

Hair Styling Procedures and Hair Morphology: A Clinico-Microscopic Comparison Study

Abstract

Background: The present study is a cross-sectional comparison to evaluate the association between hair loss and hair structural changes (gross and microscopic), and hairstyling procedures in women. **Methods:** We included 94 women; and collected data on sociodemographics, clinical history, sun-exposure, and hair-product use history. Women who reported blow drying of hair, hair straightening, use of hair iron or perming in the past 6 months were classified as cases. Age matched (± 2 years) women who did not report any of the above procedures in the past 6 months were controls. The following tests were done: hair pull test; hair density assessment; hair breakage index (HBI); and microscopic examination. A logistic regression model was used for estimation of the odds ratio (OR) and 95% confidence intervals (CI). **Results:** The mean (standard deviation [SD]) age in the case and control group was 26.4 (6.3) and 27.4 (6.3) years, respectively ($P = 0.43$). There was no significant difference in the mean (SD) HBI (1.05 [0.08] vs 1.07 [0.05], $P = 0.22$) or hair density (3.28 [0.41] vs 3.16 [0.39], $P = 0.19$). Cases were significantly more likely to have microscopic changes compared with controls (OR: 22.0, 95% CI: 4.3, 112.6; $P < 0.001$). Sun exposure for more than 3 h was significantly associated with microscopic changes (OR: 6.7, 95% CI: 1.2, 39.1; $P = 0.03$). **Conclusion:** Women with hairstyling procedures in the past 6 months were more likely to have microscopic changes, even though there was no difference in the hair assessment parameters. Specific guidelines on use of hairstyling procedures for Indian hair should be developed.

Keywords: Clinical, hair iron, hair styling, heat damage, microscopy

Introduction

Hair loss is a common complaint in dermatology clinics. Though a common cause of hair loss in men is androgenetic alopecia, causes of hair loss in women are chronic telogen effluvium, female pattern baldness, anemia, and hormone-related changes.^[1-4] Various studies have placed the prevalence of female pattern hair loss in women from 5.6% to 32%; the prevalence in the population increases with age.^[3-9] Furthermore, it has also been reported that prevalence, in general, is higher in Caucasian women compared with Asian women across all age groups.^[4]

In addition to the above mentioned reasons, physical friction or the use of chemical and/or cosmetic products (such as bleaching or hair coloring) may be an important cause of hair loss.^[10,11] Furthermore, exposure to ultraviolet light, excessive grooming, traction, use of hair straightening agents, and hair irons, and

small electric warmers may damage hair and may also be a cause of hair loss.^[11-15] A common feature of hair damage due to excessive heat is the presence of “bubble hair”.^[16] This may also lead to weakening and breakage of hair; and microscopic evaluation of hair may show uneven fraying, splitting, and breakages. In addition, features such as gas like or bubble appearance in electron microscopy have also been reported in damaged hair.^[17-20] Many experimental studies have evaluated the effect of heat and hair styling products on hair changes. These procedures may also be an important cause of hair loss in women and need to be explored in detail in clinical settings.

Over the past couple of decades, there has been an increase in the use of hairstyling products all over the world, particularly in emerging markets for cosmetic products such as India. With the advent of new saloons and changing lifestyle, hair grooming is common among women and men, even at younger

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ages. Indeed, a study found that 58% of female Indian students had colored their hair, 50% had straightened their hair, and 10% had curled their hair.^[21] Furthermore, many Indian women may use hair oil (particularly coconut oil) which may protect against hair damage.^[22] Exposure to excessive sun may also be associated with hair damage.^[23] Thus, multiple factors and behaviors which may have different effects may eventually affect the hair structure and hair loss in women. A comprehensive study that assesses these behaviors will be a useful addition to the existing experimental literature on hair damage research. Thus, we designed the present study to evaluate the association between hair loss and hair structural changes (gross and microscopic), and use of hairstyling procedures in Indian women.

Methods

The present study is a cross-sectional comparison of 94 individuals attending a dermatology clinic. The patients were divided into two groups.

Study population

The study was conducted in a dermatology clinic in Mumbai, India. Most of the patients attending this clinic are from middle to upper socioeconomic status. The clinic has multiple dermatology specialties such as psychodermatology, acne clinic, and dermatosurgery procedures. About 10–15 patients attend the clinic every day.

