Analysis of hair integrity according to the use of different tools and cutting techniques

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Abstract

Introduction: Hair cutting is present in most people's routine and over time tools and techniques have been developed to achieve it. The professional's choice of their working tools has always been based on texture and finishing effects to achieve aesthetic results. Thus, to better understand the importance of tool and haircut technique selection, we investigated the differences in segmentation patterns that the ends of the strands exhibit following various cuts – using four techniques with three types of tools. Furthermore, the question of the need to pay attention to hair cutting was raised by assimilating the concept of fiber, whose cutting direction can increase or decrease its resistance.

Material and Methods: Therefore, this study identified different cutting patterns with the aid of optical microscopy and scanning electron microscopy and analyzed the variation in hair fiber integrity through analysis of split ends and breakage.

Results and Discussions: Each cutting tool produces a unique pattern, potentially causing different damage to the hair fiber.

Keywords: Haircut; Scissors; Razor; Hair clipper; Hair damage.

1. Introduction

Hair cutting is one of the most sought-after services in beauty salons and therefore “it is a basic and fundamental skill that structures hair design” [1] and to do it, there are different tools and haircut techniques. From both the professional’s and the client’s point of view, it is possible to state that there is variation in results depending on the choice of combination between tool and technique, but little is known about the scientific justifications for such a difference. Damage to the fiber results from exposure to ultraviolet radiation, strong surfactants, chemical agents, and mechanical damage caused by incorrect handling of the hair [2]. There are many precepts based on the experience of each professional or the empirical sense that “a razor damages the hair” and “when you shave with a machine the hair becomes damaged”. Differently, in the botanical literature, there is functional guidance in the form of cutting down a given tree to facilitate the harvesting of its fruits and phytosanitary treatments [3], which can regulate the growth rate and flowering potential, even being essential for the success of culture [4].

Perhaps the reason for the lack of scientific knowledge about the physical functionality of the varieties of haircuts lies in the fact that the main aspects that the beauty professional takes into consideration when choosing their work tool are aesthetic, such as the desired final shape and texture, in addition to the ease that the material provides when cutting. For example, when choosing a tool, the professional is instructed that straighter cuts suggest more precise blades – micro serrated blades scissors. In layered or slicing cuts, beveled edge
scissors or a razor are used to provide lightness and disconnection. Men's hair, when it is very short, is normally done with a hair clipper [5].

The process of formation of fractures in the hair fiber occurs mainly at the ends, as this is the oldest and most fragile part of the hair due to the mechanical friction of brushing, thermal exposure, and chemical procedures [6]. The exact moment in which the split ends – trichoptilosis – forms during combing is when the comb reaches the weakened part of the hair fiber in a perpendicular direction and this hair is pulled, forcing the most fragile point in the cortex subsets to rupture [7]. The longitudinal shear of the hair shaft is in some way related to flexion and bending, so the fracture of the hair fiber, both longitudinally and transversely, involves factors other than traction. Thus, we can classify the types of rupture as longitudinal, split ends and transverse, a clean and single rupture caused by the circumferential fracture of the cuticular layer extended towards the cortex [8].

At the same time, the surfactants in shampoos and ultraviolet radiation cause internal damage to the structure of the hair, in addition to the mechanical acts of handling the hair being responsible for the external weakening of the hair [9, 2]. Scissors are the tools that have the greatest seductive power for hairdressers, due to their versatility and freedom of creation [5]. The scissors are made up of two mobile parts, which move reciprocally around an axis. With this, the cutting blades slide over each other obtaining the cutting point. When closing the scissors, the cutting point moves from the direction close to the axis towards the tip of the scissors [10]. There is a huge variety of types and sizes of scissors on the market nowadays. The size of the scissors is defined in inches and the models are defined by the shape of their cutting blades and their respective functions.

