What is normal black African hair? A light and scanning electron-microscopic study

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Background: The hair of normal black Africans forms a mat of tightly interwoven hair shafts. The effect of this on the structure of the hair shaft and the response to grooming is unknown.

Objective: Our purpose was to use light and scanning electron microscopy (SEM) to examine the structure of Negroid-type hairs and effects of combing in black African volunteers.

Methods: Hair samples were collected, by combing, from Africans and compared with those from Caucasian and Asian volunteers. The volunteers had never used chemical treatments. Their hair had not been cut for at least 1 year and grooming had been limited to shampooing, drying, and combing.

Results: More than 2000 hairs in 12 African volunteers were examined by light microscopy. The hairs appear as a tight coiled springlike structure. Many shafts exhibited knots (10%-16% vs 0.15%) and appear broken compared with hair shafts from other ethnic groups. SEM of African hairs showed features consistent with repeated breaks of the shaft. Examination of hairs in situ showed interlocking of hair shafts.

Conclusion: These observations provide an understanding of the physical nature of, and effect of combing on, black African hair. (J Am Acad Dermatol 2000;43:814-20.)

Racial differences in scalp hair have been the subject of much interest, and several reports have been produced.[1-9] Chemical analysis has shown no major biochemical differences between the various racial groups.[1-6] The black African hair, of the indigenous peoples of mainly southern Africa, is characterized by tight springlike coiling of the hair shaft. Initially the flattened cross-sectional appearance of the shaft was thought to determine the macroscopic appearance of hair, but more recently it has been proposed that the shape and form of the hair follicles play an important role.[8] Most of the medical literature available on African hair describes diseases such as pseudofolliculitis barbae, dissecting folliculitis of the scalp, and acne keloidalis nuchae.[10-13] Grooming practices as well as side effects that occur as a result of these, namely hot-comb and traction alopecia, plus contact reactions to various chemicals have also been described.[10-13] Few epidemiologic studies of these conditions are available, but reported cases seem more common in people of African descent. Without an understanding of what is the normal microstructural appearance and behavior of black African hair, it is difficult to elucidate the pathogenesis of diseases unique to hair-bearing areas in Africans.

It is hoped that this study will stimulate further research into diseases specific to black African hair and be the basis of a more rational approach to the development of suitable, less damaging cosmetic treatments.

The aims of this study were (1) to see whether detailed examination of natural (untreated) hair would give us any clues to the understanding of the appearance and behavior of African hair and (2) to ascertain the effects of grooming (limited to shampooing, drying, and combing), if any, on this type of hair.

To obtain information on the morphologic features of African hair, root to tip light and scanning electron microscopic techniques were used to examine the hairs of Africans and compare them with those of Caucasians and Asians.

METHODS

Subjects

Morphologic study. Single samples of hair obtained by grooming were collected from 12 black

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Table I. Average number of hairs obtained plus average length and percentage of hairs with attached roots observed on 4 consecutive days from two volunteers for each racial group

Volunteer	Average hairs/day	Average hair length (mm ± SD)	Percentage hair with roots
African male	146.6	65 ± 0.9	36.75
African female	144.25	35 ± 0.58	32.25
Caucasian female 1	68.25	273 ± 6.4	75.75
Caucasian female 2	47.75	166 ± 4.2	94
Indian female	29	235 ± 2.7	97.25
Japanese female	21	266 ± 2.9	87.25

African volunteers (7 female, 5 male; age range, 15-35 years). The samples were examined by light and scanning electron microscopy (SEM).

