Hidden Risks of Formaldehyde in Hair-Straightening Products

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Formaldehyde (FA) is a colorless, flammable, highly pungent gas that remains ubiquitous in the environment despite being a known carcinogen and allergen.[1] In the cosmetic industry, FA commonly is used as both a preservative and active ingredient in hair-straightening products. Due to its toxicity and the thermal instability of FA releasers (ie, the release of FA at high temperatures), the US Food and Drug Administration has proposed a ban on formaldehyde and other FA-releasing chemicals (eg, methylene glycol) as an ingredient in hair-smoothing or hair-straightening products marketed in the United States.[2] However, the implementation of this ban is not yet in effect.

Hair-straightening products that are referred to as chemical relaxers typically contain alkaline derivatives. Alkaline hair straighteners—which include lye relaxers (active ingredient: sodium hydroxide), no-lye relaxers (active ingredients: potassium hydroxide, lithium hydroxide, calcium hydroxide, guanidine hydroxide, or ammonium thioglycolate), and the Japanese hair straightening process (active ingredient: ammonium thioglycolate)—do not contain FA or FA-derivatives as active ingredients.[3] Alternatively, acidic hair straighteners—popularly known as keratin treatments—contain either FA or FA-releasers and will be the primary focus of this discussion. As many patients are exposed to these products, we aim to highlight the cutaneous and systemic manifestations of acute and chronic exposure.

How Hair-Straightening Products Work

Hair straighteners that include FA or its derivatives generally contain high and low molecular weights of keratin peptides. The keratin peptides with high molecular weights diffuse into the cuticle while the low-molecular-weight peptides can penetrate further into the cortex of the hair shaft.[4] Formaldehyde forms cross-links with the keratin amino acids (eg, tyrosine, arginine), and the application of heat via blow-drying enhances its ability to cross-link the hydrolyzed keratin from the straightening product to the natural keratin in the hair fibers; the use of a heated flat iron further enhances the cross-linking and seals the cuticle.[5] The same mechanism of action applies for "safe keratin" (marketing terminology used for FA releasers) treatments, whereby the hydrogen and salt bonds of the hair are weakened, allowing for interconversion of the cysteine bonds of the hair fibers. This chemical conversion allows for the hair shafts to have a stable straight configuration. Of note, this mechanism of action differs from the action of chemical relaxers, which have a high pH and straighten the hair by opening the cuticles and permanently breaking the disulfide bonds in the cortex of the hair shaft—a process that restructures the keratin bonds without requiring heat application.[5]

The outcome of a keratin treatment, as seen on light microscopy, is the replenishment of gaps in the hair's cuticle, therefore increasing its mechanical and thermal properties.[6] This can give the appearance of increased shine, softness, and tensile strength. However, Sanad et al[6] report that, as viewed on transmission electron microscopy, these keratin treatments do not repair lost cuticles, cuticle splitting, or detached cuticle layers from damaged strands.

Lastly, some patients notice lightening of their hair color after a hair-straightening treatment, which is possibly due to inhibition of the enzymatic synthesis of melanin, decomposition of melanin granules, or a direct reaction from chemical neutralizers with a high pH.[6] Knowledge of the mechanism of action of hair-straightening treatments will aid dermatologists in educating patients about their immediate and long-term effects. This education subsequently will help patients avoid

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inappropriate hair care techniques that further damage the hair.

Environmental Distribution and Systemic Absorption of Formaldehyde

Atmospheric FA is absorbed via cutaneous and mucosal surfaces. Atmospheric FA concentrations produced when hair-straightening products are used cannot routinely be predicted because the amount generated depends on factors such as the pH of the preparation, the temperature to which the product is heated during straightening, duration of storage, and aeration and size of the environment in which the product is being used, among others.[7]

Peteffi et al[7] and Aglan et al[8] detected a moderate positive correlation between environmental FA concentrations and those in cosmetic products, particularly after blow-drying the hair or using other heat applications; however, the products examined by Peteffi et al[7] contained exceedingly high concentrations of FA (up to 5.9%, which is higher than the legal limit of 0.1% in the United States).[9] Of note, some products in this study were labelled as "formaldehyde free" but still contained high concentrations of FA.[7] This is consistent with data published by the Occupational Health and Safety Administration, which citied salons with exposure limits outside the national recommendations (2.0 FA ppm/air).[10] These findings highlight the inadvertent exposure that consumers face from products that are not regulated consistently.

Interestingly, Henault et al[11] observed that products with a high concentration of FA dispersed more airborne particles during hair brushing than hair straightening/ironing.[11] Further studies are needed to clarify the different routes and methods contributing to FA dispersion and the molecular instability of FA-releasers.

Clinical Correlation

Products that contain low (ie, less than the legal limit) levels of FA are not mandated to declare its presence on the product label; however, many products are contaminated with FA or inappropriately omit FA from the ingredient list, even at elevated concentrations. Consumers therefore may be inadvertently exposed to FA particles. Additionally, occupations with frequent exposure to FA include hairdressers, barbers, beauticians and related workers (33.6% exposure rate); sewers and embroiderers (26.1%); and cooks (19.1%).[12]

Adverse health effects associated with acute FA exposure include but are not limited to headache, eye irritation, allergic/irritant contact dermatitis, psoriasiform reactions, and acute kidney and respiratory tract injuries. Frontal fibrosing alopecia; non-Hodgkin lymphoma; and cancers of the upper digestive tract, lungs, and bladder also have been associated with chronic FA exposure.[7,13] In a cohort of female hairdressers, a longer duration of FA exposure (>8 years) as well as cumulative exposure were associated with an increase in ovarian cancer (OR, 1.48 [0.88 to 2.51]).[12] Formalin, the aqueous derivative of FA, also contains phenolic products that can mediate inflammatory response, DNA methylation, and carcinogenesis even with chronic low-level exposure.[14] However, evidence supporting a direct correlation of FA exposure with breast carcinoma in both hairstylists and consumers remains controversial.[7]

Sanchez-Duenas et al[15] described a case series of patients who were found to have psoriasiform scalp reactions after exposure to keratin treatments containing FA. The time to development of the lesions was inversely correlated with the number of treatments received, although the mean time to development was 12 months postprocedure.[15] These researchers also identified no allergies to the substance on contact testing, which suggests an alternate pathogenesis as a consequence of FA exposure, resulting in the development of a psoriasiform reaction.[15]

Following adjustment for sex, age, menopause status, and skin color, frontal fibrosing alopecia also has been associated with the use of formalin and FA in hair straighteners.[14] This is possibly related to the ability of FA and many phenolic products to induce chronic inflammation; however, a cumulative effect has not been noted consistently across the literature.

Future Directives

Continuous industry regulation is needed to ensure that use of FA is reduced and it is eventually eliminated from consumer products. Additionally, strict regulations are required to ensure products containing FA and FA-releasers are accurately labeled. Physicians and consumers should be aware of the potential health hazards associated with FA and advocate for effective legislation. While there is controversy regarding the level of absorption from environmental exposure and the subsequent biologic effects of absorption, both consumers and workers in industries such as hairdressing and barbering should reduce exposure time to FA and limit the application of heat and contact with products containing FA and FA releasers.

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