mainly used by men and require repeated application, resulting in a gradual darkening of the hair shaft.²⁹ They may be associated with adverse effects such as unpredictable coloring and metal deposits, producing brittle dull hair.⁷

Semipermanent coloration with dispersed dyes involves no chemical oxidative reactions, but the coloring mixture is blended with an alkaline solution, which disrupts the cuticle to enable diffusion of the dye molecules into the cortex.⁷ Dyes are retained in the hair shaft by weak polar



Figure 4. A white patient experienced hair loss after Brazilian keratin treatment for hair straightening (macroscopic view, A; dermoscopic view, B) with an increased number of scalp arborizing vessels and discrete scaling.

and Van der Waals attractive forces, thus lasting 6 to 10 shampoos.²⁹

Permanent dyes are the most commonly used hair colorants, but they also have the greatest potential for causing damage to the hair shaft. Highly alkaline solutions cause the cuticle to swell, allowing for penetration of the dye molecules into the cortex.⁷ They also must be mixed with hydrogen peroxide before application to bleach the hair, with or without a booster of ammonium or potassium persulphate. Bleaching oxidizes the existing melanin in the cortex. The oxidation reaction destroys some of the disulfide bonds within the keratin and can damage the cuticle, making it more porous, with subsequent exaggerated effects of further chemical treatment. Permanently raised cuticles result in altered moisture content and dull brittle hair.^{7,30}

Environmental Weathering

UV Light—Bleaching is common in individuals with brunette or blonde hair who expose their hair to UV radiation. Brown hair tends to develop reddish hues because of the photooxidation of melanin pigments, whereas blonde hair develops a photoyellowing effect. The yellow discoloration occurs because of the UV light–induced oxidation of the sulfur molecules within the blonde hair shaft and the photodegradation of cystine, tyrosine, and tryptophan residues, as well as disulfide bond breakage.^{8,9}

Exposure to sunlight may lead to hair dryness, decreased strength, rough texture, loss of color and luster, stiffness, and brittleness. Cuticular breakdown precedes cortical degeneration.⁹ The deleterious effect of sunlight is well-illustrated by the seasonal recurrence of trichorrhhexis.³¹

CONCLUSION

Hair weathering poses cosmetic concerns to patients. It may occur from cosmetic or environmental factors. Understanding the pathogenesis of hair weathering will aid the physician in pinpointing treatments.

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