Quantitative study. To obtain detailed information on the effect of grooming, an additional study involved the examination of sequential samples from two black African volunteers (one male, one female from South Africa, aged 31 and 32 years, respectively). Both had kept their hair natural and free of any chemical or physical (braiding or twisting) grooming except shampooing and combing and had never used hair curling or straightening techniques. The male subject had not had a haircut for 10 years and the female subject for 1 year. Both used identical plastic afro-combs. In addition, two Caucasian (Northern European) female subjects (16 and 18 years of age) and two Asian female volunteers (one Indian aged 29 years and one Japanese aged 19 years) were included for comparison. These volunteers had not had their hair cut in the previous year and had never used any chemical or physical grooming except daily shampooing (commercially available shampoos) and combing. From each of the 6 volunteers, the hair removed by combing, after washing and drying with a towel, was collected on 4 consecutive days. In addition, after collection of the hair samples, the two African volunteers had a mat of hair removed by shaving and portions of the hair mats were examined by electron microscopy to provide information on the in situ interrelationships of the hairs.

Light microscopy

For the morphologic study, the hairs from each volunteer were examined and the length measured. This involved the examination of more than 2000 African hairs, 450 Caucasian hairs, and 200 Asian hairs.

In the quantitative study, on each of 4 consecutive days, the number of hairs removed by combing were counted and the length of the hairs was measured for each of the two volunteers from each ethnic group. A random sample of 100 hairs (or all hairs if <100) from each volunteer for each day were mounted on glass slides. These were examined by light microscopy for the presence of knots as well as counting the number of hairs with the root attached and the number with no roots (broken).

Table II. Incidence of knots in a random sample of 100 hairs from the African volunteers on 4 consecutive days

Day	African male (/100 hairs)	African female (/100 hairs)
1	12	7
2	19	12
3	17	10
4	18	11
Average	16.5	10

SEM

A random sample of between 10 and 20 hairs from each volunteer was examined from base to tip by SEM. The hairs were mounted on stubs and sputter-coated with gold before examination in a Philips 505 scanning electron microscope. The base (root or broken end) and tip (original tip, cut end, or broken end) of each hair was evaluated along with any damage to the hair shaft. In addition, to examine the in situ relationship, portions of the hair mat removed from the African volunteers were also mounted on stubs and examined.

RESULTS

Light microscopy

Morphologic study. Light microscopy confirmed the tight coiled springlike appearance of the black African hair compared with the straight or gently curved hair shafts of the Caucasian and Asian volunteers. It was observed that the average length of the detached hairs from the 12 African volunteers (54 ± 22 mm) was significantly shorter than the Caucasian (219 ± 75 mm) and Asian (250 ± 21 mm) groups. Examination of the hair shafts showed a high incidence of hairs with no attached root (broken) in the African samples. In addition, it was observed that many of the African hair shafts exhibited knots.