We identified the potential participants for this study from this dermatology clinic. All participants were divided into two groups, namely, the case group, and the control group. The definitions were as follows: 1) Case group: Women 18–40 years who presented to the dermatology clinic and reported any of the following procedures in the past 6 months: blow-drying of hair, hair straightening, use of hair iron or perming; 2) Control group: All age-matched women attending the clinic (age-matched ± 2 years, only females ≥ 18 years) who did not report any of the above-mentioned procedures in the past 6 months. All women with evidence of cicatricial alopecia, alopecia areata, and present infections of the scalp were excluded.

Study procedures

History and clinical evaluation

After consent, sociodemographic history, details of hair loss, treatment taken for hair loss, application of hair products, detailed use of hair straightening procedures (type of procedure, detailed history of the procedures, frequency of treatment, first use, any complaints associated with it), sun exposure, clinical history of chronic conditions, and menstrual irregularities were collected on a pre-designed form.

Hair assessment

Hair assessment procedures were as follows: 1) Naked eye examination of scalp and hair: texture and the type

of hair loss was recorded; 2) Hair pull test: Hair-pull test was performed in all regions of the scalp; 3) Hair density and hair breakage index^[24,25]: Hair density per mm² was evaluated in all the regions; and 4) Hair Breakage Index: It is another important measurement of hair weathering. It is a fraction of the diameter of hair in the distal region of the scalp (about 7 cm from the scalp) to the proximal region of the scalp (about 1 cm from the scalp). A higher HBI indicates a higher level of hair damage. All these hair measurements were done for frontal ventral, medial, left temporal, and right temporal regions using a trichoscope. The average of all these five regions was also calculated.

Microscopy

After these evaluations, light microscopy (performed onsite by one co-author who is a trained dermatologist and dermatopathology) was used to examine any changes in hair structure. The hairs were collected from the case and control group and examined under light microscopy. Any changes in the hair structure related to uneven breakages, fraying/splaying/weathering changes, or presence of bubbles were noted.^[19] A Scanning electron microscopic (SEM) examination of a sample of hair from the case group was also done.^[17]

Statistical analysis

Means and standard deviations (SD), or median and interquartile range (IQR) were estimated for continuous variables. We estimated the proportions for categorical variables and prevalence proportions for categorical outcomes (such as proportion of women with hair damage). The means across groups were compared using the *t*-test and the medians were compared using the Mann-Whitney test. The proportions were compared using the Chi-square tests or Fisher's exact test for low expected cell counts. A logistic regression model (for multivariate analysis) was used to estimate the odds ratio (OR) and 95% confidence intervals (CI). The main outcome for logistic models was - 'changes in the hair under light microscopy'. The main explanatory variable in the logistic model was case/control status. The potential confounders in the model were: age, socioeconomic status, sun exposure, comorbidities, and use of oil/conditioner. A linear regression model was used for 'average hair breakage index' as the main outcome variable. The explanatory variables and potential confounders were same as the those in the logistic model. The Akaike information criteria was used as a measure of fit of the multivariate models.

The study was approved by the local ethics committee.

Results

The mean age of the participants in the case and control group was 26.4 (6.3) and 27.4 (6.3) years, respectively ($P = 0.43$). About 25% of women had a previous history of anemia, 8% had a history of menstrual

irregularities, and 9% reported a history of thyroid disorders and polycystic ovarian disorder, respectively [Table 1]. Lifetime use of hair iron (87% vs 36%, $P < 0.001$) and hair perming were significantly higher in the case group compared with the control group. Women in the case group were more likely to have straightened their hair (58% vs 19%, $P < 0.001$) and blow-dried (53% vs 28%, $P = 0.012$) ever in their lifetime. About 39% of women reported use of hair coloring products, the proportion was not significantly different in cases and controls (45% vs 34%, $P = 0.29$). About 46% of our study population used shampoos for three or more times/week, 55% reported use of conditioners, and 87% reported oil use. Women in the control group were less likely to use shampoo and conditioner compared with those in the case group. However, oil use was similar in both groups. About 45% of our study participants reported use of other hair products (20% had used some form of serum and 24% had used other hair products). In general, duration of sun exposure was more in the case group compared with control group. Detailed analyses of these parameters are presented in Table 2.

