Comparison of Hair Shaft Damages after treating Chemical Stresses in Asian, Caucasian, and African hairs

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-Abstract-

Comparison of Hair Shaft Damages after treating Chemical Stresses in Asian, Caucasian, and African hairs

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Purpose: The goal of this study was to investigate the differences in serial pattern damage in Asian, Caucasian and African hair after chemical stresses such as straightening and coloring.

Materials and Methods: The chemical stress-induced hair damage was studied in hair from three ethnic group. The hair was divided into control and treatment groups (straightening, coloring and combination of straightening and coloring). Commercial products were used for straightening and coloring treatment. After 24 hours from the final treatment, the hair damage patterns were evaluated using transmission electron microscopy

(TEM), lipid TEM and a halogen moisture analyzer. The grades of hair cuticle and cortex damage were evaluated by three dermatologists.

Results: In the TEM examination, the Asian hair showed a more resistant cuticle after straightening treatment, and the Caucasian hair cuticle and cortex were relatively susceptible to the coloring treatment. After the combination treatment of straightening and coloring, the African hair was the most resistant to stress. In the lipid TEM examination, no notable differences in cell membrane complex damage among the three groups of hairs were observed. Among the three ethnic groups, Caucasian hair showed the lowest water contents after straightening, coloring and combination treatments.

Conclusions: Present study suggests that Caucasian hair is relatively susceptible to and African hair is more resistant to chemical stress, such as straightening and coloring.

Keywords: Ethnic hair, Chemical stress, TEM, Lipid TEM, Hair water content

Comparison of Hair Shaft Damages after treating Chemical Stresses in Asian, Caucasian, and African hairs

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I. Introduction

Hair is a very important and distinctive feature that plays a major role in self-perception. To some extent, hair expresses personality and personal image. Hair is one of the few physical features that can easily be changed. The length, color, and shape of hair can be modified to create a completely different style. Shampooing, conditioning, and styling of the hair are repeated processes because hair is in a cycle of constant renewal and shedding. Hair is the only body structure that is completely renewable without scarring, as long as the follicle remains a functioning unit. Hair growth occurs at a rate of 0.35 mm/d, and damaged hair can be trimmed and replaced with new growth[1].

The color of the human skin and the morphology of the hair are different among races, and genetic factors are the major cause of these differences. Many studies regarding skin differences between races have been published; however studies of ethnic hair differences began only with the increased interest in cosmetics.

Hair morphology is classified as either straight, wavy, curly, woolly and peppercorn[2]. Straight hair is mainly observed in Asians and Caucasians, whereas curly or peppercorn hair is mainly observed in Africans[3]. Hair is also classified into Asian, Caucasian and African hair by ethnicity[4].

Studies of the hair differences between races have been performed to confirm the morphological and biochemical differences. Morphologic studies are mainly focused on the hair color, shape and the changes in response to external stimulations and are based primarily on electron microscope data. In the case of Asian and Caucasian hair, the surface cuticle layer of the hair maintains uniform patterns which determine the relatively smooth hair texture. In

Africans, however, hair grows twisted so the cuticle layer has irregular arrangements and is easily damaged by physicochemical irritations such as combing and shampooing[5]. Asian hair has the largest mean diameter, followed by that of Caucasian hair, while the cross-section of African hair is ovoid and irregular[6].

Regarding mechanical properties, African hair has weaker tensile strength and breaks easier than does Caucasian hair. African hair has extremely curly configurations and is thus more difficult to comb than are hairs from other ethnic groups[4].

Hair is the keratinized laminar fibrous tissue produce by hair follicles. Similar distributions of the proteins and amino acids which constitute the hair keratin exist among different ethnic group [6-9]. The medulla is the center layer of a hair. The cortex, which makes up 80% of the total hair component, encircles the medulla, while the cuticle layer, which accounts for 15% of the hair component, encircles the cortex[10]. The cuticle layer is composed of cuticle cells that overlap one other by 75 to 80%. The other 20 to 25% of the cuticle cell surface protrudes from the surface, resembles scales, protects the internal hair structures and gives hair its shiny appearance[3]. The cortex possesses a majority of the hair proportion and contains the melanin which determines hair color. The medulla is composed of many vacuoles. The cuticle layer and cortex are the main focus of hair care.

There are several differences in the amino acid components which form the keratin proteins in the cuticle layer and cortex. Cuticle cells are classified into epicuticle, the A layer, exocuticle and endocuticle according to the amount of cystine and the structural characteristics. The epicuticle, which is the membrane of the cuticle cell, has a lipid membrane on the surface. The A layer, exocuticle, and endocuticle, which are the major components of the cuticle cell, contain 30%, 15%, and 3% cystine, respectively[11]. The cystine components in the cuticle layer account for a greater percentage of the composition than do those in the cortex. In addition, the cuticle layer is lipophilic due to the presence of hydrophobic amino acids. Moreover, the amino acids of the keratin proteins which construct the cuticle layer and cortex are mainly composed of unsaturated bonds which are easily damaged by reactive oxygens[12].

The cell membrane complex attaches to cuticle cells to prevent their detachment. The cell membrane complex is a lamellar structure and has an outer β-layer, middle δ-layer and inner β-layer[11]. The δ-layer is composed of proteins and polysaccharides, the β-layer is a lipid component in which 18-methyleicosanoic acids (18-MEA) and proteins are linked with covalent bonds. This thin lipid membrane covers the outside of the cuticle and reduces hair friction[13].

Diverse causes of extrinsic hair shaft damage have been documented and can be roughly divided into physical and chemical causes[14]. Physical causes of hair shaft damage include friction from hair accessories, washing, and towel drying. Friction is a major factor that damages the hair surface, especially wet hair, although other factors, such as photodamage and daily grooming, may also lead to hair damage. Exposure to ultraviolet radiation damages hair fibers, and sunlight can lead to dryness, rough surface texture, decreased color and luster, and increased stiffness and brittleness[14,15]. Chemical causes of hair damage include bleaching, hair dyeing and perming. Frequent use of chemical agents is a major cause of damage to the hair shaft. When cosmetic products are used incorrectly or too frequently, changes in hair texture corresponding to morphological changes on the hair surface may be produced[16,17].

Hair color is a popular form of self-expression. From natural hues to vivid tints, people may often experiment with a dramatic new look. Hair color formulations are the same for all hair types. Coloring agents may be temporary, semi-permanent or permanent, depending on the desired duration and final color. Typical permanent hair colorants contain hydrogen peroxide buffered to pH 10 with ammonium hydroxide. The roles of the oxidant are to bleach the melanin, lightening the underlying substrate color, and to oxidize the dye precursors to form chromophores. The final color achieved by the consumer is a combination of natural color lightening and deposition of synthetic color inside the hair. However, the oxidant in the dye can also react with the hair proteins and lipids, leading to changes in the hair fiber properties, especially over multiple cycles. These properties include a reduction in shine, reduced manageability, poor wet and dry feel, and increased likelihood of split ends[18].

