

Int J Trichology. 2015 Jan-Mar; 7(1): 2–15.

PMCID: PMC4387693

doi: [10.4103/0974-7753.153450](https://doi.org/10.4103/0974-7753.153450)

Hair Cosmetics: An Overview

[Maria Fernanda Reis Gavazzoni Dias](#)^{1,2}

¹Department of Dermatology, Fluminense Federal University, Niterói, Brazil

²Department of Dermatology, Azulay Dermatology Institute, Rio de Janeiro, Brazil

Address for correspondence: Prof. Maria Fernanda Reis Gavazzoni Dias, Rua Mariz e Barros 176, Sala 608 Icarai, Niterói CEP, 24220121, Rio de Janeiro, Brazil. E-mail: mgavazzoni@gmail.com

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Abstract

Hair cosmetics are an important tool that helps to increase patient's adhesion to alopecia and scalp treatments. This article reviews the formulations and the mode of action of hair cosmetics: Shampoos, conditioners, hair straightening products, hair dyes and henna; regarding their prescription and safetiness. The dermatologist's knowledge of hair care products, their use, and their possible side effects can extend to an understanding of cosmetic resources and help dermatologists to better treat hair and scalp conditions according to the diversity of hair types and ethnicity.

Keywords: Hair, hair care, hair cosmetics

INTRODUCTION

Although dermatologists are experts in managing scalp and hair diseases, the esthetic of some cosmetic therapies still remain elusive. Knowledge of hair cosmetics and esthetic procedures as well as of the hair shaft structure and physical behavior is indeed relevant in today's medical practice.[1] Although hair cosmetics are widely available, the medical literature is rather scarce, and specialized literature is not readily accessible. The aim of this chapter is to allow a better understanding of the hair shaft structure and behavior, as well as information about the hair cosmetics. Knowing their mode of action, safetiness and ingredients will enable the physician to better assess different problems secondary to cosmetic treatments. Cosmetic hair care procedures are mostly used by African-descendent women, whose hair fragility has been related to be worsen by hair care practices. According to McMichael[2] hair fragility leading to breakage can occur due to genetic predisposition, weathering from various hair care practices. Hispanic patients also have curly or very curly hair that may clinically behave as sensitive as African hair when exposed to hair care procedures. Although scientific data is lacking to prove whether Hispanic hair is really as sensitive, it is common to see Hispanic women with chemically straightened hair, suffering from hair breakage and asking for the dermatologist help and advice to overcome the problem. Also, it is important to distinguish hair shed due to telogen effluvium from hair shed due to hair shaft breakage, which is not always clear from the patient point of view.

HAIR

Hair is an integrated system with a peculiar chemical and physical behavior. It is a complex structure of

several morphological components that act as a unit. The hair shaft of mammals is divided into three main regions: Cuticle, cortex and medulla. The medulla is present in coarser hair like grey hair, thick hair and beard hair, and it is absent in fine hair of children. There is more medulla in the coarser hair of Asians than Caucasians. The medulla may be involved in the splitting of hairs since it provides an area of weakness as a pathway for the propagation of cracks along the axis of the fiber.[3,4]

The cuticle is a chemically resistant region and consists of flap overlapping scales (keratinocytes) like shingles on the roof. The shape and orientation of the cuticle cells are responsible for the differential friction effect in hair. The cuticle is generally formed by 6–8 scales thick for Asians, slightly less in Caucasians and even less in African hair. A thinner cuticle layer makes African hair more prone to breakage. Each cuticle cell contains a thin proteinaceous membrane, the epicuticle, covered with a lipid layer that includes the 18-methyl eicosanoic acid (18-MEA) and free lipids. Beneath the cuticle cells membranes there are three layers, all containing heavily cross-linked protein, mostly cystine, the A-layer, the exocuticle or B-layer and the endocuticle. The first one contains the higher amount of cystine, and the third one contains the lowest. The 18-MEA is responsible for the hydrophobicity of the hair and its removal by alkaline chemical cosmetics procedures may damage hair by increasing hydrophilia.[5]

The cell membrane complex (CMC) is intercellular matter. CMC consists of cell membranes and adhesive material (cement) binding the cell membranes between two cuticle cells, two cortical cells and cuticle-cortex cells. The most important layer of the CMC is called the beta-layer, and it is considered to be the intercellular cement and it is sandwiched by other layers from each cell. The CMC and the endocuticle are very vulnerable regions to the chemical treatments such as bleaching, dyeing and hair straightening/perm procedures. Also, the everyday grooming and shampooing friction may disrupt the CMC.[3,4,5]

CMC fractures may be seen before the hair fiber is ruptured. The exposure to repeated rough washing, unprotected drying, friction actions, sunlight and alkaline chemical treatments lead to a decrease in the lipid content of the cell surface changing it from the state of hydrophobicity to a more hydrophilic, negatively charged surface.[3,4,5,6]

The cortex constitutes the major part of the mass of the human hair, and it is formed by elongated, fusiform cells connected by a CMC and contains protein and melanin granules. The cortex cell also contains spindle-shaped fibrous structures called macrofibrils, each one consists of microfibrils that are highly organized fibrillar units and matrix. The matrix is formed by crystalline protein of high cystine content. The macrofibrils are arranged in a spiral formation. Inside the microfibrils there are subfilamentous units called protofilaments, each contains short sections of alpha-helical proteins in coiled coil formation polypeptide chains of proteins. The alpha-helix is held coiled by chemical forces such as: Ionic forces, hydrogen bonds, Van de Waal forces and disulfide bonds. Hair straightening process consists on breaking the forces that hold the coil, allowing it to be stretched. If the rupture of the chemical bonds is followed by curling the hair, it is called “perm,” meaning permanent curling. The process of reduction the hair involves hair swelling and very alkaline substances such as sodium or lithium hydroxide, guanidine, ammonium thioglycolate, pH higher than 9.0. All this can produce splits or cracks to the endocuticle and the CMC, but the major damage to hair after using hair reducing products is indeed due to misuse of the products and lack of care during combing hair in the reduced state.[4,5,6,7] Hair damage caused by the use of chemical procedures can be minimized, avoided or repaired by the correct use of hair care products. Hair cosmetics may enhance hair hydrophobicity, strengthen the cuticle and minimize electrical charges and friction forces.[2,5,6,8]