The razor can be used as an execution or finishing tool, normally used to create smoothing effects for heavy hair [1]. They have a fixed or disposable blade designed to cut or shave beard hair and/or hair. Among the razor models, there are those with protection on the blade, a type of comb to avoid accidents that are more common among hairdressers and those without protection on the blade commonly used by barbers [10]. The machines perform their function through the vibration of a movable comb on the other fixed. Among its main characteristics is the action like the blades of a pair of scissors, on the other hand, it must be used to capture and cut with a minimum impact on the hair, as the blade cutting process can lead to fiber distension [10, 11].

The aim of this research, experimental, transposes the reasoning mentioned above, as it is focused on observing a phenomenon with the action of specific factors [12], whose objective is to analyze the variation in the integrity of the strand of hair according to the use of different tools and their applied cutting techniques, in natural Caucasian hair strands and submitted to mechanical brushing and instrumental analysis.

2. Materials and Methods

2.1 Tools

Three professional haircut tools were selected: 5.75-inch straight beveled edge hairdressing scissors (White Line - JP10 W, Jaguar); hair razor (Comb Guard, Feather); hair clipper (Super Taper, Wahl).

2.2 Cutting techniques

The choice of cutting techniques was also based on the possibility of executing the cut from beginning to end with a single technique, establishing 4 types of cutting:

- Cut A: beveled edge hairdressing scissors, in a direction perpendicular to the hair fiber. Holding the strand between the index and middle fingers, the scissors cut the strands horizontally/perpendicularly to the fiber. Cutting occurs when the fixed and movable blades meet when opening and closing the scissors. Technique applied to damp hair (Figure 1).

- Cut B: beveled edge scissors in a direction parallel to the hair fiber. Holding the strand between the index and middle fingers, the scissors cut the strands vertically/parallel to the fiber. Cutting occurs when the fixed and movable blades meet when opening and closing the scissors. Technique applied to dry hair to ensure that the scissors will section the strand as parallel as possible, as with damp hair the strands become agglomerated, and the precision of the movement is lost (Figure 2).

- Cut C: hair razor, at 45°, diagonal to the hair strand. Holding the strand between the index and middle fingers, the razor is positioned horizontally, but it is tilted at 45° to the fiber.
The cutting movement is due to the friction and drag of the blade on the hair, therefore, it is applied to damp hair, to keep the hair lubricated to facilitate cutting (Figure 3).

- **Cut D**: hair clipper, in the direction perpendicular to the fiber. Holding the strand between the index and middle fingers, the hair clipper cuts the hair strands horizontally/parallel to the fiber. Cutting occurs when the fixed and movable blades of the hair clipper’s mechanical movement meet. The technique is applied to dry hair to obtain better precision (Figure 4).

The haircuts were performed by the same person, trying to maintain the standard of force, pressure and length.

![Figure 1](image1.png)
**Figure 1.** Movement of cut A with beveled edge scissors perpendicular to the fiber. **A.** Initial movement. **B.** Final movement.

![Figure 2](image2.png)
**Figure 2.** Movement of cut B with beveled edge scissors, parallel to the fiber. **A.** Initial movement. **B.** Final movement.

![Figure 3](image3.png)
**Figure 3.** Movement of cut C with hair razor at 45° in a diagonal direction to the fiber. **A.** Initial movement. **B.** Final movement.
2.3 Instrumental analysis

To measure the damage inflicted on hair strands with different tools and techniques, this study used the following analyses: split ends, breakage, scanning electron microscopy and optical microscopy. To this end, six natural Caucasian hair strands were used for each type of cut, 15cm long and weighing 8g, the total being 40 hair strands (Figure 5). All hair strands were previously washed with a 20% sodium lauryl ether sulfate solution, then subjected to the corresponding cutting process for each group.

Figure 4. Movement of cut D with a hair clipper, in the direction perpendicular to the hair fiber. A. Initial movement. B. Final movement.

Figure 5. Natural Caucasian hair strands used in the cutting groups.