Hair straightening can be achieved mechanically by pressing or chemically using relaxers. Hair relaxing is somewhat similar to permanent waving except curly hair is permanently straightened instead of straight hair being curled. Disulfide bonds are cleaved using an alkaline reducing agent; the hair is then mechanically straightened using a comb during the reducing phase to restructure the positions of disulfide bonds between new polypeptide keratins. Finally, the new bonds are consolidated using an oxidizing agent[17].

In the present study, the differences in serial damage patterns among Asian, Caucasian and African hair after chemical stresses such as straightening and coloring were investigated.

II. Materials and Methods

(1) Materials

Hairs from three ethnic groups, Asian, Caucasian, and African, were purchased from De Meo Brothers (New York, USA). All hairs were prepared as 2 g, 15 cm length tresses. The tresses were cleaned via immersion in a 300 ml, 5% sodium lauryl ether sulfate solution for 5 minutes, then rinsed with running distilled water for 30 seconds. Subsequently, the tresses were dried thoroughly in an ambient condition for 24 hours.

(2) Hair treatment

The three hair groups were divided into a control and five chemical stress groups (Table I, Figure 1).

For hair straightening treatment, ammonium thioglycolate was applied to completely dry hair samples, which were then straightened with a comb. After combing, the samples were placed in a 65℃ hot chamber for 10 minutes and rinsed with running distilled water. The hair samples were lightly dried with a towel, and peroxide neutralizer was applied. The hair samples were straightened with a comb and placed in an ambient condition for 15 minutes. After washing with running distilled water, the hair samples were dried in an ambient condition. After 24 hours, the straightening treatment was repeated three times over a period of three days for a subset of each group (As-S3, C-S3, Af-S3).

Hair coloring was performed with a commercial product (light brown, Somang Ltd., Seoul, Korea) that was applied to the hair samples and rinsed with running distilled water after 30 minutes. The hair samples were then dried in an ambient condition. After 24 hours, three repeated coloring treatments were performed over three days in a subset of each ethnic group (As-C3, C-C3, Af-C3).

In the hair straightening and coloring combination groups (As-S1C1, C-S1C1, Af-S1C1), hair straightening was performed first, followed 24 hours later by coloring.

(3) Measurements

After 24 hours from the final treatment, the hair damage patterns were evaluated using transmission electron microscopy (TEM), lipid TEM and a halogen moisture analyzer.

1) TEM examination

TEM examination was performed to evaluate the damage of cuticle layer and cortex.

Hair was placed in propylene oxide for 15 minutes. After preparation with a 1:1 propylene oxide:epon mixture overnight, the hair was embedded in an epon mixture. Horizontal sections approximately 60 to 70 nm in size were cut and stained with uranyl acetate and lead citrate. The specimens were viewed with a TEM (JEM-1200EDXII, 80 kV:JEOL, Tokyo, Japan).

2) Lipid TEM examination

Lipid TEM examination was performed to evaluate cell membrane complex damage.

Hair was fixed in Karnovsky solution (2% glutaraldehyde plus 2% paraformaldehyde), rinsed in 0.1 M sodium cacodylate and post-fixed with Lee's fixative (0.5% RuO_4 : 2% OsO_4 : 0.2 M cacodylate buffer = 1:1:1) at room temperature for 90 minutes. This procedure was designed to minimize hair injury and to better view the lipid layer of the hair[19]. Next, each section was dehydrated in alcohol solutions substituted with propylene oxide and embedded in the epon mixture. The embedded section was double stained with uranyl acetate and lead citrate. The section was then analyzed using TEM (JEM-1200EDXII, 80 kV:JEOL, Tokyo, Japan).

3) Hair water content

Water content was analyzed using a halogen moisture analyzer (HG53, Mettler Toledo, Zürich, Switzerland). Individual tresses were cut into 1 cm pieces and preserved in an 82% RH desiccator for seven days before being analyzed for moisture content. A fragment of hair (300 mg, 1 cm in length) was placed on the saucer of the balance,, and the change in weight during heating was recorded every 30 seconds. The hair sample was heated for the first 40 minutes at 65˚C, which was assumed to be the temperature of most hair dryers, and for the next 30 minutes at 180˚C to evaporate all water. As shown in Figure 2, the first convergence point (A) was observed between 30 and 40 minutes after the start of heating, and the second convergence point (B) was observed between 60 and 70 minutes after the start of heating. Based on the difference in weight between A and B, the second transpiration moisture content was calculated according to the following equation:

$$\text{Variation in water content (\%)} = (A/A\text{-}B) \times 100$$

A: water content of the sample after the elapsed time

B: water content of the virgin hair before each treatment

4) Grades of hair cuticle and cortex damage

Kim et al.[19] analyzed over 2000 scanning electron microscopic (SEM) and TEM findings of normal and various types of damaged hair to develop a standard grading system. Three individual dermatologists evaluated the TEM electron micrographs according to this grading system (Table II). For both TEM and lipid TEM examination, about ten hairs from each groups were used. Five electron micrographs were taken from single hair, therefore about fifty electron micrographs from each control and treatement groups were taken. The representative electron micrographs were chosen when over 80% of electron micrographs showed similar damage pattern.

III. Results

(1) Evaluation of cuticle layer damage according to TEM

Virgin hairs from three ethnic groups (control group; As-0, C-0, Af-0) showed intact cuticles composed of more than six layers (Tcu0, Figure 3). In the straightening treatment group, the Asian hair cuticles were more resistant than were the hairs from the other two groups, and the Caucasian and African hair cuticles showed similar damage patterns (Figure 4). In the coloring treatment group, the Caucasian hair cuticles were most vulnerable to damage. The African hair cuticles appeared to be more resistant to coloring than were the Asian and Caucasian hair cuticles (Figure 5). In the hair straightening and coloring combination group, the African hair cuticles appeared to be more resistant than were Asian and Caucasian hair cuticles. The Caucasian and Asian hair cuticles showed similar damage patterns after the combination treatment (Figure 6).

(2) Evaluation of cortex damage according to TEM

Hairs from the three virgin ethnic groups (control group; As-0, C-0, Af-0) showed intact cell membrane complexes with no damaged melanin granules (Tco0, Figure 3).

In the straightening treatment, the cortexes of all three ethnic hair groups showed similar damage patterns (Figure 7). In the coloring treatment, the African hair cortex appeared to be more resistant to a single color treatment than were the Asian and Caucasian hair cortexes. However, the cortexes of all three ethnic hair groups showed similar damage patterns after the three-time coloring treatment (Figure 8). In the combination treatment group, the African hair cortex appeared to be more resistant to damage than were the Asian and Caucasian hair cortexes. The Caucasian and Asian hair cortexes showed similar damage patterns after the combination treatment (Figure 9).