HAIR DAMAGE

The hydrophobicity of the hair is possible thanks to the 18-MEA lipid layer. Removal of this covalently

linked fatty acid renders the fiber hydrophilic. When wet, virgin hair can be stretched by 30% of their original length without damage; however, irreversible changes occur when hair is stretched between 30% and 70%. Stretching to 80% causes fracture.[4] Hair is porous and damaged hair is intensely so. Water absorption causes the hair shaft swelling. Excessive or repeated chemical treatment, grooming habits, and environmental exposure produce changes in hair texture and if extreme can result in hair breakage. These changes can be seen microscopically as “weathering” of the hair shaft and contribute to tangling, and frizzing. Weathering is the progressive degeneration from the root to the tip of the hair. Normal weathering is due to daily grooming practices. When the hair is extremely weathered and chemically treated, there may be scaling of the cuticle layers, removal of the 18-MEA and cuticle crack. If the cuticle is removed, the exposure of the cortex and further cortex damage may lead to hair fiber fracture. The use of hair cosmetics may restore hair cuticle damage and prevent hair breakage by reducing friction and water pick up.[2,4,5,8,9]

SHAMPOOS

Shampoos are not only scalp cleaners, but indubitably act as preventing the hair shaft damage. Many scalp diseases are also treated by active ingredients that are added to the shampoo's formulations. It is desirable that whatever may the disease or condition be (dermatitis, seborrhea, alopecia, psoriasis), the hair strands are kept aesthetically presentable, preserving its softness, combability and shine while treating the scalp. [10,11,12,13,14,15]

Shampoos are typically composed of 10–30 ingredients although products with as few as four ingredients are available. The products are grouped into: (1) Cleansing agents; (2) additives that contribute to the stability and comfort of the product; (3) conditioning agents, intended to impart softness and gloss, to reduce flyaway and to enhance disentangling facility, and (4) special care ingredients, designated to treat specific problems, such as dandruff and greasy hair.[11,12,13]

Conditions that are mostly affected by the use of aggressive shampoos are: Difficulty in untangling the strands, and the frizz effect. Attrition, the main cause of frizz, can be minimized by adequate formulation of cleaning products. On the other hand, if the shampoo formulas do not present the adequate composition, fiber attrition is aggravated.[10,16]

Although considered as safe products, shampoos can cause contact dermatitis. Common allergens in shampoos are: Cocamidopropyl betaine, methylchloroisothiazolinone, formaldehyde-releasing preservatives, propylene glycol, Vitamin E (tocopherol), parabens and benzophenones.[14,15]

SURFACTANTS

Surfactants are cleaning agents that substituted soap [Table 1]. They act through the weakening of the physicochemical adherence forces that bind impurities and residues to the hair. Surfactants dissolve these impurities, preventing them from binding to the shaft or the scalp. The cleansing ability of a shampoo depends on how well it removes grease as well as the type and amount of surfactants used.[5,10]

Residues are nonsoluble fats (sebum) that do not dissolve with water. In order to be removed from the hair shaft, surfactants present a hydrophobic molecular portion, and another hydrophilic. The former will chemically bond with the fat, while the latter will bond with the water. The surfactants are generally composed of a chain of fatty hydrocarbons (tail) and a polar head. The polar extremity is capable of giving this portion of the molecule hydrophilic traits that allow it to dissolve in water and wash away the residues. The surfactants in contact with the water attain the structural formation of a micelle. Their structure becomes spherical with a hydrophilic exterior, which can be rinsed with water, and a hydrophobic interior where the fats and residues are binded. When enough shampoo molecules have embedded their

hydrocarbon ends in the particle, the surrounding water molecules attract the ionic ends of the surfactant. The particle then becomes emulsified, or suspended in water. In this form, it can be rinsed away. [4,5,11,12,13] Depending upon the electric charge of the polar extremity, the surfactants are classified in four groups: Anionic, cationic, amphoteric and nonionic. The main cleansing agents are anionic. The soap, which is also an anionic detergent, in contact with water, leaves an alkaline residue that is very harmful to the hair and skin and that precipitates in the form of calcium salts which accumulate in the hair strands, leaving them opaque and tangled. Such effects do not happen with the new anionic surfactants that are derived from the sulfation of fatty acids and analogue polioxietilenes (alquil sulfates, alquil ether sulfates) which are smooth cleansers and cosmetically superior. The current expression “sulfateless shampoo” refers to a preparation without the anionic surfactant. Theoretically the sulfateless shampoo creates a minimum electrical net, but there are no published analysis about effectiveness of these products regarding either cleansing power or hair shaft aggression. [11,12,14,15,16]

Cationic, amphoteric and nonionic surfactants are added to some shampoo formulas to reduce the static electricity generating effects caused by the anionic surfactants. Since they carry a positive charge, cationic surfactants bond quickly to the strands negatively charged due to the use of anionic surfactants and reduce the frizz effect. Besides, they optimize the formation of foam and the viscosity of the final product. The static electricity verified after the use of shampoo is exactly the result of a balancing out between the electric charges during the removal of sebum and residue. Negative charge of the hair fiber repels the also negative charge of the micelle. The repulsion of charges allows rinsing with water. However, the result is an increase of the preexisting negativity of the strands and the formation of stable complexes that bond with the keratin, creating repulsion between the strands due to excessive static electricity. Although the cationic agents try to neutralize this effect, there is the interference of the shampoo pH, which can increase the static electricity and reduce charge neutralization. [4,5,6,12,14,15,16]

Anionic surfactants

Anionic surfactants are characterized by a negatively-charged hydrophilic polar group. Examples of anionic surfactants are ammonium lauryl sulfate, sodium laureth sulfate, sodium lauryl sarcosinate, sodium myreth sulfate, sodium pareth sulfate, sodium stearte, sodium lauryl sulfate, alpha-olefin sulfonate, ammonium laureth sulfate. Although very good in removing sebum and dirt, anionic surfactants are strong cleaners and may cause an increase on electrical negative charges on the hair surface and increase frizz and friction. In order to minimize damage, other surfactants called secondary surfactants such as nonionic and amphoteric surfactants are added to the formulation. [5,11,17,18]

Cationic surfactants

Cationic surfactants have a positively charged hydrophilic end. Typical examples are trimethylalkylammonium chlorides, and the chlorides or bromides of benzalkonium and alkylpyridinium ions. All are examples of quats, so named because they all contain a quaternary ammonium ion. They tend to neutralize the negatively charged net of the hair surface and minimize frizz. They are often used as shampoo's softeners. [5,11,17,18]

Amphoteric surfactants

For the amphoteric surfactants, the charge of the hydrophilic part is controlled by the pH of the solution. This means that they can act as anionic surfactant in an alkalic solution or as a cationic surfactant in an acidic solution. They are very mild and have excellent dermatological properties. There are two types of amphoteric compounds: Alkyl iminopropionates and (amido) betaines. [5,11,17,18]