2.3.1 Split ends analysis and breakage

This analysis tried to count the incidence of split ends in each sample. After cleaning and cutting, the hair strands were brushed 15,000 times by an automatic combing machine, with a dryer attached, 7,500 times on the front and 7,500 times on the back of the strand. Then proceed to counting the split ends formed [13]. For statistical analysis, exploratory data analysis was performed using the student’s t test, with a significance level of 95%.

2.3.2 Scanning Electron Microscopy (SEM) Analysis

Three strands of hair were removed from each hair cutting group to observe their respective patterns. The samples were coated with gold ion deposition [16]. For analysis, a scanning electron microscope (JSM-5800, Jeol) was operated in SEI mode (secondary electrons) at 10 kV with a sample angle of 60°. For this test, a comparative analysis of the
photographs was carried out to support the physical description and imply qualitative characteristics of the images [17].

2.3.3 Optical Microscopy Analysis

Optical microscopy was operated for a detailed description of the hair cutting patterns of the groups and subsequent evaluation of the mechanical action on the hair fiber, using an optical microscope (Nikon) equipped with 4x and 10 x objective lenses, connected to a television that projects the images and allowed photos to be recorded with a camera (Nikon D3200), with an 18-55mm lens. For this evaluation, a comparative analysis of the photographs was carried out to support the physical description and infer qualitative characteristics of the images.

3. Results

The results obtained from subjective analyzes - optical microscopy and SEM - before brushing are described below. Through optical microscopy analysis, it was possible to identify hair cutting patterns in the distal portion of the hair fiber in a more comprehensive way and in the SEM a deeper view. In cut A, with scissors in horizontal position, the hair strands showed a horizontal and intact linear cut pattern. Therefore, the majority of the hair strands analyzed had a straight cut and practically no burrs (Figure 6). In the scanning electron microscopy images, it is possible to observe that the hair strands of cut A have good linearity and cleanliness in the cut area (Figure 7).

![Figure 6](image6.png) A and B. Cut A pattern seen by optical microscopy, with 4x magnification. The red arrows represent a horizontal and intact linear cut pattern.

![Figure 7](image7.png) A and B. Cut A pattern in scanning electron microscopy, 750x magnification at 10Kv. The red arrows show a straight cut and practically no burrs.

The hair strands in group B, cut with the scissors vertically, presented, for the most part, a diagonal line cut, but with alternation between more linear diagonal cuts and other slightly domed extension cuts (Figure 8). The SEM recording of cut B shows an area of diagonal cut, but not so linear and with irregularities and exposure of the internal part of the hair strand, easily revealing the cortex. (Figure 9). The hair strands in group C, which were cut with hair
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razor, also presented a diagonal cut that extends across the distal part of the hair strand, but with greater irregularity than cut B, which was elongated, with greater extraction of the cuticular area (Figures 10 and 11).

Figure 8. A and B. Cut B pattern, with 4x magnification. The red arrows show alternation between more linear diagonal cuts and other slightly domed extension cuts.

Figure 9. A and B. Cut B pattern in scanning electron microscopy, 750x magnification at 10Kv. The red arrows represent irregularities and exposure of the internal part of the hair strand, easily revealing the córtex.

Figure 10. A and B. Cut C pattern seen by optical microscopy, with 4x magnification. The red arrows represent a diagonal cut that extends across the distal part of the hair strand with greater irregularity.

Using the SEM, one can notice the large extension from the starting point to the ending point of the section C area, which considerably exposes the cortical cells, in a predominantly diagonal line. However, the cut demonstrated the entire hair fiber, apparently without burrs.
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The hair strands in group D were cut using a hair clipper and presented a mostly horizontal cut, but with irregularities, burrs and a crack was also observed in the portion proximal to the cutting line. Therefore, most of the fibers analyzed presented a more irregular horizontal cut with burrs (Figures 13 and 14). In the SEM images, it is clear that Section D also has a linear cutting line, like Section A. However, internally the cortical cells are ruptured in a more irregular way, as if they had been sawed. Additionally, it can be observed that the machine induces fractures in the hair strand above the cutting point, resembling cracks (Figure 15).