Hair loss in case and control groups was not significantly different (83% vs 96%, $P = 0.09$). Furthermore, on examination, there was no significant difference in the hair loss patterns in both groups. About 10% had female pattern hair loss and 1% had chronic diffuse hair loss [Table 3]. In general, there were no significant differences in the hair pull test between the case and control groups. Similarly, there was no significant difference in the mean (SD)

HBI between the case and control groups (1.05 [0.08] vs 1.07 [0.05], $P = 0.22$). Finally, there was no significant difference in the mean (SD) hair density between both the groups (3.28 [0.41] vs 3.16 [0.39], $P = 0.15$). Detailed measurements in both groups are shown in Table 4.

About 51% of hair collected showed microscopic changes; the proportion was significantly higher in the case group compared with the control group (89% vs 27%, $P < 0.001$). About 21% individuals had bulges; cases had a higher proportion of bulges compared with controls (44% vs 7%, $P = 0.001$). Similarly, 48% of cases and 23% of controls showed fraying/splaying; the difference was statistically significant ($P = 0.04$). Pigmentary changes, dents, and thinning of hair were also observed in the case group; however, these changes were not seen in the control group [Figure 1]. For instance, 33% of cases had pigmentary changes and 15% had thinning of hair. We did not find any of these changes in the control group ($P < 0.001$). On electron microscopic examination, changes suggestive of weathering were observed among cases [Figure 2 a and b].

After adjusting for age, socioeconomic status, sun exposure, medical history, oil use, and conditioner use, women in the case group were significantly more likely to have microscopic changes compared with the control group (OR: 22.0, 95% CI: 4.3, 112.6; $P < 0.001$). Women who reported sun exposure for more than 3 h were significantly more likely to have microscopic changes compared with those who reported for less than 3 h (OR: 6.7, 95%

Table 1: The demographics and clinical history in 94 women

| | Total n (%) | Case group n (%) | Control group n (%) | P |
|-------------------------------------|-------------|------------------|---------------------|------|
| Total | 94 | 47 | 47 | |
| Age | | | | |
| Mean (SD) | 26.9 (6.3) | 26.4 (6.3) | 27.4 (6.3) | 0.43 |
| Socioeconomic status | | | | |
| Upper | 11 (11.7) | 6 (12.8) | 5 (10.6) | 0.02 |
| Upper Middle | 72 (76.6) | 40 (85.1) | 32 (68.1) | |
| Lower Middle | 11 (11.7) | 1 (2.1) | 10 (21.3) | |
| Clinical complaints | | | | |
| History of Anemia | | | | |
| No | 71 (75.5) | 38 (80.9) | 33 (70.2) | 0.23 |
| Yes | 23 (24.5) | 9 (19.2) | 14 (29.8) | |
| History of menstrual irregularities | | | | |
| No | 87 (92.6) | 44 (93.6) | 43 (91.5) | 0.69 |
| Yes | 7 (7.5) | 3 (6.4) | 4 (8.5) | |
| History of thyroid disorders | | | | |
| No | 86 (91.5) | 41 (87.2) | 45 (95.7) | 0.14 |
| Yes | 8 (8.5) | 6 (12.8) | 2 (4.3) | |
| History of PCOS | | | | |
| No | 86 (91.5) | 42 (89.3) | 44 (93.6) | 0.46 |
| Yes | 8 (8.5) | 5 (10.6) | 3 (6.4) | |
| History of other medical conditions | | | | |
| No | 75 (79.8) | 39 (82.9) | 36 (76.6) | 0.44 |
| Yes | 19 (20.2) | 8 (17.0) | 11 (23.4) | |