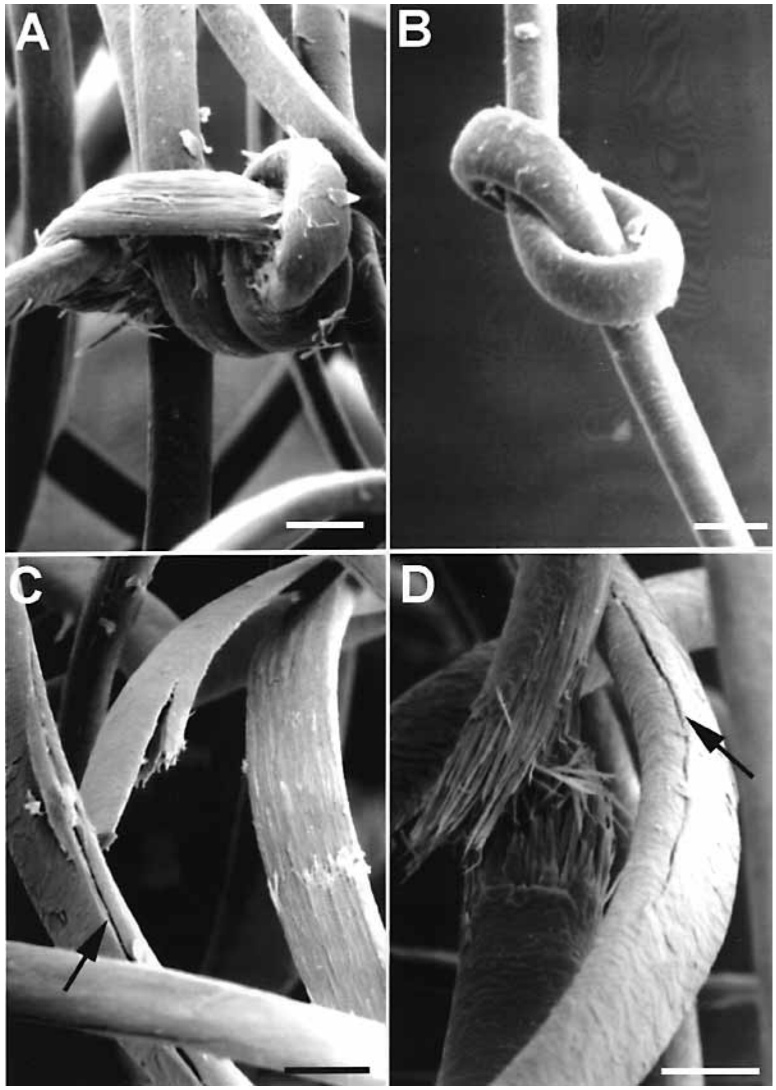

Fig 1. A, Detail of knot in the African hair. Note complex nature of the knot with damage to the cuticle exposing the cortical fibers. **B,** Detail of the only knot observed in the Caucasian hair, which appears to be looser with no damage to the cuticular layer. **C** and **D,** Details from African hair mat shows the longitudinal fissures of the shafts *(arrows)* plus examples of splitting **(C)** and breaking **(D)** of the hair shaft. (**A-D,** Scale bar = 0.1 mm.)

Quantitative study. The number of hairs removed each day by combing was found to be variable for each volunteer, but constantly more hairs and of shorter length were found in the samples from the African volunteers compared with the Caucasian and Asian volunteers (Table I). This study confirmed the lower incidence (<40%) of hairs with attached roots in the African samples compared with more than 75% and approximately 90%, respectively, for the Caucasian and Asian samples (Table I). When the number of hairs with knots was examined, it was found that an average of 16.5% and 10%, respectively, of the random samples of 400 hairs from the two African volunteers exhibited single knots (hairs with multiple knots were not included). This high incidence was found to be relatively constant for each of the 4 days examined (Table II). This compares with the rarity of knots in the hairs of the Caucasian and Asian volunteers. Only a single knot was observed in the hairs from one of the two Caucasian and none from the Asian volunteers (only 1 of 674 hairs examined had a knot).

SEM

The basic SEM appearances of the hair shafts were similar for all 12 African volunteers and only differed