(3) Evaluation of cell membrane complex damage according to lipid TEM

Virgin hairs from the three ethnic groups showed intact intercellular lipid layers, indicating that they all adequately tolerated the coloring treatment. Only the Asian hair showed a bulged cell membrane complex after the three-time coloring treatment (Figure 10). The hairs from the three ethnic groups showed similar damage patterns after the straightening and combination (straightening and coloring) treatments, with the treatment resulting in the most extensive cell membrane complex damage (bulging) in all three ethnic hair groups compared to those of the other chemical stresses (Figure 11).

(4) Hair water content

In the control group, the African hair had the highest water content, followed by the Asian and Caucasian hairs. Compared to the control group, water content was increased after the straightening treatment. Between the straightening treatment groups, the three-time straightening group showed a more substantially decreased water content than did the one-time straightening group.

Caucasian hair had the lowest water content before and after the straightening treatment (Figure 12a). Water content in all groups was also decreased after the coloring treatment, with Caucasian hair having the lowest water content both before and after the coloring treatment (Figure 12b). In the combination treatment, hair water content was increased in the African and Caucasian hairs (Figure 12c).

IV. Discussion

Human hair is categorized into three major groups according to ethnic origin: Asian, Caucasian, or African. Although a considerable amount of data has been published on human hair, very little data on the influence of ethnic origin exists for hair characteristics[4]. Asian hair has a greater diameter with a circular geometry. African hair presents a high degree of irregularity in the hair diameter along the hair shaft and has an elliptical cross-section. Caucasian hair has an intermediate diameter and cross-sectional shape compared to those of the other groups. In terms of variability, African hair shows the greatest percentage of variability in cross-section compared with Asian and Caucasian hairs. The variation in the African hair cross-section confirms the presence of regular restrictions along the fiber[6,20,21]. Therefore, African hair has a physical shape resembling a twisted oval rod, whereas Caucasian and Asian hairs are more cylindrical[6]. African hair shows frequent twists, with random reversals in direction and pronounced flattening[21].

In terms of mechanical properties, African hair generally has less tensile strength and breaks more easily than does Caucasian or Asian hair[20,21]. The tensile strength of a fiber is highly dependent on its cross-sectional size. Although Asian hair has a larger diameter and consequently a higher tensile strength than that of Caucasian hair, these two types of hairs exhibit very similar behaviors under stress. African hair differs from both Caucasian and Asian hairs with regard to it reduced breakage limit. To date, there is no rationale explaining this phenomenon because neither structural nor chemical composition differences were observed among the three types of hair. However, several hypotheses based on morphologic and geometric considerations could provide an explanation of the mechanical characteristics, such as the natural constrictions along the fibers, the twisted shapes of the fibers, and the presence of microcracks or fractures in the fiber[5, 22-24].

In the present study, African hair had a tendency to form longitudinal fissures and splits along the hair shafts, which were not observed in the Caucasian or Asian hair. In addition, a high proportion of the African hairs exhibited a knot formation, which was rarely observed in Caucasian or Asian hair. The most significant feature of the overall hair samples was that the majority of the African hairs had fractured ends compared with those of the Asian and Caucasian hairs, in which original or cut tips predominated. Similarly, the basal end also exhibited evidence of breakage in contrast to those of the Caucasian and Asian samples, in which the majority of hairs had attached roots. These observations are consistent with repeated breakage of the African hairs. In contrast, in the Caucasian and Asian groups, the majority of hairs appear to have been shed rather than broken, irrespective of the hair length, as evidenced by the attached roots and undamaged tips[25].

The chemical compositions, especially the proteins and amino acids constituting the keratin, are similar in African, Asian, and Caucasian hair[6-9].

Regarding the radial swelling rate of hair, African hair showed the lowest rate of change in diameter after rinsing with distilled water, whereas Asian and Caucasian hair had similar higher rates. There is no obvious explanation for this result based on hair composition and structure[4].

In studies of hair follicles, blacks were found to have fewer elastic fibers anchoring the hair follicles to the dermis compared to the numbers observed in white subjects. Melanosomes were found to be present in both the outer root sheath and in the bulbs of vellus hairs in blacks but not in whites;[26] black hair also tended to have more pigment and microscopically larger melanin granules in comparison with hair from white and Asian individuals[27].

Scalp hairs measure 60 to 80 μm in diameter, and their exteriors consist of a layer of flat, imbricated scales pointing outward from root to tip. From the external surface to the internal core, the hair shaft is divided into layers known as the cuticle, cortex, and medulla. Enveloped by the protective layers of the cuticle is the fibrous hair cortex, which constitutes the bulk of the fiber. As the hairs grow and move relative to one another, the outward pointing cuticular edges facilitate removal of trapped dirt particles and desquamated cells from the scalp. The cuticle protects the underlying cortex and acts as a barrier. The normal, undamaged cuticle has a smooth surface, allowing reflection of light and limiting friction between shafts[28]. During the process of keratinization, the plasma membranes of cortical cells are modified and form a strongly adhesive layer between the adjacent cells, known as the cell membrane complex. This is the only continuous phase in the hair fiber, fusing the cortical cells and providing adhesion to cuticle cells. The cell membrane complex consists of a central core (δ -layer) bound on both sides by two lipid-endowed β -layers. Presently, the composition of the β -layer has not been completely established, although it is known to contain few proteins and appears to be polysaccharidic in nature.

The hair cortex is composed of elongated, interdigitated, spindle-like cells approximately 100 μm long and 5 μm across at the maximum width. The cortex accounts for most of the hair shaft and is responsible for the great tensile strength of the hair. The cortex is localized around the medulla and is composed of elongated cortical cells packed tightly together and oriented parallel to the fiber direction. The organization of the cortical cells allows them to be stretched extensively. These cells contain an amorphous sulfur protein matrix and keratin filaments[29]. Dispersed throughout the structure of the cortex are the melanin pigment particles[30].

The medulla is not always present within the hair shaft, and plays little or no role in hair cosmetics.

Available data on moisture binding of hairs of different ethnic origin reveal no significant differences in uptake, either at intermediate humidity or at the saturation point. Reactive cosmetic hair treatments (waving, straightening, bleaching, and coloring) usually result

in some disruption of the fiber structure. Such damage usually has little effect on the water absorption of the hair at ambient humidity but causes a significant increase in swelling or liquid retention upon wetting[30].

Hair is first damaged at the surface level, progressively resulting in a rough touch and matted appearance. The internal structure is altered as well, leading to reduced resistance and therefore to fibers that break easily[31,32]. Under SEM examination of the hair surface after bleaching, the cuticle scales of the bleached hair were irregular and lifted, and some pitting and breaking were observed[33]. Reportedly, Asian and Caucasian hairs behave differently regarding mechanical aggressions, such as extension[34]. Seshadri and Bhushan[34] studied the cuticle surface while increasing strain and found that Asian hair showed fewer lifted cuticle edges compared to those observed in stressed Caucasian hair.