Table 2: Lifetime behavior and gadget use in 94 women

| | Total n (%) | Case group n (%) | Control group n (%) | P |
|--------------------------|-------------|------------------|---------------------|--------|
| Total | 94 | 47 | 47 | |
| Lifetime behavior | | | | |
| Straightening of hair | | | | |
| No | 58 (61.7) | 20 (42.6) | 38 (80.9) | <0.001 |
| Yes | 36 (38.3) | 27 (57.5) | 9 (19.2) | |
| Hair iron | | | | |
| No | 36 (38.3) | 6 (12.8) | 30 (63.8) | <0.001 |
| Yes | 58 (61.7) | 41 (87.2) | 17 (36.2) | |
| Hair perming | | | | |
| No | 90 (95.7) | 44 (93.6) | 46 (97.9) | 0.31 |
| Yes | 4 (4.3) | 3 (6.4) | 1 (2.1) | |
| Blow drying | | | | |
| No | 56 (59.6) | 22 (46.8) | 34 (72.3) | 0.012 |
| Yes | 38 (40.4) | 25 (53.2) | 13 (27.7) | |
| Hair coloring | | | | |
| No | 57 (60.6) | 26 (55.3) | 31 (65.9) | 0.29 |
| Yes | 37 (39.4) | 21 (44.7) | 16 (34.0) | |
| Shampoo use | | | | |
| 3 or more times per week | 43 (45.7) | 25 (53.2) | 18 (38.3) | 0.15 |
| <3 times per week | 51 (54.3) | 22 (46.8) | 29 (61.7) | |
| Conditioner use | | | | |
| No | 41 (44.7) | 16 (34.0) | 26 (55.3) | 0.038 |
| Yes | 52 (55.3) | 31 (65.9) | 21 (44.7) | |
| Oil use | | | | |
| No | 12 (12.8) | 6 (12.8) | 6 (12.8) | |
| Yes | 82 (87.2) | 41 (87.2) | 41 (87.2) | |
| Use of Fine Comb | | | | |
| No | 87 (92.6) | 44 (93.6) | 43 (91.5) | 0.69 |
| Yes | 7 (7.5) | 3 (6.4) | 4 (8.5) | |
| Swimming | | | | |
| No | 87 (92.6) | 43 (91.5) | 44 (93.6) | 0.69 |
| Yes | 7 (7.5) | 4 (8.5) | 3 (6.4) | |
| Steam Room | | | | |
| No | 90 (95.7) | 47 (100.0) | 43 (91.5) | 0.12 |
| Yes | 4 (4.3) | 0 (0.0) | 4 (8.5) | |
| Sauna use | | | | |
| No | 90 (95.7) | 45 (95.7) | 45 (95.7) | |
| Yes | 4 (4.3) | 2 (4.3) | 2 (4.3) | |
| Sun exposure | | | | |
| No sun exposure | 8 (8.6) | 1 (2.2) | 7 (15.2) | 0.12 |
| <1 h | 48 (51.6) | 26 (55.3) | 22 (47.8) | |
| 1-3 h | 33 (35.5) | 17 (36.2) | 16 (34.8) | |
| >3 h | 4 (4.3) | 3 (6.4) | 1 (2.1) | |

CI: 1.2, 39.1; $P = 0.03$). The interaction between sun exposure, and use of hairstyling and hair color in the past 6 months (case group) was tested in the regression model; this interaction term was not statistically significant. There was no significant association between medical conditions, oil and conditioner use, and microscopic changes in these women. Even though the average HBI was higher in the case group compared with the control group, the difference was not statistically significant (1.77, 95% CI: -2.51, 6.05, $P = 0.41$). There was a significant association between

microscopic changes and lifetime use of hairstyling tools in multivariate analysis. Women who had blow-dried their hair ever were significantly more likely to have a microscopic change compared with those who have never done it (OR: 6.6, 95% CI: 1.7, 25.4; $P = 0.006$).

Discussion

In our study, women in the case group were significantly more likely to have reported lifetime use of hair iron, hair straighteners, and blow-drying. Hair loss was similar

Table 3: Hair loss complaints and clinical examination in 94 women

| | Total n (%) | Case group n (%) | Control group n (%) | P |
|-------------------------------|-------------|------------------|---------------------|------|
| Total | 94 | 47 | 47 | |
| Hair loss | | | | |
| No | 10 (10.6) | 8 (17.0) | 2 (4.3) | 0.09 |
| Yes | 84 (89.4) | 39 (82.9) | 45 (95.7) | |
| Bothered about hair loss | | | | |
| Not bothered | 1 (1.1) | 0 (0) | 1 (2.2) | 0.23 |
| Reasonably bothered | 24 (25.5) | 14 (35.9) | 10 (22.2) | |
| Very much bothered | 59 (62.8) | 25 (64.1) | 34 (75.6) | |
| Examination | | | | |
| Type of hair | | | | |
| Smooth/Silky | 55 (62.5) | 30 (68.2) | 25 (56.8) | 0.63 |
| Dry/Rough | 26 (29.6) | 11 (25.0) | 15 (34.1) | |
| Frizzy | 7 (7.9) | 3 (6.8) | 4 (9.1) | |
| Hair loss | | | | |
| Mild/Minimal | 62 (67.4) | 32 (71.1) | 30 (63.8) | 0.54 |
| Moderate | 24 (26.1) | 12 (26.7) | 12 (25.5) | |
| Severe | 2 (2.2) | 0 (0.0) | 2 (4.3) | |
| Diffuse hair loss | 4 (4.4) | 1 (2.2) | 3 (6.4) | |
| Hair Loss pattern | | | | |
| No specific hair loss pattern | 83 (89.3) | 42 (91.3) | 41 (87.2) | 0.49 |
| Female pattern hair loss | 9 (9.7) | 3 (6.5) | 6 (12.8) | |
| Chronic diffuse hair loss | 1 (1.1) | 1 (2.2) | 0 (0.0) | |