Nonionic surfactants

Nonionic surfactants have no electric charge. They do not ionize in aqueous solutions because their hydrophilic group is of a nondissociable. Many long chain alcohols exhibit some surfactant properties. Prominent among these are the fatty alcohols, cetyl alcohol, stearyl alcohol, and cetostearyl alcohol (consisting predominantly of cetyl and stearyl alcohols), and oleyl alcohol. [5,6,11,17,18,19,20]

CONDITIONERS

Conditioners are used to decrease friction, detangle the hair, minimize frizz and improve combability. Conditioners act by neutralizing the electrical negative charge of the hair fiber by adding positive charges and by lubricating the cuticle that reduces fiber hydrophilicity. They contain anti-static and lubricating substances that are divided into 5 main groups: Polymers, oils, waxes, hydrolyzed aminoacids and cationic molecules. [5] The most active and used conditioner agent is a silicone. [21,22,23] There are different types of silicones with different deposition, adherence and wash out capacity which will lead to different performances of the conditioner. [21,22,23] The ideal conditioner is capable of restore the hydrophobicity of the fiber and neutralize the static electricity. Depending on the capacity of entering the fiber, the conditioner may reach the cuticle surface or the inner part of the cortex. Smaller molecules can reach the cortex. Larger ones act on the cuticle. Low molecular weight polypeptides (<10.000 Da) can diffuse into hair. Bigger molecules (500.000 Da) can diffuse into the cuticle, especially on bleached hair. The preferred route is intercellular diffusion or diffusion through the nonkeratin regions, although intracellular diffusion may also occur. Higher molecule weight polymers (<600.000 Da) may sorption on the surface of the hair shaft. [5] Cationic ingredients such as cationic polymers are very popular in hair products. They can be so substantive to the hair that they can be difficult to remove. They are highly substantive to hair because of the hair's low isoelectric point (pH - 3.67). Any cosmetic with higher pH bears a net negative charge on the hair surface, and therefore cationic charges (positive) are attracted to it. [4,5,12,16,20] Also, Van der Waals forces and entropy are necessary to bind the molecule to the fiber, and they must be resistant to rinsing with water. [5,22] Examples of such polymers are: Benzyl dimethyl ammonium chloride and distearyldimonium chloride. The good correlation between silicone oil droplets stability, deposition on hair and resultant friction of hair support that droplet size and uniformity are important factors for controlling the stability and deposition property of emulsion based products such as shampoo and conditioner. [20]

It is common to use cationic ingredients in many shampoos' formulations with anionic surfactants in order to result in charge neutralization forming a cationic-anionic complex, a neutral hydrophobic ingredient. Therefore, we can understand that the interaction between the ingredients is more important than the ingredient alone, as we are led to believe by the media. It is very common to think that a new release product that contains a certain ingredient has the magic ability to transform dull hair into shiny and smooth hair. Most of the time, the major ingredients do not change, and sometimes the capacity of the ingredients to interact inside the shampoo's or conditioner's chassis or system is what makes the product acts better. Bleached and chemical treated hair have a higher affinity to conditioning ingredients because they have a low isoelectric point (higher concentration of negative sites) and are more porous than virgin hair. [5,20]

Functions of the conditioners are: [5,12]

- Improve combability
- Mimetize the hair natural lipid outer layer: 18-MEA
- Restore hydrophobicity
- Seal the cuticle
- Avoid or minimize frizz, friction: Neutralize the negative charged net
- Enhance shine, smoothness and manageability.

SILICONES

Silicones are hybrid (inorganic-organic) inert, heat-resistant and rubber-like polymers derived from crystal quartz. Silica (silicon dioxide) common in sandstone, beach sand, and similar natural materials, is the initial material from which silicones are produced.

Dimethicone is the most widely used silicone in hair care industry, and entropy is important for its adsorption to the hair surface. Dimethicone is the main ingredient of the two-in-one shampoos. Others are: Aminosilicones, siloxysilicates, anionic silicones and others. They differ on deposition and solubility in a water medium, therefore acting differently on the hair. Some silicones can even enhance the shine of hair fiber by reflecting the light. Dimethicone has the effect of protecting the hair shaft from abrasive actions while siloxysilicates increase hair body.[5,21,22,23]

Polysiloxane polymers may re-cement lifted cuticle scales and prevent damage from heat. Amino functional silicones are cationic substances but not necessarily are more substantive to the hair than dimethicone, depending on the size of the molecule and the charge of the system. Dimethicones are hydrophobic, so they adsorb better on virgin hair and root rather than tips. To enhance the deposition of dimethicone on chemical treated and damaged hair the products use cationic bridging agents which act increasing affinity between hair and the silicone.[4,5,12,24,23]

Other polymers are the polypeptides and proteins for they are very substantive to the hair for having many ionic and polar sites for bonding and are large molecules to attach to the hair surface (van der Waals force). Small molecules can even diffuse into hair (<1000 Da) especially on damaged hair. Protein hydrolysates, in particular those with low molecular weight distribution, have been known to protect hair against chemical and environmental damage. Many types of protein hydrolysates from plants and animals have been used in hair and personal care such as keratin hydrolysates obtained from nails, horns and wool. Most of these hydrolysates are obtained by chemical hydrolysis and hydrothermal methods, but recently hydrolyzed hair keratin, feather keratin peptides have been obtained by enzymatic hydrolysis using *Bacillus spp* in submerged fermentation. The hydrolysed protein derived from feather was deposited on the cuticle scales, and helped sealing the cuticle especially after heating with a flat iron, improving hair color and shine.[25] A higher amount of protein was deposited on chemical treated hair, especially bleached. As the hydrolyzed amino acids are positively charged, it is possible that the negative charge of the damaged hair attracts the positively charged molecules neutralizing the electrical charges and diminishing frizz and friction.[25]

Keratin hydrolysates are usually prepared from keratin-containing animal parts, such as feathers, horns, hoofs, hair and wool, collected from discarded materials. Some industries have developed products that use a complex of nonanimal free amino acids derived from wheat, corn and soy proteins to mimic the natural composition of keratin. However, keratin is an irreplaceable protein in respect to its mechanical and protective properties, and the using of amino acids do not replace or restore the damaged molecule structure.[25]

OTHER SUBSTANCES: MINERAL AND VEGETABLE OILS

There are few articles published about the effect of mineral and vegetable oils on human hair. The main physical property of this class of ingredients is the hydrophobicity of the oil. Saturated and monosaturated oils diffuse into the hair much better than polyunsaturated oils.[5]