Figure 11. Detail of the distal portion of a hair strand subjected to cut C, seen by optical microscopy at 4x magnification, with an extensive area of cortex exposure. The red arrows represent a diagonal cut that extends across the distal part of the hair strand with greater irregularity and with greater extraction of the cuticular area.

Figure 12. A and B. Cut C pattern, Razor, at 45° to the fiber, in scanning electron microscopy, 750x magnification at 10Kv with which considerably exposes the cortical cells.

Following the objective instrumental evaluations, the analysis of split ends revealed that cut B, despite having the highest average number of split ends, exhibited the smallest increase in the ratio of split ends before and after the mechanical action (3.08 times the initial number). Cuts D and A closely followed the performance of cut B, with increases of 3.25 and 3.75 times, respectively. Conversely, cut C showed the greatest increase in the occurrence of split ends, with an average increase of 12 times compared to the state before and after mechanical action. The data summary is presented in Table 1. The breakage analysis data also indicates that cut B had the lowest average number of broken hair strands (20.83). This was followed by cut C (24.00), with cut A closely behind (26.50). Cut D showed the poorest performance, with an average of 30.83 broken strands (Table 2).
Figure 13. A and B. Cut pattern C, cutting machine perpendicular to the fiber, seen by optical microscopy, with 4x magnification easily revealing the cortex. Burrs and a crack was also observed in the portion proximal to the cutting line, in the red arrows.

Figure 14. Detail of cut D pattern, with indication of the "slit" observed, in optical microscopy.

Figure 15. Cut D pattern, hair clipper, at 45° from the fiber, in scanning electron microscopy: (A) irregularity of the cortex (750x magnification at 10Kv); (B) detail of the lateral crack above the cutting line (1200x magnification at 10Kv). In the red arrows can be observed that the machine induces fractures in the hair strand above the cutting point, resembling cracks.

4. Discussion

Through visual analysis of the samples – using both optical microscopy and scanning electron microscopy – it is possible to ascertain that each of the four types of cuts, along with their respective tools, demonstrates a distinct pattern along the cut line. Cut A exhibited a horizontal, regular and neat linear incision. Interestingly, this pattern resembles that found in another study, in fibers with transverse ruptures due to stretching. This cutting pattern
preserves the cuticular layers and cortex, which provide protection and mechanical resistance of the hair strand, respectively. However, this pattern did not reduce the friction area of the hair fiber. Cut A had the third worst result in both analyzes - breakage and split ends.

**Table 1.** Number of split ends before and after the combing process in different types of cuts.

<table>
<thead>
<tr>
<th></th>
<th>Cut A</th>
<th>Cut B</th>
<th>Cut C</th>
<th>Cut D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.67</td>
<td>2.5</td>
<td>3.75</td>
<td>0.92</td>
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<tr>
<td>±</td>
<td>±0.92</td>
<td>±1.38</td>
<td>±1.69</td>
<td>±2.19</td>
</tr>
</tbody>
</table>

*mean ± standard deviation.

**Table 2.** Number of breaks after the combing process in different types of cuts.

<table>
<thead>
<tr>
<th></th>
<th>Cut A</th>
<th>Cut B</th>
<th>Cut C</th>
<th>Cut D</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>26.50</td>
<td>20.83</td>
<td>24.00</td>
<td>30.83</td>
</tr>
<tr>
<td>±</td>
<td>±7.01</td>
<td>±2.40</td>
<td>±6.36</td>
<td>±3.25</td>
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</table>

*mean ± standard deviation.