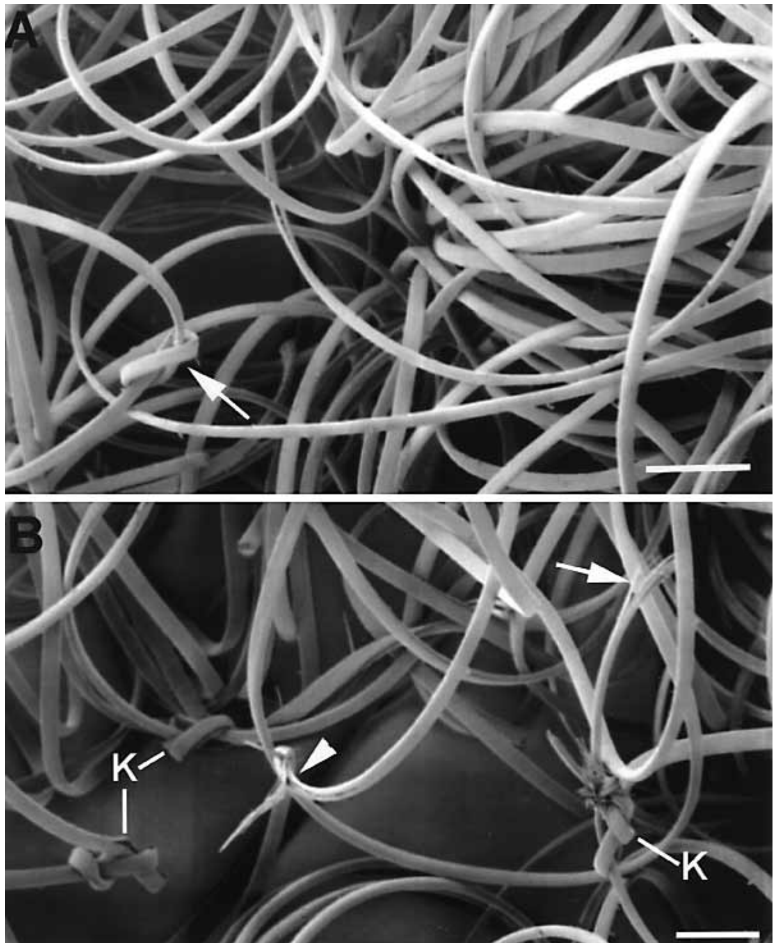

Fig 2. A, Low-power micrograph of African hair mat shows the intertwining and interlocking of the hair shafts plus the presence of a knot *(arrow).* **B,** Part of hair mat shows the high incidence of knots *(K)* plus the fraying of a hair shaft *(arrowhead)* and a broken tip *(arrow)*. (**A** and **B,** Scale bar = 2 mm.)

from the Caucasian and Asian hair in having a more flattened cross-sectional appearance. The coiling appearance resulted from a smooth curving of the hair shaft and was not associated with twisting or collapse of the shaft (Figs 1 and 2). The African hair shafts were enclosed by a well-preserved cuticle (Fig 3, *E*) similar to that observed for the other racial groups (Fig 3, *F*). However, increased evidence of wearing with some loss of the cuticular pattern was observed towards the tip of the hair in all 3 racial groups (Fig 3, *A-D*). The most extreme wearing, with complete loss of cuticular structure, was seen toward the tip of the hairs of the Caucasian subject with the longest hair (Fig 3, *B* and *C*). However, the hair shafts of the African volunteers did exhibit structural damage with evidence of longitudinal fissures, resulting in splitting of the hair shafts (Figs 1, *C* and *D*, and 2, *A*). The splitting was also associated with knot formation (Fig 2, *B*). Longitudinal fissures were not observed in the Caucasian or Asian hairs. It was also observed that many of the black African hairs (approximately 40%) were fractured with no attached root. This compares with the hairs from the Caucasian and Asian volunteers where the majority (>75%) of hairs possessed an attached root. In addition, the vast majority (>80%) of African hairs possessed tips with a frayed or serrated appearance with macrofibrils of the cortex exposed (Fig 3, *A*). This is consistent with breaking of the hair shaft, and partial breaks were observed in the hair mats (Fig 1, *D*). In contrast, the majority of Caucasian (>50%) and Asian (>90%) hairs possessed either the original (Fig 3. *B*) or cut tips (Fig 3, *C* and *D*).

SEM confirmed the high incidence of hair shafts with knots from the African volunteers. Examination of the knots revealed that some were complex and very tight, often resulting in structural damage with splitting and fraying of the hair shaft (Figs 1, *A*, and