Oils play an important role in protecting hair from damage. Some oils can penetrate the hair and reduce the amount of water absorbed in the hair, leading to a lowering of swelling.[26] This can result in lower hygral fatigue (repeated swelling and drying), a factor that can damage hair. The oil can fill the gap between the cuticle cells and prevent the penetration of the aggressive substances such as surfactants into the follicle. Applying oil on a regular basis can enhance lubrication of the shaft and help prevent hair breakage. Rele

and Mohile in 2003, studied the properties of mineral oil, coconut oil and sunflower oil on hair.[27] Among three oils, coconut oil was the only oil found to reduce the protein loss for both undamaged and damaged hair when used as a prewash and postwash grooming product. Both sunflower and mineral oils do not help in reducing the protein loss from hair. This difference in results could arise from the composition of each of these oils. Coconut oil, being a triglyceride of lauric acid (principal fatty acid), has a high affinity for hair proteins and because of its low molecular weight and straight linear chain, is able to penetrate inside the hair shaft. Mineral oil, a hydrocarbon, does not penetrate. Sunflower oil is a triglyceride of linoleic acid with a bulky structure and double bonds and has limited penetration to the fiber, not reaching the cortex. The mineral oil and the sunflower oil may have a film effect and adsorb to the surface of the cuticle enhancing shine and diminishing friction and for these, avoid hair damage.[22]

Keis *et al.* in 2005 studied the effect of coconut oil, olive oil, sunflower oil and mineral oil on the hair.[28] Except for mineral oil, heat decreased the capillary adhesion of the other oils, resulting from the penetration into the hair fiber by diffusion, leaving a thin film on the surface. Although thick films of oil can mask the lifted scales of the cuticle, it may leave an oily and heavy look to the hair. It is preferred to reapply oils that leave a thin layer on the surface and are well absorbed by the fiber. In 2009, the Brazilian oils and butters were studied by Fregonesi *et al.*[29] They analyzed the following substances: Passion fruit seed (77% linoleic acid), Brazilian nut (38% oleic acid and 35% linoleic acid), palm olein (47% oleic acid), buriti (79% oleic acid), palm stearin (42% palmitic acid and 41% oleic acid), tucumã (48% lauric acid and 27% myristic acid), ucuúba (75% myristic acid), sapucainha (47% chaulmoogric acid, 27% hydnocarpic and 19 gorlic acid). Oil treatment reduced the combing force percentage for wet conditions. However, the hair treated with butters showed poor combing. Treatments using oils reduced the formation of split ends in the hair. Tresses treated with Brazilian nut and mineral oils gave the lowest formation of split ends.[29]

The reduction of combing forces is a combination of water wetting and the lubricant effects of the oil on the fibers. Butters increased the combing force. Butters in raw state are not as fluid as oils and do not spread easily along hair tresses. The Brazilian nut, passion fruit seed, palm olein, buriti and mineral oils produced combing force reduction. Mineral oil has no affinity to hair's proteins and is not able to diffuse in the fiber. Mineral oil main effects are its higher spreading capability on the hair surface which improves gloss, combing facility and reduces split end formation.[29]

In 2007 Keis *et al.*[30] studied the effect of oil films on moisture vapor on human hair to analyze the capability of oils to reduce the moisture pick up. Although coconut oil penetrates, the fiber and mineral oil does not, there is the equivalent reduction on water sorption for both oils. Increasing the thickness of the oil layer on the fiber surface increased hair moisture regain. The oil that remains in the cuticle layer and not the oil that penetrates the cortex is the one responsible for the decrease in the water pick up.

Marrocan argan oil has become very popular as a hair cosmetic main ingredient, referred as capable of keeping the hair moisturized and hydrophobic. Morocco's argan oil is now the most expensive edible oil in the world. The argan tree (*Argania spinosa* L. Skeels), an endemic tree in Morocco, is the most remarkable species in North Africa, due to its botanical and bioecologic interest as well as its social value. The oil is rich in tocopherols and polyphenols, powerful antioxidants.[31] Argan oil is extracted from the kernels of argan fruits that have been sun-dried for either a few days or up to several weeks. The fruit drying time influences the quality of the extracted oil.[32] Although there is scientific literature about the use of the moroccan oil for chronic conditions such as atherosclerosis and psoriasis for its cardioprotective properties, there is a lack of data about the benefits for hair care.[33,34]

DIFFUSION INTO KERATIN FIBERS

There are two main ways for a substance to penetrate the hair fiber: Transcellular and intercellular diffusion, transcellular diffusion involves epicuticle, A-layer, exocuticle, endocuticle and is much harder path way because of the high cross-linked regions. Intercellular diffusion involves the intercellular cement, and it is the preferred route for large molecules because the low-sulfur and nonkeratin proteins are more easily swollen. Both routes can occur depending on the size of the molecule, hair damage and cosmetic system of the applied product.[5]

Diffusion rate into keratin fibers depends on the cross-link density of hair. Reactions like bleaching, that decreases the cross-link density increases the rate of transcellular diffusion, meaning that bleached hair is more rapid penetrated by conditioners, dyes, hair straightening substances or any product applied to the hair fiber. However, penetration into the intercellular regions can lead to scale lifting and cause hair damage. Scale lifting is induced by the deposit of insoluble cationic-anionic complex, meaning which can occur because of the interaction and bonding of the anionic surfactants of the shampoo with the cationic conditioning ingredients.[5,35]

LEAVE-ON CONDITIONERS

Creme rinses basically contain cationic surfactants, long-chain fatty alcohol or other lipid components. Cationic polymers are the also used, such as polyquaternium-10. Some examples that we can find among the ingredients are cetrimonium chloride and stearylalkonium chloride. Examples of lipids are cetyl alcohol, stearyl alcohol or silicones such as dimethicone. Deep conditioners contain more concentrated ingredients or just more viscosity. Some polymers are reported to build-up the hair and bind to anionic surfactants. The complex resists shampooing from hair. Creme rinses are supposed to be rinsed with water. Setting lotions or mousse known as leave-on products are designed to be applied on wet hair or dry hair and left without rinsing. They are aqueous based or alcohol-water solvent systems. These products do not form rigid bonds and act by enhancing interfiber forces and by providing a detangling effect to facilitate combing and style retention.[5,17,35]

AFRICAN HAIR AND CURLY HAIR

Afro-ethnic hair presents variation of diameter at several points along the thread (the diameter at twisting points is smaller than at other areas), less water content, and most importantly, an ellipsoid shape. Hair fibers present torsions at many regions along the thread, while Caucasian hair has a cylindrical cross-section.