However, no data has been reported regarding differences in ethnic hair pattern damage after chemical stresses such as coloring and straightening.

To summarize the results of the present study, Table III shows the grades of hair cuticle and cortex damage among the treatment groups. With the straightening treatment, Asian hair showed more resistant cuticles than did the hairs from the other two ethnic groups. With the coloring treatment, the cuticles and cortices of Caucasian hair were relatively susceptible to stress compared to the hairs from the other two ethnic groups. With the combination treatment of straightening and coloring, assumed as the most extensive stress among the treatments, African hair was the most resistant to stress. In terms of cell membrane complex damage, no notable differences among the three ethnic hair groups were observed. All three ethnic hair groups tolerated the coloring treatment relatively well and showed similar damage patterns after the straightening and combination treatment.

In the water content analysis, the African hair group had the highest water content, followed by those of the Asian and Caucasian hair. After the straightening treatment, water content increased in all ethnic hair groups compared to that of the control, and Asian hair had the highest water content compared to the other two ethnic hair groups. However, after the coloring treatment, water content decreased in all three ethnic groups. With the combination treatment, no differences were observed in any ethnic group compared to the control group. However, Caucasian hair showed the lowest water contents after the straightening, coloring and combination treatments. Wortmann et al.[35] reported there were no significant differences between normal and significantly bleached hair in either water sorption isotherm or water diffusion coefficient. However, no data has been reported to date regarding water content of chemically-treated ethnic hair.

V. Conclusions

Present study suggests that Caucasian hair is relatively susceptible to and African hair is more resistant to chemical stress, such as straightening and coloring.

Because no data exists regarding the differences in ethnic hair after chemical stress, the present study could be a cornerstone for further evaluation.

Table I. Control and chemical stress group in three ethnic hairs.

Ethnicity	Control	Chemical Stress (repetitions)				
		Straightening (x1)	Straightening (x3)	Coloring (x1)	Coloring (x3)	Straightening (x1) and Coloring (x1)
Asian	As-0	As-S1	As-S3	As-C1	As-C3	As-S1C1
Caucasian	C-0	C-S1	C-S3	C-C1	C-C3	C-S1C1
African	Af-0	Af-S1	Af-S3	Af-C1	Af-C3	Af-S1C1

Table II. Grades of hair cuticle layer and cortex damage observed with TEM.

Grades of hair cuticle layer damage (Tcu)	
Grade	Criteria
Tcu0	Intact cuticle layer ≥ 6 layers
Tcu1	Outer cuticle detachment, cuticle ≥ 5 layers
Tcu2	Tcu1 + Bubbles in the endocuticle
Tcu3	Remaining cuticle: 3−4 layers
Tcu4	Remaining cuticle ≤ 2 layers
Grades of hair cortex damage (Tco)	
Grade	Criteria
Tco0	Intact CMC, no damaged melanin granules
Tco1	Damage in the CMC (bubbles): confined to a 500 nm depth
Tco2	Damage in the CMC (bubbles): beyond a 500 nm depth
Tco3	Holes in the CMC or damage to the melanin granules

* TEM : Transmission electron microscope, CMC : cell membrane complex

(cited from Kim et al[19]. Am J Dermatopathol 2010;32:432–438.)

Table III. Summary of the grades of hair cuticle and cortex damage in treatment groups.

Ethnicity	Chemical Stress (repetitions)				
	Straightening (x1)	Straightening (x3)	Coloring (x1)	Coloring (x3)	Straightening (x1) and Coloring (x1)
Asian	Tcu2	Tcu2	Tcu1	Tcu2	Tcu3
	Tco2	Tco2	Tco1	Tco2	Tco2
Caucasian	Tcu3	Tcu3	Tcu2	Tcu3	Tcu3
	Tco2	Tco2	Tco2	Tco2	Tco2
African	Tcu3	Tcu3	Tcu0	Tcu2	Tcu2
	Tco2	Tco2	Tco0	Tco2	Tco1

Figure 1. Hairs from three ethnic groups were divided into control and chemical stress groups.

After straightening and coloring, hair samples had changed shapes and colors.

(0: Control group, S1: Single straightening treatment, S3: Three straightening treatments

C1: Single color treatment, C3: Three color treatments,

S1C1: Combination treatment of straightening and coloring)

Figure 2. Illustration of transpiration moisture.

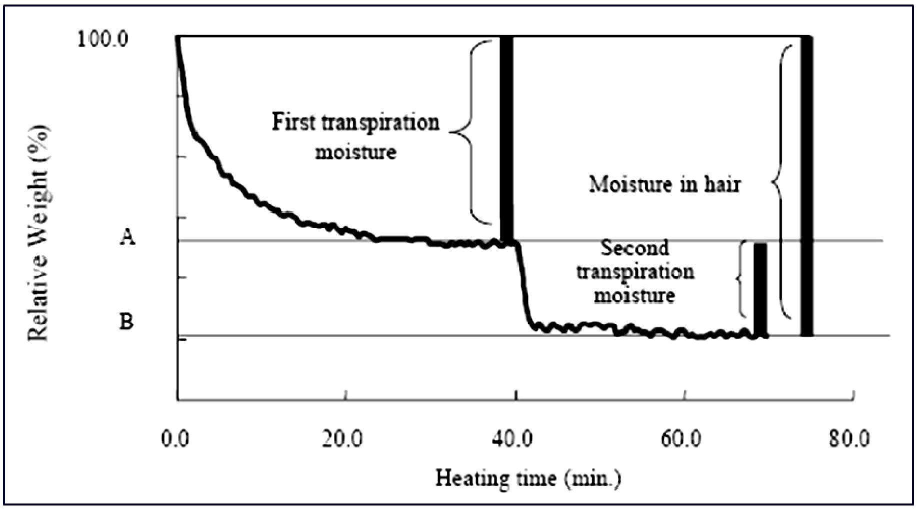


Figure 3. Intact cuticle and cortex of control hair group by TEM.

Three virgin ethnic hairs showed intact cuticles with more than six layers (Tcu0) and an intact cell membrane complex with no damaged melanin granules (Tco0) (TEM, X 10,000).