Table 4: Hair parameters and microscopic examination in 94 women

| | Total | Case group | Control group | P |
|----------------------------------|----------------|----------------|---------------|--------|
| Hair pull test ^a | | | | |
| Frontal | 1 (0, 1) | 1 (0, 1) | 1 (0, 1) | 0.40 |
| Medial | 1 (0, 1) | 0 (0, 1) | 1 (0, 1) | 0.11 |
| Ventral | 1 (1, 2) | 1 (0, 1) | 1 (1, 2) | 0.05 |
| Rt Temporal | 1 (1, 1) | 1 (1, 1) | 1 (1, 1) | 0.61 |
| Lt Temporal | 1 (1, 1) | 1 (0.5, 1) | 1 (1, 1) | 0.70 |
| Average | 0.9 (0.6, 1.2) | 0.6 (0.6, 1.2) | 1 (0.6, 1.2) | 0.15 |
| Hair Breakage Index ^b | | | | |
| Frontal | 1.07 (0.16) | 1.08 (0.15) | 1.07 (0.16) | 0.79 |
| Medial | 1.05 (0.16) | 1.05 (0.21) | 1.06 (0.10) | 0.80 |
| Ventral | 1.04 (0.09) | 1.03 (0.08) | 1.05 (0.10) | 0.47 |
| Rt Temporal | 1.08 (0.11) | 1.07 (0.09) | 1.09 (0.13) | 0.40 |
| Lt Temporal | 1.06 (0.11) | 1.04 (0.11) | 1.09 (0.10) | 0.02 |
| Average | 1.06 (0.07) | 1.05 (0.08) | 1.07 (0.05) | 0.22 |
| Hair density ^b | | | | |
| Frontal | 3.37 (0.62) | 3.49 (0.66) | 3.26 (0.57) | 0.07 |
| Medial | 3.44 (0.77) | 3.53 (0.69) | 3.34 (0.84) | 0.23 |
| Ventral | 2.97 (0.66) | 2.96 (0.66) | 2.98 (0.68) | 0.88 |
| Rt Temporal | 3.21 (0.64) | 3.19 (0.65) | 3.23 (0.63) | 0.75 |
| Lt Temporal | 3.10 (0.61) | 3.21 (0.66) | 2.98 (0.53) | 0.06 |
| Average | 3.22 (0.40) | 3.28 (0.41) | 3.16 (0.39) | 0.15 |
| Microscopic changes ^c | | | | |
| Any change | 36 (51%) | 24 (89%) | 12 (27%) | <0.001 |
| Bulges | 15 (21%) | 12 (44%) | 3 (7%) | 0.001 |
| Fraying/Splaying | 23 (32%) | 13 (48%) | 10 (23%) | 0.04 |
| Other changes | 14 (20%) | 14 (52%) | 0 (0%) | <0.001 |

^aMean (SD), ^bMedian (Interquartile range), ^cProportion in those with microscopic evaluation

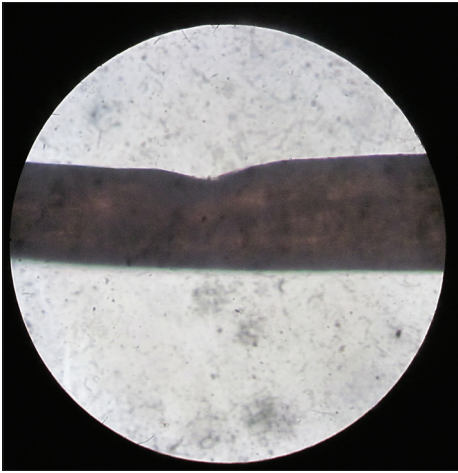


Figure 1: Light microscopy showing a dent in the hair cuticle

in both groups. There were no significant differences in hair assessment parameters (hair density, HBI, and hair pull test) in both groups. However, microscopic changes (such as bulges, weathering changes, pigmentary changes, dents, and thinning of hair) were significantly more likely in those women who had used hairstyle tools in the past 6 months compared with those who did not use them. A longer duration of sun exposure was also associated with microscopic changes in hair.