The small angle of the waves of very curly hair makes it more susceptible to breakage, when mechanically worked making curly hair more difficult to comb without provoking frizz. Although the production of sebum is high on African hair, curly and wavy hair they are more prone to have oily scalp but dryer hair fiber. Sebaceous glands of African descendants are frequently less active, when compared with the Caucasian ones, and they produce low amounts of sebum. This way, both scalp and threads are dry because they do not have good lubrication, even when the cuticle is preserved and the scalp tends to be less hydrated. Usually, the scalp is relatively dry in order to the naturally irregular distribution of sebum. [7] Distribution of sebum along the fibers by combing and brushing is a way of lubricating curly hair because of the natural difficulty of the sebum produced on the scalp to diffuse along the fiber.[5,7,36]

To reach variety of styling, very curly hair is frequently straightened by pressing or by chemical relaxing/straightening. But, as the fiber is extremely sensible and prone to breakage it is not unusual that curly and straightened hair do not achieve long length and breaks during the growing process. [9,37,38,39,40,41,42,43]

Fine straight hair can transport sebum very well, and curly-coarse hair tend to minimize tress clumping

and limpness. The use of conditioners and leave-on products decrease interfiber friction making hair easier to comb. Chargeability also decreases helping to improve dry combing.[4,5,6]

The use of anti-dandruff shampoos can make hair more difficult to comb. High cleansing shampoos remove surface oils and increase chargeability by depositing small amounts of anionic surfactants onto the hair. Less flyaway is achievable by lubricating the fiber surface and decreasing static charge. Grooming a nonlubricated hair may lead to hair breakage. Abrasion and friction are important factors that cause hair damage by protein loss. The use of conditioners with oils and silicones are important to minimize the rubbing and friction of the cuticle cells for chemical treated hair and after the use of anti-dandruff shampoos.[4,5] Black hair has less density than Caucasian hair. The number of hair follicles in Caucasians is 120.000 and in African descendants is 90.000. This is the way the African descendants may experience some feeling of hair loss after performing a hair straightening procedure because when the hair loses volume, the scalp may be exposed because of the lower number of hair follicles.[17,44]

HAIR STRENGTH

Patients want their hair to be resistant to breakage with no split ends. Hair strength is a mix of hair body mass and resistance to breakage. A strong hair is a hair with its full capacity of growing healthy in both diameter and length and an intact cuticle and cortex.[5]

We know that split ends are more likely to occur in weathered and oxidized hair. But, split ends happen when the cuticle is removed (damaged) and the cortex-cortex CMC serves as a route for the propagation of axial splits in the fiber, leading to the formation of cracks and split ends. Hair strength depends on cuticle integrity and amount of water in the fibers, conditions that are related to chemical damage. Chemical damage by bleaches, dyes, straighteners and even sunlight can weaken hair and increase inter-fiber friction, leading to breakage. An important factor involved in hair breakage is the occurrence of tangles created by combing forces. Where the break occurs along the fiber, correspond to the point of higher combing forces. The type of fracture depends on hair condition and wet versus dry combing or brushing. Combing dry hair is more related to short segment breaks, and wet combing is related to long segment breaks. The short segment breaks are more related to split ends. Straight to wavy hair combed dry, produces higher end pick forces than mid-length forces, but when wet, produces higher mid-length combing forces corresponding to where hair breaks and to the amount of breakage. The work of combing highly coiled hair is lower wet than dry. The reverse holds for wavy to straight hair. Split ends form more readily from the abrasion (friction) in combination with torsional deformations (grooming and styling). Splitting occur when the cuticle is damaged and weakened. Crack is formed in the cortex. Few cuticle layers do not hold the ends of the hair fiber together. Also, highly oxidized cortex cell membrane by free radical chemistry is more susceptible to split. Hair treated with free radical cosmetics and exposed to sunlight is susceptible to splitting.[5,8,38]

Also, hair body is maybe defined as the structural strength and resiliency of a hair mass, sensed by patients as having a soft and firm touch and full volume. Full volume is meaning a scalp full covered with terminal hair fibers that grow to the desired length without breaking.

Strong hair

Hair density + diameter + resistance to breakage (no split ends) + length + smooth fiber interaction (no frizz) + no tangles (easy combing, manageability) + integrity of the cuticle layers + integrity of the cortex-cortex CMC + integrity of the cuticle surface lipids (18-MEA) + healthy hair follicle (to produce a normal healthy hair fiber). Strong hair appears as long, full, shiny, manageable hair. Manageable hair is the same as easy combable hair, perceived as soft hair, easy to finger comb. Weak hair appears as dull, with irregular

length (due to split ends), frizzed, rough, sometimes with low density on the scalp, tangled and difficult to finger comb.[5,8,38]

COSMETICS FOR THIN HAIR

Prescription medications are often focused on improving scalp hair density. Dermatologists are very used to prescribe minoxidil and finasteride in order to stimulate the anagen hair phase. But it is not always possible to obtain terminal thick hair fiber. Many postmenopausal women may achieve a better cosmetic look if the medical prescription is combined to cosmetic hair care products that may increase hair fiber diameter in a nonpermanent way.[45]

Fiber diameter is another key contributor to thinning hair, but it is less often the focus of medical or cosmetic treatments. Acrylate polymer combined with dimethicone may affect the diameter and behavior of scalp hair fibers to counteract decreasing fiber diameters. It may be applied in the morning, leaving minoxidil to be used at bed time. In the work of Davis *et al.* the existing terminal scalp hair fibers yielded an increase in the cross-sectional area of approximately 10% of the previous diameter.[45]

CONSIDERATIONS ABOUT THE HAIR WASHING AND GROOMING PROCEDURES

Shampoo must aim the scalp more than a hair. The entire scalp has to be rubbed with the shampoo from the front to the back, and small amounts of shampoo have to be applied on each region of the head under the hair. Applying the shampoo on the top of the head will increase hair friction and cause hair tangling. After full rinse of the shampoo, the hair must be gently towel dried, and the conditioner should be applied on the hair length avoiding the scalp. The conditioner has to be completely rinsed out. Application of hair conditioners after shampoo will lower inter fiber friction and reduce combing forces. If the hair is curly, leave-on products may be used during wet combing. The use of leave-on products on straight virgin hair may cause an oily look and dull the hair. Gentle hair is dealing actions (gentle shampooing, gentle towel drying, gentle brushing or combing) is recommended. Many products may be used to lubricate and seal cuticle cells, such as silicones (dimethicone and aminoterminal silicones) and vegetable oils. Grooming with a hair dryer or flat iron requires a silicone heat protector that will spread the heat along the hair fiber surface avoiding water boiling and the development of hair bubbles.[4,5,6,8,20,46,47]