(As: Asian hair, C: Caucasian hair, Af: African hair, 0: Control group)

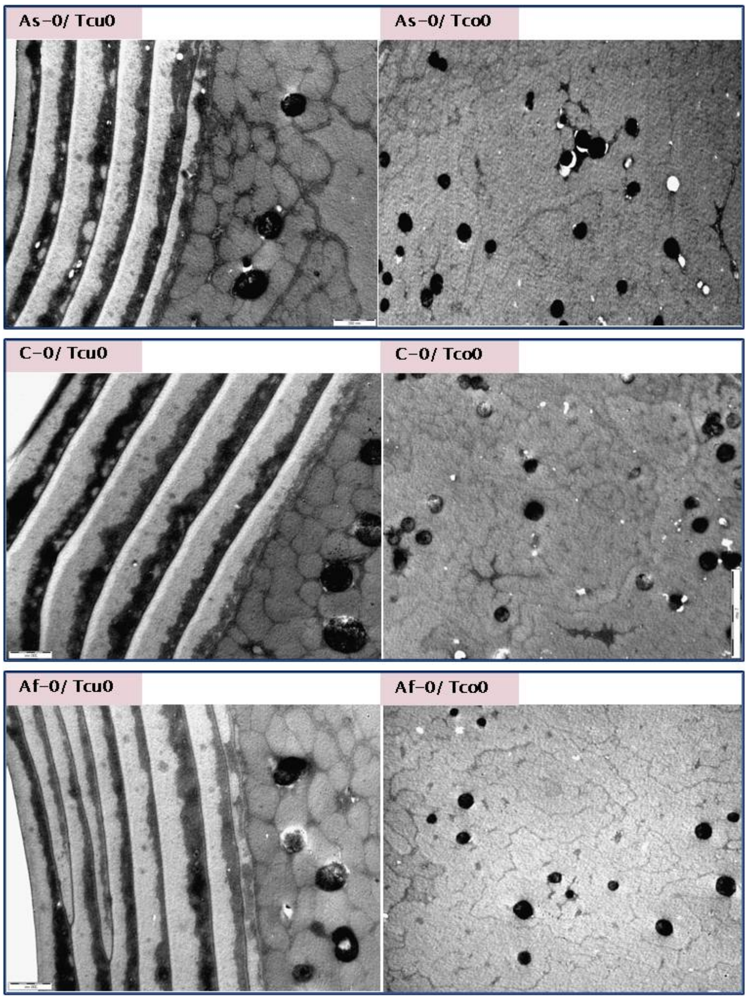


Figure 4. Cuticle damage in hairs after straightening treatment by TEM.

The Asian hair cuticles were more resistant to straightening treatment than were the other two ethnic hairs. The Caucasian and African hair cuticles showed similar damage patterns after the straightening treatment (TEM, X 10,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

S1: Single straightening treatment, S3: Three straightening treatments)

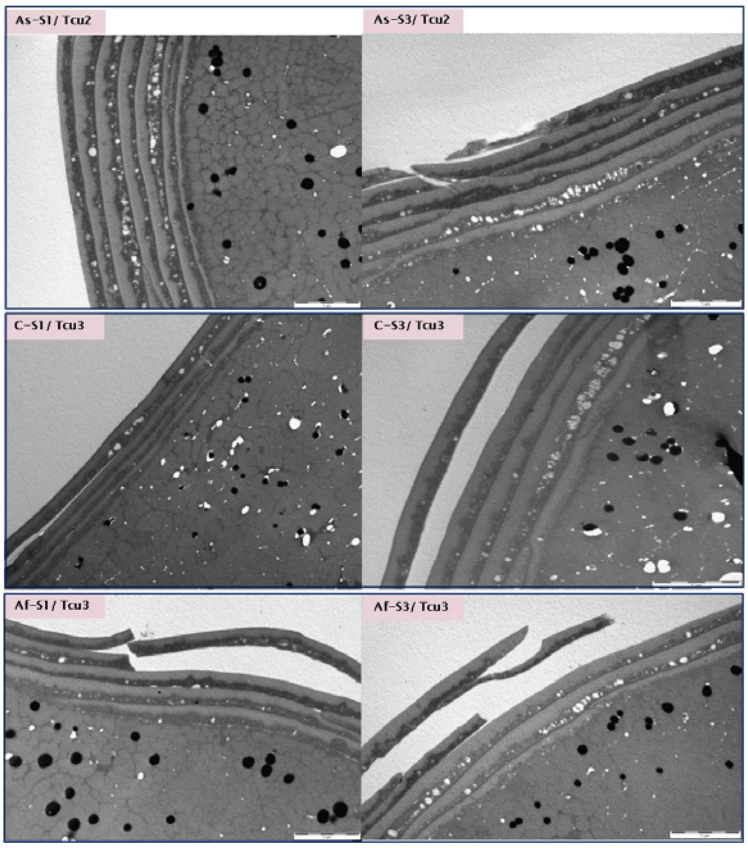


Figure 5. Cuticle damage in hairs after coloring treatment by TEM.

The Caucasian hair cuticles were the most vulnerable to coloring treatment. The African hair cuticles appeared more resistant to coloring than did the Asian and Caucasian hair (TEM, X 10,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

C1: Single color treatment, C3: Three color treatments)

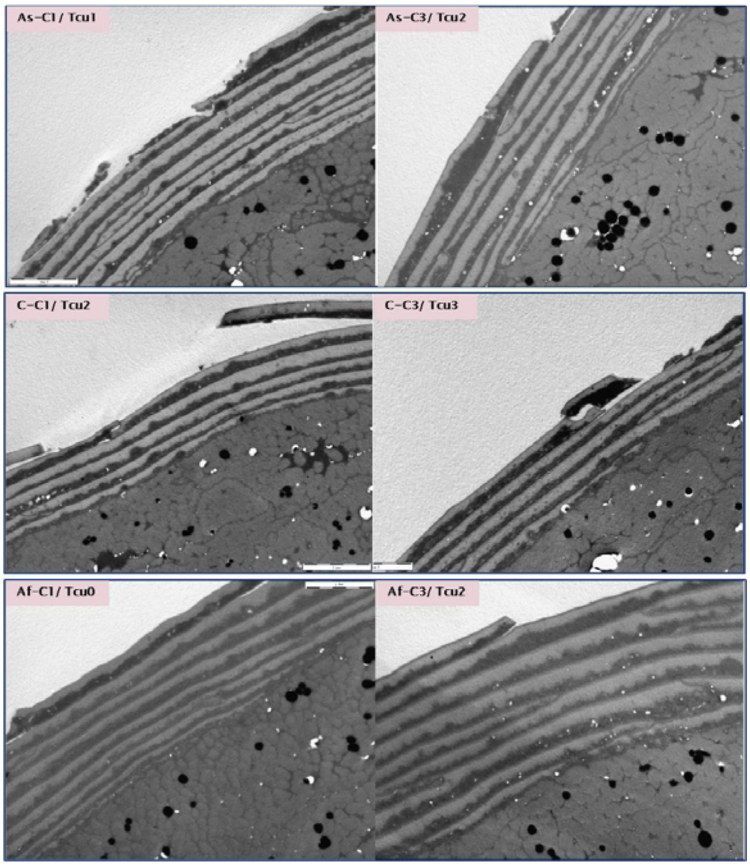


Figure 6. Cuticle damage in hairs after combination of straightening and coloring treatment by TEM.