Experimental studies have shown that exposure of heat (either through thermal devices or atmospheric heat) may result in the denaturation of alpha-keratin and change the structure of the hair cuticle.^[26-28] These changes may differ according to the ethnicity of individuals; this is due to the difference in anatomical structure and hair composition in these ethnic groups. For example, Asian hair is circular, has a higher number of cuticle layers, and is compact compared with Caucasian hair.^[27,29] Furthermore, even though the chemical composition is similar in different hair types, African hair has less moisture.^[29-31] Though, in general, alternate heat and wet cycles result in cracks in hair cuticle; the loss of protein and changes in the cuticle were more in the Asian hair compared with the Caucasian hair.^[27] Any damage to proteins may reduce water absorption and retention in hair; thus, altering the cosmetic appearance of hair.^[32] Thus, it is quite likely that the same instrument at the same temperature and same procedure may have different effects on different hair types, and potentially, the damage may be higher in Asian hair. In our study, the prevalence of microscopic changes in women who had any hairstyling procedures in the past six months was very high 89%. Thus, hairstyling products and the potential damage due to these produces need to be tested in Indian population and specific guidelines should be generated for their use in the population.

Sun exposure and use of hair coloring products/dye may also be associated with hair damage.^[10,11,23,33] Indeed, as with thermal damage, hair damaged with chemical

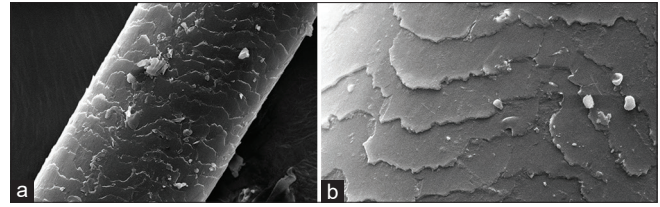


Figure 2: (a and b) Scanning electron microscopy showing changes in the cuticle

treatments had lower water content.^[34] Even though hair coloring and styling may lead to damage of hair shaft, Harrison and Sinclair^[35] have concluded that prevalence of hair problems is not concordant with the prevalence of use of these hair products in the community. Thus, they suggest that hair damage due to styling and color may be related to frequency of use. On sun exposure, Dario and coworkers^[14] have reported that damage due to solar radiation may be due to protein degradation and formation of reactive oxygen species. In our study, we did find that even after adjusting for hairstyling and color used in the past 6 months, women who were exposed for a longer duration were more likely to have microscopic changes. Thus, sun exposure may be independent risk factor for hair damage along with hair styling. Hair photoprotection may be considered to avoid these changes in the population.^[36] Though use of hair oil and cosmetic (such as conditioners) may prevent hair breakage and is associated with less hair damage,^[24,37] we did not find any association between the use of these products and microscopic changes.

The study was not without its limitations. All the potential investigations such as color changes by diffuse reflectance spectrophotometry, stress/strain curves for mechanical properties, and quantitative protein loss were not conducted in the study.^[23] Rather, parameters that can be conducted easily in clinical settings were evaluated. A detailed microscopic examination in addition to these clinical parameters, which is again a procedure that can be completed in clinical settings, was done. Thus, our evaluation parameters were based on the ease of examination. Furthermore, comprehensive data on clinical presentation, history (general and hair related), and hair examination were collected. Finally, multivariate analyses to identify independent risk factors associated with changes in the hair of these individuals were used in our study.

Nonetheless, in spite of these limitations, the study does provide useful information on the relationship between the use of hairstyling procedures and hair changes. Women who had used any of these procedures in the past 6 months were significantly more likely to have microscopic changes compared with those who had not used these; this relation was maintained even among those who had used these products ever during their lifetime. Thus, a detailed history of the use of hair styling products and procedures is essential for diagnosis and management of hair loss in women. Notably, there were no significant differences

in hair assessment parameters. Thus, in addition to clinical/hair assessment, a microscopic examination of hair will potentially be useful for evaluation and management of hair loss in women. Though, a previous study had suggested that these hair damages may be visible on SEM,^[33] we did find substantial changes on light microscopy as well. Thus, hair can be evaluated in settings that do not have facilities for SEM. Furthermore, it will be important to develop guidelines for use of hairstyling products for Indian hair, due to the difference in structure and composition of hair, and an increase in use of these hair styling procedures in the population.

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Conflicts of interest

There are no conflicts of interest.

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