INTRODUCTION

The hair thread is a natural fiber formed by keratin, a protein containing a high concentration of sulfur coming from the amino acid cysteine. Hair loss is a common complaint among patients. Hair loss may occur due to increase in breaking of hair due to a reduction in tensile strength of hair fiber. Tensile strength and breaking point of textile fiber can be measured using Zwick/Roell Z010 (materials and components testing, Germany). We used the instrument to measure the tensile strength and breaking point of hair among four groups of volunteers.

MATERIALS AND METHODS

Institutional Ethics Committee approval was granted and informed consent from the volunteers was obtained. Assent and parental consent were obtained for those below 12 years. The study included four categories of volunteers. Each category includes two groups for comparison. Four categories are as follows: (1) Vegetarian and nonvegetarian, (2) those who regularly apply oil and those who do not apply oil, (3) childhood and elderly, (4) pigmented and nonpigmented hair. Hence, the four categories included eight groups in total. 15 volunteers were recruited under each group. Thereby, totaling 120 volunteers. Recruitment of volunteers was shown in the Figure 1.

We excluded those with proven hair shaft or scalp pathology, nutritional disorders, major systemic illness. Premature graying of hair, children below 5 years were not included in the study. Those who use hair dye, hair dryer regularly and those who undergo hair straightening procedure were also excluded.

ABSTRACT

Background: Hair strength depends on various factors such as nutrition, environmental factors, sunlight, oiling, aging, conditioner, etc.

Aim: To compare the tensile strength and breaking point of the hair shaft between (1) vegetarian and nonvegetarian. (2) Those who regularly apply and those who do not apply oil. (3) Pigmented and nonpigmented hair, (4) childhood and elderly.

Materials and Methods: Hair fibers were mounted in tensile strength testing machine Zwick/Roell Z010 and gradual force was administered. The elongation of hair fiber in mm and the maximum force required to break the hair strand were recorded for each fiber.

Results: Elasticity of the children’s hair was more than the elasticity of adult (P = 0.05) although tensile strength in children hair was not statistically significant (>0.05). Similarly, the tensile strength was more among those who regularly consumed nonvegetarian food but the difference was not statistically significant (P > 0.05). There was no statistically significant difference in other groups (P > 0.05).

Conclusion: Elasticity in children hair is statistically more than elderly hair although there is no significant change in tensile strength.

Key words: Elasticity of hair, tensile strength of hair, Zwick/Roell Z010
The study required 15 cm long hair for measuring tensile strength and hence only female volunteers were included and were instructed to wash their hair on the day of sampling. 10 samples from each female volunteer, each measuring 15 cm in length was collected by cutting the hair close to the scalp. 5 of the 10 hair samples were subjected to experiment.

As there is no definite criterion for nonvegetarian, we included those either consuming 750 g of nonvegetarian food per week or consuming nonvegetarian food 5 days in a week. Vegetarian was defined as those who almost never consume meat. Those who applied oil 5 days in the week were included among those applying oil. Those who almost never/very rarely applied oil were included among those not applying oil. Child was defined as age 6–12 years and elderly as above 60 years. Gray hair was defined as those volunteers with more than 80% graying of scalp hair.

To enable easy visualization, the collected hair samples in denominations of 10 were mounted on white cardboard for each category and gray hair was mounted over the black cardboard [Figure 2]. We used Zwick/Roell Z010; German made equipment [Figure 3] that generally measures tensile strength and breaking point of textile fibers. We followed American Standards for Testing Material D 3822.

Single hair strand was mounted in between the two grips [Figure 4]. The gradual force in grams was delivered, and the elongation of hair fiber in mm, and the maximum force required to break the hair strand were recorded for each fiber. Each hair strand was subjected to test in a similar manner. The results of each group was plotted in the graph [Figures 5-8] analyzed statistically using t-test to compare each group. The mean value <0.05 was considered as statistically significant. Data were analyzed using SPSS (19.0) is a comprehensive system for analyzing data manufactured by International Business Machines Corporation (IBM). It is called IBM SPSS statistical software.