The African hair cuticles appeared more resistant to combination treatment than did the Asian or Caucasian hair cuticles. The Caucasian and Asian hair cuticles showed similar damage patterns after the combination treatment (TEM, X 10,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

S1C1: Combination treatment of straightening and coloring)

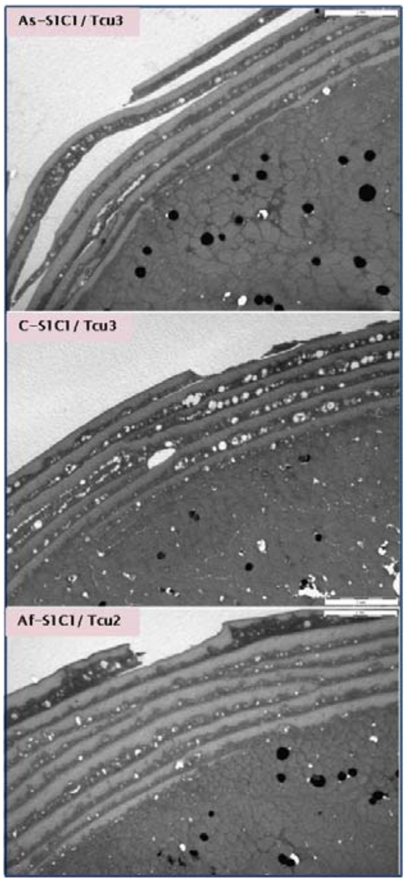


Figure 7. Cortex damage in hairs after straightening treatment by TEM.

The cortexes of all three ethnic hairs showed similar damage patterns (TEM, X 20,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

S1: Single straightening treatment, S3: Three straightening treatments

Arrow: Melanin granule)

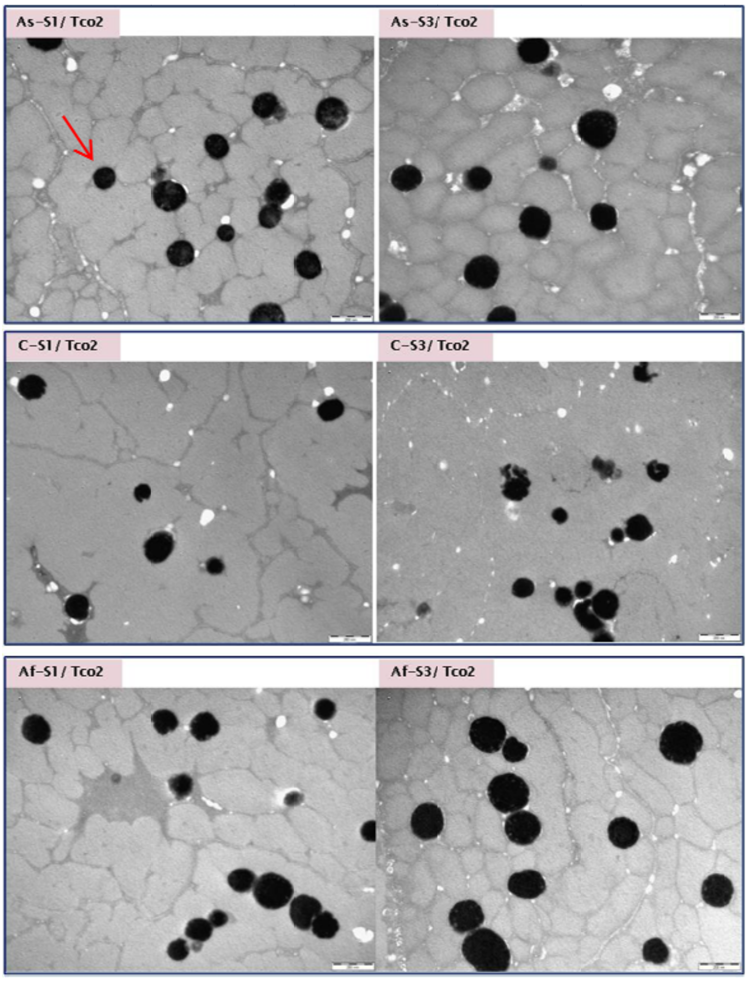


Figure 8. Cortex damage in hairs after coloring treatment by TEM.

The cortex of African hair appeared more resistant to one-time coloring than were those of Asian and Caucasian hair. However, the cortexes of all three ethnic hairs showed similar damage patterns to three-time coloring (TEM, X 20,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

C1: Single color treatment, C3: Three color treatments)

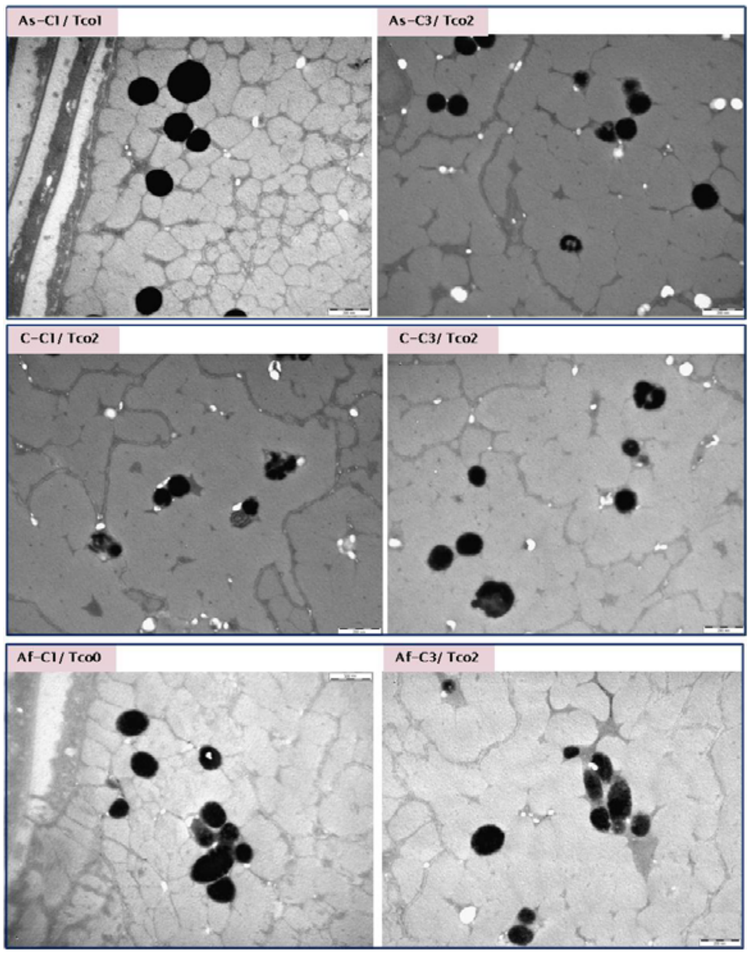


Figure 9. Cortex damage in hairs after combination of straightening and coloring treatment by TEM. The cortex of African hair appeared more resistant to the combination treatment than did those of Asian or Caucasian hair. The cortexes of Caucasian and Asian hair showed similar damage patterns after the combination treatment (TEM, X 20,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