HAIR STRAIGHTENERS

Historically, the first hair straightener procedure was used for African hair and consisted on applying petrolatum based oils on the hair combined with hot irons or hot combs pressed to the hair so the device could slide easily and straighten the tresses. This type of process produces only temporary straightening, functioning cohesive and adhesive forces in a highly viscous system to keep the fibers parallel. The habit of hair straightening was first used to allow manageability of very coarse hair but nowadays having straight hair has become popular all over the world.[7,37]

Official hair straighteners are called chemical relaxers, and the effect of hair straightening is permanent. Alkaline straighteners contain 1–10% sodium hydroxide (lye-relaxer), lithium hydroxide, calcium hydroxide or a combination of these ingredients such as guanidine carbonate and calcium hydroxide (no-lye relaxers). The high pH (9.0–14.0) of the emulsion swells the hair, thus opening cuticle scales, which allows the alkaline agent (OH⁻) to penetrate into the hair fibers up to the endocuticle. In the contact with the cortex, the straightening product reacts with keratin, breaking and rearranging the disulfide bridges, which making the spiral keratin molecule soft and stretched.[5,7,46]

The chemical relaxers may not be applied on the scalp for they can cause skin burn. It is indicated that some petrolatum is applied along the hair line and on the ears before the application of the relaxer to

prevent alkaline burns. Alkalies react with keratin cystine groups producing lanthionyl residues, a stable thioester crosslink. It is called “lanthionization” and consists on the substitution of a third of the cystine amino acid content for lanthionine, with lower hydrolysis of peptide bonds.[5,7]

Disulfide bonds are cleaved using an alkaline reducing agent; then the hair is mechanically straightened using a comb during the reducing phase to restructure the position of disulfide bonds between new polypeptide keratins. They also react with peptide bonds, hydrolytically cleaving this linkage, producing acid and amine groups, and producing residues of aspartic and glutamic acids. The relaxers are applied on prewashed hair and after usage, must be rinsed off with running water. They provide the most permanent hair straightening but if applied with the wrong technique may cause scalp burns and hair breakage. The pH of alkaline straighteners varies from 12 to above 13. Hair is sensitive to pH value changes and alkaline solutions swell the fibers and open the cuticle scales. This can make the hair susceptible to friction, lowering its resistance and strength.

Hair straightening needs to be repeated every 12 weeks or longer. The emphasis should be only on new growth hair since repeated treatments can lead to hair breakage, which usually occurs at the junction of the new growth and previously treated hair. Careful application to new growth only and previous conditioning of the hair can help prevent excessive breakage. In the work of Shetty *et al.*, the most common adverse effects reported after chemical hair straightening were: Frizzy hair in 67%, dandruff in 61%, hair loss in 47%, thinning and weakening of hair in 40%, greying of hair 22%, and split ends in only 17%.

There is no need to use external forces or heat, such as a hot iron because of phenomena called “supercontraction” that provides enough stress to straighten the fiber in a permanent basis. Sodium hydroxide (lye-relaxer) may straighten the hair in only 20 min. Although hair relaxers are desired for increasing length, Khumalo *et al.* found that the achieved hair length was significantly shorter than expected. This may be true because of the supercontraction effect.[47]

Ammonium Thioglycolate is another “no-lye” relaxer that can cause extreme swelling of the fiber, but causes less supercontraction than the alkaline relaxers that work with lanthionization. It is a chemical reducing agent which selectively weakens the hair's cystine bonds instead of disrupting the entire protein. Afterward, the thioglycolate must be oxidized (neutralized) with a special solution of hydrogen peroxide. If a hot iron is applied during the process, the permanent straightening can be achieved. This is the basis of the process called “japanese hair straightening or thermal reconditioning.” Thermal reconditioning involves “supercontraction” and transformation of alpha-helical keratin proteins in amorphous protein. No lanthionine is formed during this process, and 90% of the initial cystine content is retained with 10% additional cystine as cysteic acid.

This means that the use of thioglycolate causes less protein loss than hydroxides.

Hydroxides and thioglycolate are not mutagenic and show no evidence of carcinogenicity. If applied with the right technique and without touching the scalp, they are considered safe.[5,7,48,49,50,51,52,53] Syed and Naqvi found that the no-lye relaxer (guanidine hydroxide) was less irritating to the scalp than lye relaxer (sodium hydroxide). The authors recommend that African descendants and individuals with very curly hair and sensitive scalp use no-lye relaxers.[39]

Hydroxides and thioglycolate are incompatible with each other. If the hair is treated with hydroxides the same hair cannot be treated with thioglycolate. Also, both are incompatible with bleached hair. So, it is not unusual to receive a patient complaining that the hair broke (hair shed because of hair breakage) after the use of a relaxer. To avoid mistakes like that, the salon professional must perform a test that consists on the application of the product on a strand of hair to prove compatibility. If the hair breaks during the test, another relaxer must be tried, or the hair is too weak to be straightened. Hair conditioning substances may

be added to thyoglicolate straighteners in order to minimize hair damage.[48,53]

The use of formaldehyde formulations became very popular since 2003, and the first country to start this practice was Brazil in Rio de Janeiro. The most used products, a decade ago, were based on a solution or cream containing a home-made formaldehyde formulation obtained from a mixture of conditioners, hydrolyzed protein and a 37% formaldehyde solution, easily obtained as an over-the-counter substance, sold in every drugstore in Brazil. The formaldehyde solution was commonly used to sterilize medical materials and hospitals, and easy to find in every drugstore. The practice soon became so popular that called attention of the health vigilance organizations in Brazil (ANVISA) that prohibited the use of any product containing formaldehyde in concentrations above 0.2% for cosmetics and 5% for nail polish. Afterward, the formaldehyde was replaced by a potentially 10 times more mutagenic and the neurotoxic product belonging to the same aldehyde group: The glutaraldehyde. Easily obtained from hospitals and clinics, glutaraldehyde was commonly used as a sterilizer. It was soon not a home-made product anymore, but a demi-industrialized nonlegal substance, commercialized in every salon in Brazil. The solutions came in beautiful colored bottles of 500 ml to 1 liter. The label carried a false ANVISA registration number, and the product was sold to the salons by door-to-door sellers.[54,55,56,57]

Soon, almost every salon in Brazil was performing the Brazilian Keratin Treatment (BKT). Still, consumers complained of burning eyes, strong smell and burning mouth and nose. To avoid sensorial discomfort while applying the BKT, the ingredients used today are based not on formaldehyde or glutaraldehyde, but on formaldehyde-releasers such as methilene glycol or glyoxylic acid. Both substances are capable of releasing formaldehyde when heated during the blow-dry and hot iron application.