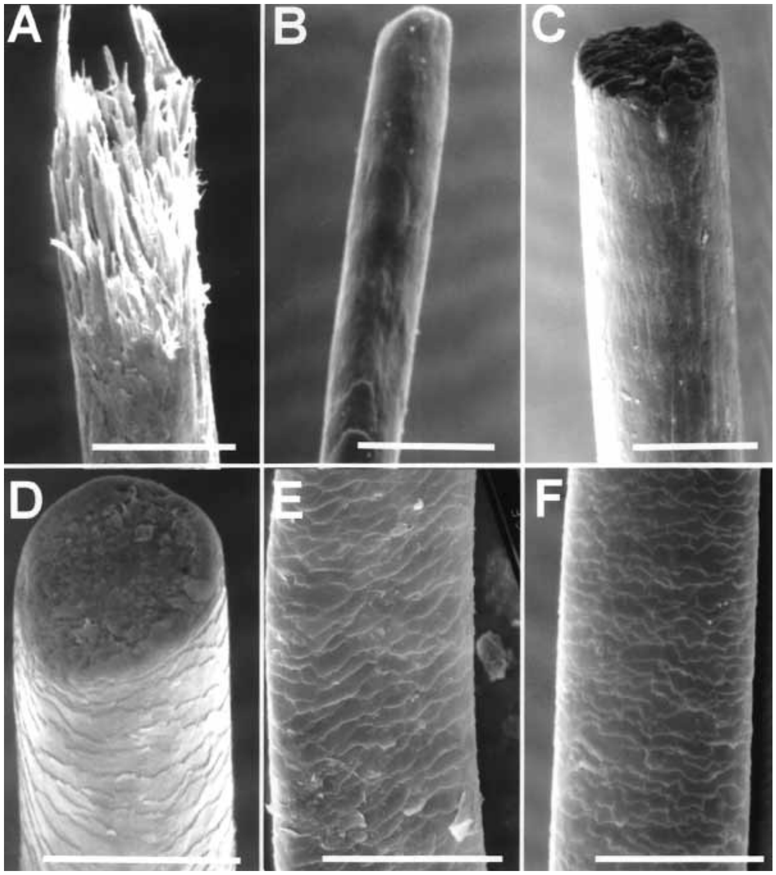

Fig 3. A, SEM of an African hair shows serrated appearance of a fractured tip with exposure of the cortical fibers. **B,** SEM of Caucasian hair shows original tip with loss of cuticular pattern resulting from weathering. **C,** Tip of Caucasian hair with flattened end, probably as a result of cutting. Note extensive wearing of the hair shaft with loss of the cuticular pattern. **D,** Tip of Asian hair exhibits a cut end and relatively little weathering of the hair shaft. **E,** Part of mid-portion of an African hair shaft shows the well-preserved cuticular pattern with no evidence of weathering. **F,** Mid-portion of Caucasian hair shaft shows the well-preserved cuticular pattern. (**A-F,** Scale bar = 0.1 mm.)

2, *A* and *B*). In comparison, the single knot observed by light microscopy from one of the Caucasian volunteers, when examined by SEM, appeared looser with no evidence of structural damage to the hair shaft (Fig 1, *B*).

Examination of the intact hair mats, which reflected the in situ interactions of the hairs, confirmed the high incidence of knots (Fig 2, *A* and *B*). In addition, it showed the marked intertwining and interweaving of the hair shafts that hold the hairs together to form the matlike structure (Fig 2, *A* and *B*). All the structural damage, exhibited by the hairs obtained by combing, was reflected in the hairs within the mat.

DISCUSSION

To our knowledge, this is the first study to directly compare the damage caused by normal grooming on the hair of various racial groups. The study is based on samples from 12 black Africans (Southern Africa) (normal individuals with no clinical abnormalities) that were compared with hair samples from volunteers of Asian (Indian and Chinese) and Caucasian (northern Europe) groups. However, although the study has not examined the possible variations within the various ethnic groups, the results give some insight into the general effects of grooming on the hair of the various racial groups.