S1C1: Combination treatment of straightening and coloring)

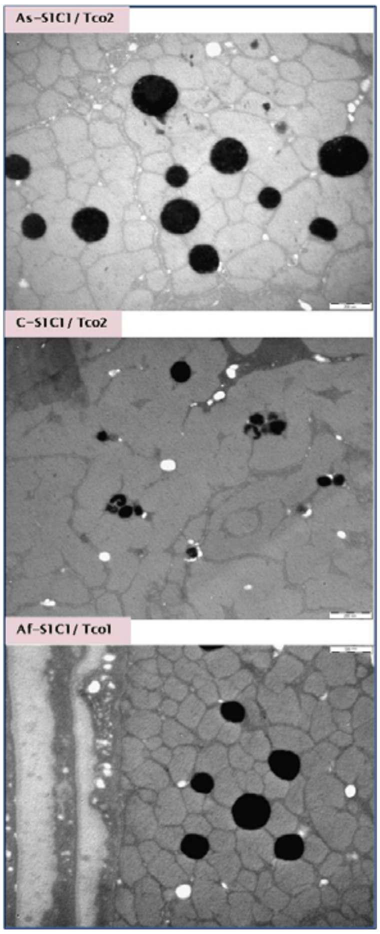


Figure 10. Cell membrane complex evaluation in the control and coloring treatment groups by lipid TEM.

The three virgin ethnic hairs showed intact intercellular lipid layers. All ethnic hairs tolerated the coloring treatment well. Only the Asian hair showed a bulged cell membrane complex after three color treatments (TEM, X 100,000).

(As: Asian hair, C: Caucasian hair, Af: African hair, 0: Control group,

C1: Single color treatment, C3: Three coloring treatments,

Arrow: Bulged damaged cell membrane complex)

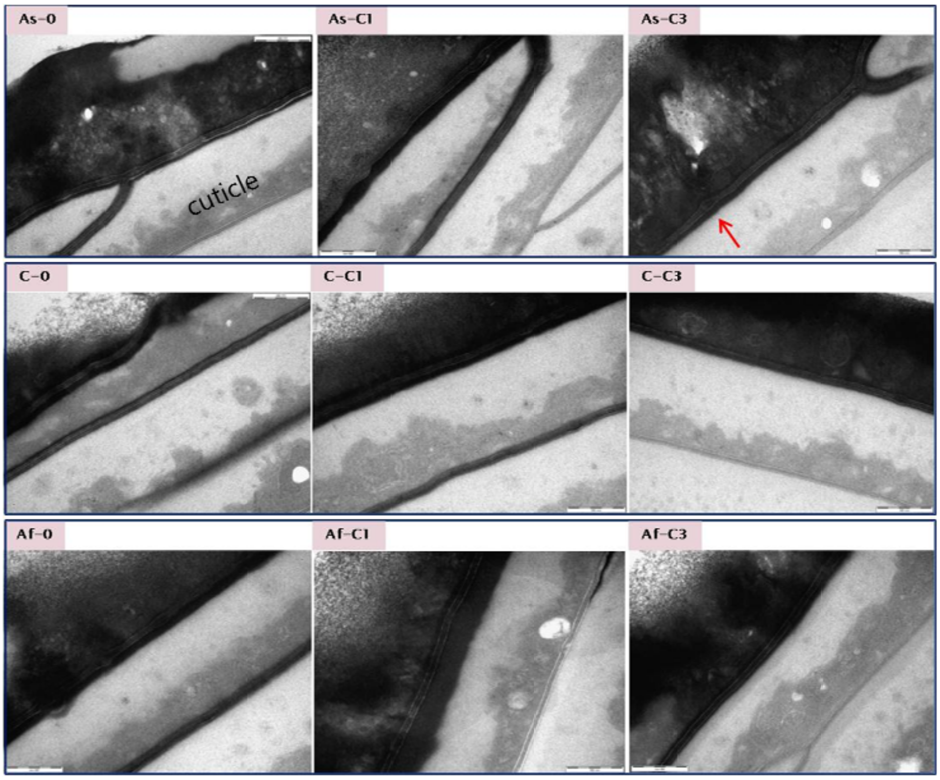


Figure 11. Cell membrane complex evaluation in the straightening and combination treatment groups by lipid TEM. All ethnic hairs showed similar damage patterns after straightening and combination (straightening and coloring) treatments (TEM, X 100,000).

(As: Asian hair, C: Caucasian hair, Af: African hair,

S1: Single straightening treatment, S3: Three straightening treatments

S1C1: Combination treatment of straightening and coloring,

Arrow: Bulged damaged cell membrane complex)