Brazilian Keratin Treatment has increased popularity because the procedure is compatible with bleached hair and gives the hair a natural smooth, shiny look, impossible to acquire with the chemical relaxers.

Brazilian Keratin Treatment is known by many names such as albumine hair straightening, acetic acid treatment, and hair botox. The health organizations in Brazil and in other countries continue to claim that only the chemical relaxers (lye and no-lyes relaxers) are officially legalized and safe to be used as hair straighteners, although the use of formaldehyde-releasers (“formaldehyde-free”) are growing in popularity each day with promises of safetiness with no scientific embasement and without the official permission of the Brazilian or USA governments.[58,59]

The mode of action of the formaldehyde is different from the others relaxers because formaldehyde or other aldehydes are not hair straightening products. The hair is remodeled straight because water breaks hydrogen bonds of the keratin molecule as happens in a regular blow-dry. The newly redesigned keratin is then kept in this shape because the formaldehyde crosslinks the keratin filaments in such a perfect alignment that the hair is now set straight and shines like no virgin straight hair is capable of. The light that strikes the hair reflects from the realigned keratin filaments and brings the effect of a brighter shiny hair. A study by Simpson and Crawshaw[60] which analyzed the reactivity of formaldehyde and wool keratin, found that formaldehyde forms cross-links with the keratin amino acids; arginine, lysine, tyrosine, histidine, and the amide derivatives of aspartate and glutamate.

The most interesting characteristic of the aldehydes in the hair is that they are compatible to every other chemistry available to hair treatment, such as bleaching, permanent dyes and hair relaxer, lye or no lye. In Brazil, African and Hispanic hair is straightened first with chemical relaxers and afterwards treated with BKT to improve shine and softness.

WHAT IS CARBOCYSTEINE?

Carbocysteine is a compound named glyoxyloyl carbocysteine or oxoacetamide carbocysteine.

Carbocysteine is produced by alkylation of cysteine with chloroacetic acid and is a mucolytic agent with no effect on hair keratin. The compound called carbocysteine hair treatment represents the combination of glyoxylic acid + cysteine + acetic acid. Glyoxylic acid contains an aldehyde functional group. In fact, the aldehyde is not observed in solution or as a solid. In general aldehydes with electron-withdrawing substituents often exist mainly as they hydrate. Even though the aldehyde is a very minor component of its solutions, glyoxylic acid behaves as an aldehyde in its reactions and is considered a sensitizer and a toxic substance.[61,62]

We may conclude that carbocysteine is not a hair straightening product by itself, and it is formulated combined with an aldehyde such as glyoxylic acid.

DAMAGE BY HEAT

Thermal treatments produce decomposition of tryptophan residues to kynurenine type oxidation products. The consequences are yellowing of white hair and darkening of bleached hair. After the thermal treatment with the addition of lipid products, hair may seem to be easier to comb. However, after shampooing and removing the lipids, hair dries out exposing the damage caused by excess of heat.

Although using a hair dryer causes more surface damage than natural drying, the work of Lee and cols concluded that using a hair dryer at a distance of 15 cm with continuous motion causes less damage than drying hair naturally.[63] However, during BKT the flat hot iron is applied to the hair surface 15–20 times on the same spot where the product has been spread. This practice is obviously, very aggressive to the hair fiber proteins integrity.[64]

SAFETY OF BRAZILIAN KERATIN TREATMENT

In 2004, the International Agency for Research on Cancer (IARC) reclassified formaldehyde (FA) from a probable (Group 2A) to a known human carcinogen (Group 1) citing results for nasopharyngeal cancer (NPC) mortality from the follow-up through 1994 of the National Cancer Institute formaldehyde cohort study. To the contrary, in 2012, the Committee for Risk Assessment of the European Chemicals Agency disagreed with the proposal to classify FA as a known human carcinogen carcinogenicity (Carc. 1A), proposing a lower but still protective category, namely as a substance which is presumed to have carcinogenic potential for humans (Carc. 1B).[65] However, Marsh and cols disagree with this last decision and suggest that the NCI publications that contain data from the 1994 mortality follow-up should be re-analyzed for they understand that there is incomplete data to correlate formaldehyde exposure and NPC.[66]

Shrestha *et al.* found that children prenatally exposed to formaldehyde, polycyclic aromatic hydrocarbons, perchloroethylene, or acetaldehyde in the third trimester had an increased odds of Wilms' tumor per interquartile increase in concentration.[67] Couto found a relationship between pregnancy, maternal exposure to hair dyes and hair straightening cosmetics, with and early age leukemia.[68] Mazzei *et al.* analysed home made hair straightening products containing formaldehyde and verified that the antibacterial activity was detected in all creams with positive mutagenicity induction. They concluded that the creams showed an intense genotoxic response.[69]

DNA-protein crosslinks measured in peripheral blood cells of hospital workers suggest that the formaldehyde might enter the systemic circulation of humans exposed to formaldehyde.[70] A review about the association of leukemia and formaldehyde made by Eastmond *et al.*, still has unclear results.[71]

Pierce *et al.* conducted a study to characterize potential formaldehyde exposures of salon workers and clients during keratin hair smoothing treatments. The results of this study show that professional hair is

smoothing treatments – even those labeled “formaldehyde-free” – have the potential to produce formaldehyde concentrations that meet or exceed current occupational exposure limits.[56]

Galiotte *et al.* in a study evaluated the genotoxic risk to 69 female hairdressers exposed daily to chemical substances such as hair dyes, waving and straightening preparations and manicurists' products by the Comet assay test (single-cell gel electrophoresis) The hairdressers showed a higher frequency of DNA damage that could be associated with the hairdressers' occupational environment, where different chemicals are chronically manipulated and inhaled. Considering that this profession in many countries, including Brazil, is not officially regulated, it is not discarded that the use of BKT may have some influence in the data of this work.[55]

A study of Maneli *et al.* concluded that formaldehyde concentrations in BKT products may exceed recommended levels and serve as a health hazard. Industry monitoring is needed to improve compliance and protection of hairdressers and consumers.[59]

HAIR COSMETICS REACTION

Reactions to cosmetic ingredients in decreasing order of frequency are: Fragrances, hair-coloring agents (p-phenylenediamine) preservatives: Formaldehyde, parabens, quaternium-15 (a formaldehyde donor); imidazolidinyl urea; DMDM hydantoin. Most of the cases are caused by leaving on products. Short contact cosmetics usually do not cause irritation or allergy.[72] Van Lerberghe and Baeck described an acute oozing eczema of the scalp, forehead, and neck, and important edema of the eyelids The patient had performed a hair-smoothing treatment the day before, using a product (INOAR Moroccan Hair Treatment containing formaldehyde that had been bought in Morocco by her hairdresser. The patch test was positive to formaldehyde and nonformaldehyde ingredients (++) .[73]