It is noteworthy that cuts A and D are similar regarding the horizontality of the cutting line, or it can also be stated that they cut perpendicular to the hair fiber. The significant difference between the two is the smoothness of the internal area of the hair strand, since cut D results in greater irregularity in the arrangement of cortical cells, as well as their greater exposure. Such characteristics justify the appearance of longitudinal fractures after the injury applied by the hairstylist. Another observation regarding cut D is the fracture that occurs above the cutting line due to the mechanical action of the hair clipper’s blades; while one blade performs the cut, the other slides just above, causing a lateral incision.

This incision may be responsible for increased friction between the hair and the hairstylist’s brushes, supporting the notion that repetitive friction generates an excessive load, leading to trichosis in the fiber. Therefore, it is important to note that the cutting process with hair clippers can lead to fiber distension, causing damage to the hair.

On the other hand, cuts B and C resulted in the tips of the hair being more diagonal, or even parallel, to the fiber. Cutting hair with a razor can cause significant lateral displacement along with angular rotation along the length of the hair fiber. The mechanism by which the razor blade cuts the hair differs notably from cut B, as this type of segmentation is achieved by dragging the razor across the surface of the hair cuticle, resulting in an extensive, irregular, yet polished cut line. This extends the cutting area and results in the removal of the cuticular layer of the hair fiber, as evident in the electron micrographs of cut C. Moreover, the cuticle provides both conformity and protection to the cortex; its removal renders the cortex exposed, fragile, and susceptible to damage. The hydrophobic condition of the hair is due to the F-layer present in the cuticle, and with the extensive removal of the cuticular layer, the hair strand tends to absorb more moisture, which paradoxically, leads to quicker dehydration. These chemical changes impact the hydrogen bonds, further weakening the fiber. Supporting the literature, the analysis of split ends demonstrated that there was a significant increase compared to all other cuts in the samples, both before and after the mechanical action of the brush during combing. Despite performing below expectations, cut C exhibited a positive outcome in the breakage analysis, recording the second lowest average number of broken hair strands. This is likely because the diagonal cutting pattern reduced friction between the hair fiber and the bristles of the brush.

Finally, samples from cut B exhibited a diagonal cut line, which appeared sometimes more pronounced and uneven. Nevertheless, this was the cut that achieved the best outcomes in both analyses, as it resulted in the smallest increase in split ends before and after brushing, and it had the lowest average number of broken strands. The results from cut B underscore the influence of friction on breakage. However, traction alone is not the sole factor responsible for longitudinal fractures in the hair fiber. Cut B, despite not having as distinct a polish of cut A, presented a diagonal pattern that not only reduced friction between the bristles of the brush, but also enhanced the interaction between fibers.
Starting with the breakage results, it is hypothesized that, similar to a razor cut, hairs that are cut in a direction parallel to the hair require less traction force and, therefore, generate less friction during brushing, which reduces the rate of breakage. Regarding the analysis of split ends, it is deduced that cut B demonstrates the initial concept of fiber analogy. It was observed that a fiber’s resilience to splitting increases or decreases depending on the manner in which it was cut, a phenomenon evident in both experiments. This observation challenges the notion that the neatness of the cut could influence the hair strand’s integrity through mechanical exposure. It is also important to note that section C might not have achieved similar results due to the extensive exposure of the cortical cells.

To summarize, Cut B presented the best results in both evaluations. Cut A exhibited average results. Cut C showed a very high rate of split ends but ranked second-best in terms of breakage resistance. Cut D performed poorly in terms of breakage; however, it was the second-best in terms of split end prevention.

Therefore, these results allow for a scientific basis to be offered to beauty professionals in selecting the appropriate type of cut based on variations in hair strand quality. Furthermore, it is worth highlighting that this study presented unprecedented information about the integrity of the hair fiber after cutting, and further research is necessary to expand scientific knowledge, advance, and professionalize the field of cosmetology.

5. Conclusion

Each cutting tool creates a distinct pattern, that can potentially cause damage to the hair fiber. It is imperative for hairdresser to possess comprehensive knowledge of the tools and techniques employed in hair cutting to prevent cumulative damage to the hair fiber.

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References