**RESULTS**

The breaking point and elasticity were the two parameters assessed amongst 120 volunteers. The breaking point was measured in grams per millimeter and elasticity in percentage. Table 1 shows the elasticity of the children’s...
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**Figure 5:** Tensile strength and elasticity of vegetarian and nonvegetarian hair

**Figure 6:** Tensile strength and elasticity of oiled and less oiled hair

**Figure 7:** Tensile strength and elasticity of children and elderly
hair was statistically more significant than the elasticity of adult ($P = 0.05$). In the other three groups, there was no statistically significant change in elasticity ($P > 0.05$). Although tensile strength was more in children the difference was not statistically significant ($P > 0.05$). Similarly, tensile strength was more among those who regularly consumed nonvegetarian food but the difference was not statistically significant ($>0.05$). There was no statistically significant difference in the tensile strength of other two groups ($>0.05$).

**DISCUSSION**

Hair fiber is composed of three main structures namely cuticle, cortex, and medulla inner outward. Human hair has about 65–95% proteins in its weight, 32% of water, lipid pigments, and other components.[1] About 80% of human hair is formed by a protein called keratin.[2] Keratin is rich in sulfur containing amino acids mainly cysteine. Keratin gives the hair its strength, flexibility, durability, and functionality.[1] The resistance to breakage is a function of the diameter and condition of the cortex, and it is negatively affected by chemical treatments.[3] Robbins and Scott have shown Hookean slope that explains the changes occurring while hair is being stretched. The changes undergone by the hair during the stretching may be explained by the protein conversion and the possible conversion of $\alpha$-keratin with an organized and compact helicoid disposition to $\beta$-keratin with loose peptide chains.[4] Proteins with $\alpha$-helix structure wind each other by their left side similar to two stretched ropes and curled. When the hair is stretched, this curl gives it a kind of elasticity.[5,6]

Tensile strength of hair is defined as maximum stress (force per unit area) that a hair can withstand while being stretched or pulled before breaking. Elasticity is defined as the tendency of solid materials to return to their original shape after being deformed. Hair fiber has an elastic property. The elasticity increases with an affinity of hair keratin for water. When dry, the hair thread may stretch 20–30% of its length and in contact with water, this may reach up to 50%.[1] It is possible that water in the hair may be retained after washing if oil is applied immediately. This may increase hair elasticity but in the present study this group was not included. Oil is a conditioner and may help the hair to retain moisture. It is possible that the presence of oil and moisture trapped in the hair may have an effect on the tensile strength and breaking point of the hair. However, the difference was not statistically significant.

In conditions like alopecia areata white hairs are spared. Hence, we compared the tensile strength and elasticity of

| Samples         | Breaking point | Elasticity |
|-----------------|----------------|------------|
|                 | Mean g/mm      | SD         | $t$  | $P$  | Mean (%) | SD   | $t$  | $P$  |
| Pigmented       | 83.27          | 22.17      | 0.28 | 0.77 | 43.66     | 2.69 | 1.59 | 0.12 |
| Nonpigmented    | 85.45          | 19.04      | 41.02 | 5.90 |
| Oiled           | 88.48          | 24.43      | 46.17 | 5.02 | 6.28     | 0.15 | 0.20 |
| Less oiled      | 87.59          | 17.50      | 44.08 | 3.57 |
| <12 years       | 84.29          | 15.76      | 42.85 | 2.37 | 1.97     | 0.05 |
| >60 years       | 73.97          | 17.35      | 40.30 | 2.89 |
| Vegetarian      | 83.27          | 22.17      | 43.66 | 2.69 | 0.15     | 0.12 |
| Nonvegetarian   | 85.45          | 19.04      | 41.02 | 5.90 |

Figure 8: Tensile strength and elasticity of pigmented and nonpigmented hair

Table 1: The hair of <12 years showed significantly higher elasticity than elderly hair

*Though the result showed higher breaking point for nonvegetarians hair and children hair, statistically it was not significant. SD – Standard deviation
pigmented and nonpigmented hair. However, there is no statistically significant difference.

Younger people have more anagen in growing phase. Constant weathering, exposure to numerous chemicals, and sunlight may make the hair fragile in older age group. However, the difference was not statistically significant.

In the adult female, hair fiber diameter begins to decrease after the forties and smaller diameter hairs break more readily than larger diameter hairs because they are less stiff, and they bend and tangle more readily.[8-13]

Protein is an important nutrition required for hair growth. Nonvegetarians eat more proteins and hence tensile strength was more among those on high protein diet as compared to those on a low protein diet. However, the difference was not statistically significant. We conclude that the elasticity of children hair is statistically more than elderly hair although there is no significant change in tensile strength.

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Conflicts of interest

There are no conflicts of interest.

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