HENNA

Red henna is the dried and powdered leaf of *Lawsonia inermis*. Henna has been used as a dye for the skin, hair and nails. The usage of red henna has a few reports of allergic contact dermatitis caused by it and/or its active ingredient lawsone (2-hydroxy-1,4-naphthoquinone, CI 75480, Natural Orange 6). Type I allergy is rare, and is mainly an occupational hazard in hairdressers (sneezing, conjunctivitis, running nose, dry cough, dyspnoea, swelling of the face, or generalized urticaria). Lawsone is a potent oxidant of G6PD-deficient cells; topical application of henna may therefore cause a life-threatening haemolysis in children with G6PD deficiency.[74]

HAIR DYES

There are many types of hair dyes classified according to the penetration of the dye to the surface or to deep parts of the hair shaft. In this chapter, we will approach the two most used types of hair dyes: Demi-permanent and permanent dyes.

The main difference between the dyes are their capacity to reach the cortex and stay there in a permanent way or to not reach the cortex and stay shallow on the cuticle surface and be washable after about 10-15 shampoos. Those are the demi-permanent dyes. To overcome the cuticle and reach the cortex, the product must have an alkaline pH able to open the scales. Most of the times the permanent dyes use ammonia to increase the pH. Some products are referred to be ammonia-free, but instead, they carry ethanolamine with the purpose. Both substances remove the natural cuticle lipid, the 18-metil eicosanoic acid, which confers hidrofobicity to the fiber. The use of permanent dyes may cause cuticle damage by removing the 18-MEA and making the hair hidrophilic.

Permanent hair colors are the most commonly used hair colors, because of their longevity, and ability to

lighten the original darker color. These are also superior for gray or white cover. The pigmentation is permanent and the white hair that shows after 10-15 days after the application is not due to removal of the dye by shampoo but, instead, it is due to new hair growth. The permanent dyeing is an oxidation reaction that allows the pigments to get inside the cortex. The pigments are: Para-phenylenediamine, para-toluenediamine, and para-aminophenol, and para-aminophenol, known as the primary intermediaries) with hydrogen peroxide to liberate oxygen. And they also contain resorcinol, but this substance is gradually being removed from the ingredients in some markets, for safety reasons. Once inside the cortex, they combine with aniline dyes, to produce the required color molecules. The roots need to be touch-up after 15–30 days and the product must be applied only to the new growth.

Demi-permanent dyes do not contain ammonia or ethanolamine and for this reason are gentler on the hair than the permanent colors. They also contain hydrogen peroxide, resorcinol and para-dyes. The concentration of hydrogen peroxide is lower (2%) as compared to permanent hair dyes (6%). They are not as effective in covering gray or white hair because they only reach the cuticle. They do not lighten the hair shade. Sometimes are used as products to add shine and to turn the natural hair color into a more vibrant one. Demi-permanent hair color fadeaway after 10–15 shampoos, or even earlier. [1,5,6,12,17,18,74,75,76]

HAIR STRAIGHTENING AND HAIR DYES

Chemical hair straighteners are highly alkaline. For this reason, changing the color of a chemically straightened hair, either with hydroxides or with thioglycolate, is a delicate procedure that may cause hair damage and breakage. Therefore, the demi-permanent hair dyes are indicated instead of the permanent ones. The lack of ammonia or ethanolamine is responsible for a more gentle action without opening the cuticle scales and respecting the fiber integrity. Is it, however indicated to wait 15 days after the straightening to dye the hair with demi-permanent dyes. Highlights or light shades are absolutely incompatible with chemical relaxers. Their combined use can lead to hair shaft breakage.

Chemically treated hair is highly sensitive and prone to breakage. Although the dermatology practice involves the use of anti-dandruff and anti-psoriasis shampoos and lotions containing hair damaging ingredients, as well as minoxidil and other hair solutions, it is difficult to avoid hair weathering due to chemical procedures combined with hair medical treatments. The use of hair conditioners is indeed necessary to minimize friction and frizz caused by dermatological prescribed drugs. Choosing the right ingredients is absolutely related to achieve the patient's full compliance. Understanding the difference between the surfactants as well as the mode of action of conditioning agents, if on the cuticle or in the cortex, will help choose whether lubrication, strength, body mass, volume or sleekness is desired. Excess of residues is a matter of great interest due to frequent usage of leave-on products by African descendent or Hispanic descendent patients, especially with longer hair. Removing the residues without stripping the fiber is possible if the anti-residue shampoo (laureth ammonium-sulfate) is followed by the application of a thick moisturizing hair mask preferably containing hydrolyzed aminoacids, silicones and vegetable oils. Mineral oil is mostly substituted by film-forming silicones, but may still be used combined to other cationic ingredients. The anti-residue shampoo may be used each 10 shampoos, or even more frequently, depending on the need. Extremely highlighted hair is the most sensible to anti-residue formulations. In this type of hair, it may be used less frequently or not at all.

SAFETY OF HAIR DYES

Epidemiologically and human monitoring studies have not detected any risk of carcinogenicity of the ingredients used nowadays. Contact dermatitis is the main reaction. Turati *et al.* meta-analysis definitively excluded any appreciable excess risk of bladder cancer among personal hair dye users. [77] Although paraphenylenediamine is a common allergen, resorcinol and m-aminophenol were found more frequently

in the work of Hamann *et al.*[78] Although many studies have tried to find some linkage between hair dyes ingredients and cancer hazard, there is no conclusive study confirming this hypothesis.[79]

Footnotes

Source of Support: Nil

Conflict of Interest: None declared.

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Figures and Tables

Table 1

Shampoo surfactants		
Class	Example	Characteristics
Anionic	Ammonium lauryl sulfate, sodium laureth sulfate, sodium lauryl sarcosinate, sodium myreth sulfate, sodium pareth sulfate, sodium stearte, sodium lauryl sulphate, alpha-olefin sulfonate, ammonium laureth sulphate	Deep cleansing
Cationic	Trimethylalkylammonium chlorides, and the chlorides or bromides of benzalkonium and alkylpyridinium ions	Hair softener. Mild cleansing
Nonionic	Fatty alcohols, cetyl alcohol, stearyl alcohol, and cetostearyl alcohol (consisting predominantly of cetyl and stearyl alcohols), and oleyl alcohol	Mild cleansing Some considerations about the eco-system
Amphoteric	Alkyl iminopropionates and (amido) betaines	Do not irritate the eyes. Moderate cleansing

Classification of the surfactants

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