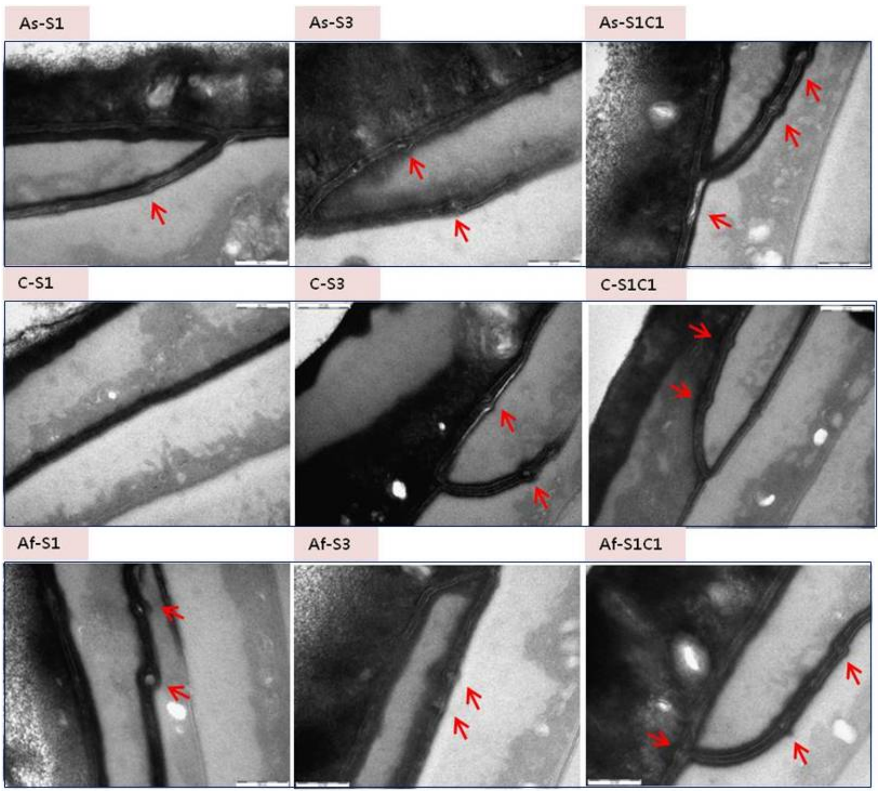


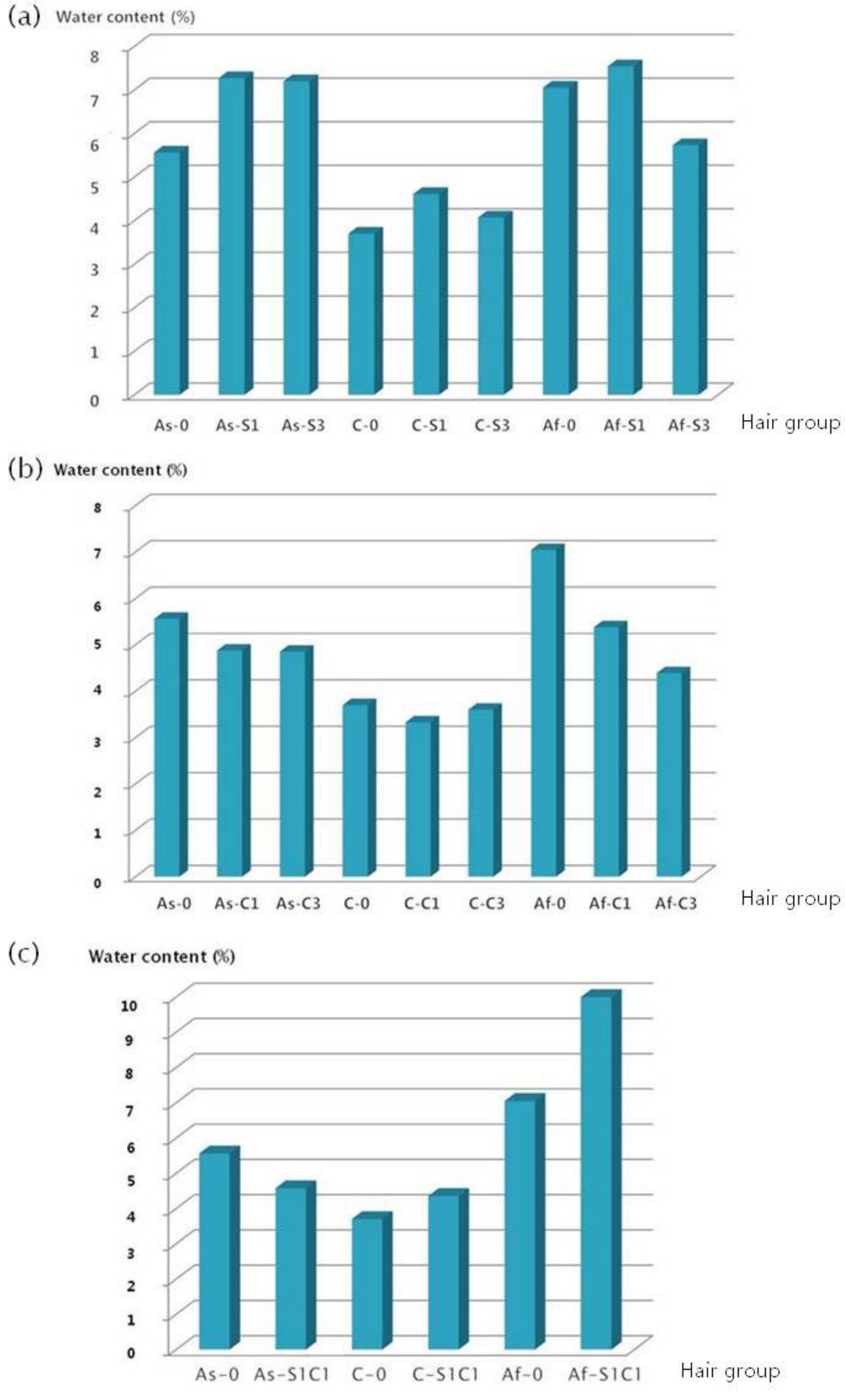
Figure 12. Hair water content in the control and treatment groups.

a: In the control group, the African hair had the highest water content, followed by those of the Asian and Caucasian hairs. Water content increased after the straightening treatment. Caucasian hair had the lowest water content before and after straightening treatment.

b: Water content decreased after the coloring treatment. Caucasian hair had the lowest water content before and after the coloring treatment.

c: After the combination treatment, hair water content increased in the African and Caucasian hairs.

(As: Asian hair, C: Caucasian hair, Af: African hair, 0: Control group,
S1: Single straightening treatment, S3: Three straightening treatments,
C1: Single color treatment, C3: Three coloring treatments,
S1C1: Combination treatment of straightening and coloring)


(a)
Water content (%)
8
7
6
5
4
3
2
1
0
As-0
As-S1
As-S3
C-0
C-S1
C-S3
Af-0
Af-S1
Af-S3
Hair group
(b)
Water content (%)
8
7
6
5
4
3
2
1
0
As-0
As-C1
As-C3
C-0
C-C1
C-C3
Af-0
Af-C1
Af-C3
Hair group
(c)
Water content (%)
10
9
8
7
6
5
4
3
2
1
0
As-0
As-S1C1
C-0
C-S1C1
Af-0
Af-S1C1
Hair group

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- 국문요약 -

화학적 스트레스에 대한 인종간 모발손상 차이

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목적 : 3개 인종 모발에서 화학적 스트레스(스트레이트, 염색) 후 손상 양상 차이를 알아본다.

대상 및 방법 : 3개 인종 모발에서 화학적 스트레스 후에 발생한 모발 손상을 조사하였다. 각 인종모발을 대조군과 처치군으로 나누고, 처치군은 스트레이트, 염색, 스트레이트와 염색 혼합군으로 나누었다. 마지막 처치 후 24시간 뒤, 손상양상을 투사전자현미경, 지질투사전자현미경 그리고 할로겐 수분분석기를 이용하여 관찰하였다. 모발 각피와 피질의 손상 정도는 두 명의 피부과의사가 점수를 매겼다.

결과 : 주사전자현미경검사상, 동양인 모발은 스트레이트 처치에 각피손상이 가장 적었고 백인 모발은 염색 처치에 각피와 피질 손상이 가장 심하였다. 스트레이트

와 염색 혼합처치의 경우, 흑인 모발이 가장 손상이 적었다. 지질주사현미경검사상, 세 인종 모발에서 특이 손상반응의 차이는 관찰되지 않았다. 수분량분석의 경우, 백인 모발은 스트레이트, 염색, 혼합 처치군에서 다른 두 인종 모발에 비해 모두 낮은 수분함량을 보였다.

결론 : 저자들은 화학적 손상(스트레이트와 염색)에 백인 모발이 더 취약하고 흑인 모발이 덜 손상된다고 제안하는 바이다.

핵심되는 말 : 인종모발, 화학적 손상, 투과전자현미경, 지질투과전자현미경,
모발수분량