The basic structure of the hair shafts consisting of a cortex enclosed by a multiple layer of overlapping cuticular cells was similar for all 3 groups. The African hairs differed in being tightly coiled and having a flattened cross-sectional appearance compared with the oval and circular appearance of the Caucasian and Asian hairs, respectively. It has been suggested by Kamath, Hornby, and Weigmann[14] that Negroid hair is inherently fragile. Their structural findings were based on examination of hair from a single volunteer and could not be confirmed in the present ultrastructural study. No twisting or collapse of the hair shafts was observed, which is consistent with the findings of Lindenlof, Forslid, and Hedblad.[8] In addition, there was no evidence of excess wearing of the cuticle of the African hairs compared with the Caucasian and Asian groups. The hair shafts of all racial groups exhibited increased wearing toward the tip, with the most severe loss of cuticular pattern observed in the Caucasian with the longest hair. The African hair shafts did not exhibit the changes associated with excessive weathering observed in clinical conditions such as trichothiodystrophy.[15] This was consistent with the observations of an identical silver staining pattern of the cortex and cuticular cells as seen by transmission electron microscopy for all 3 racial groups (D. J. P. Ferguson, unpublished results) and confirms the normal distribution of the sulfur-rich proteins in African hair.[3,4] However, it was found that the African hair had a tendency to form longitudinal fissures and splits along the hair shafts, which were not observed for the Caucasian or Asian hair. In addition, a high proportion of the African hairs exhibited knot formation, which was rarely observed in Caucasian or Asian hair. It is possible that the physical effect of washing and combing may increase knotting and intertwining by stretching out the coils, which then interlock when they spring back.

The most significant feature was that the majority of the tips of the African hair had fractured ends compared with the Asian and Caucasian hairs, in which the original or cut tips predominated. Similarly, the basal end also exhibited evidence of breakage in contrast to the Caucasian and Asian samples in which the majority of hairs had attached roots. These observations would be consistent with repeated breaking of the African hair. In contrast, in the Caucasian and Asian groups, irrespective of the length of the hair, the majority of hairs appear to have been shed rather than broken, as evidenced by the attached root and undamaged tip.

These findings may have implications for the pathogenesis of traction alopecia. Tension may not be the only cause; braiding may also increase intertwining and knotting and thus worsen the damage caused by combing, with resultant traumatic alopecia. The features of the broken ends are also consistent with acquired trichorrhexis nodosa, which can develop as a result of physical factors.[16,17]

The physical forces exerted during combing involve the separating and sliding of the hairs along the teeth of the comb. In the Caucasian and Asian hair this appears to occur with relatively little resistance, exerting minimal physical stress on the hair shafts. It is obvious from examination of the hair mats of the African volunteers that such movement of the comb would be difficult because the intertwined hair shafts could not separate and additional pressure would only increase the tightness of the interlocking hairs. The likely mechanism by which the comb could move through the hair would be by breaking the interlocking hair shafts. The presence of numerous knots would also increase resistance to the comb, leading to the tight structurally damaging knots observed and subsequent breaking of the hair shaft. These observations would explain the high incidence of repeatedly broken hairs and the few hairs with attached roots in the African samples. The physical breaking of the hair rather than normal shedding could be responsible for the significantly larger numbers of hairs removed by combing in the African volunteers. Combing is probably not the only cause and it is possible that physical factors associated with washing and drying also contribute to the damage. Such irreversible matting of the hair shafts is not normally seen in Caucasian or Asian patients, but rare examples have been observed associated with shampooing.[18]

The rate of hair growth has been documented to be, on average, 0.3 to 0.4 mm a day.[19,20] The relatively short hair observed for the African volunteers (even after 10 years) could be due to normal grooming, resulting in repeated breaking of the hair shafts. It is possible that continued hair growth is balanced by fracturing of the hair shafts and eventually reaches a steady state. It is likely that the eventual length will vary between persons depending on the intertwining of the hair and the grooming procedures used. From these observations it could be proposed that any procedure that reduces knotting of hair and/or the need for combing would result in an increase in the length of the hair by reducing the incidence of breaks in the hair shafts. This might explain, at least in part, why hair twisted into locks (dreadlocks, which do not require combing) seems to grow longer. In this case, of course, shed hair remains in the locks and thus also contributes to the length.

Further research is needed if we are to understand the pathogenesis of disease states unique to black African hair, so that these can be prevented and/or properly treated.

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