Volumizing, fly-away/frizz control and straightening claims substantiation using 3D volume measurement system

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INTRODUCTION

Flat, limp, lifeless hair is a problem that plagues many women, who desire voluminous, bouncy and healthy-looking hair. The presence of fly-away and frizz makes the hair appears dry and frizzy instead of smooth, straight and defined. Increasing hair body and volume while straightening and taming fly-away and frizz is the goal of many rinse-off conditioners and new hair care products like volumizing gel and styling mousse.

The efficiency of these products has to be scientifically evaluated. Volumizing, frizz control and straightening claims are usually substantiated by digital image processing of a single image of a hair swatch positioned over a back light panel. Measurement of the hair swatch bulk area and the fly-away frizz area is then interpolated to volume, frizz control and straightening claims. These claims could benefit from a 360 degrees analysis of the hair swatch.

However, it is not trivial to proceed to 3D volume reconstruction and measurement of a hair swatch using conventional technique like 3D laser scanner as a hair swatch is composed of a multitude of fibers and do not define a continuous solid object (1). Image processing based on density evaluation to separate between bulk and fly-away/frizz as developed for the single image technique is often necessary.

In this article, we present an innovative imaging technique to reconstruct the 3D volume of a hair swatch. A complete analysis of the bulk and the fly-away/frizz of the hair swatch is proposed. An application for anti-frizz/volume products is studied.

PRESENTATION OF THE TECHNIQUE

This new imaging technique is based on the 3D reconstruction of 2D silhouette of a rotating 3D object (2). This method has already been demonstrated on 3D objects with well-defined boundaries (3). Due to

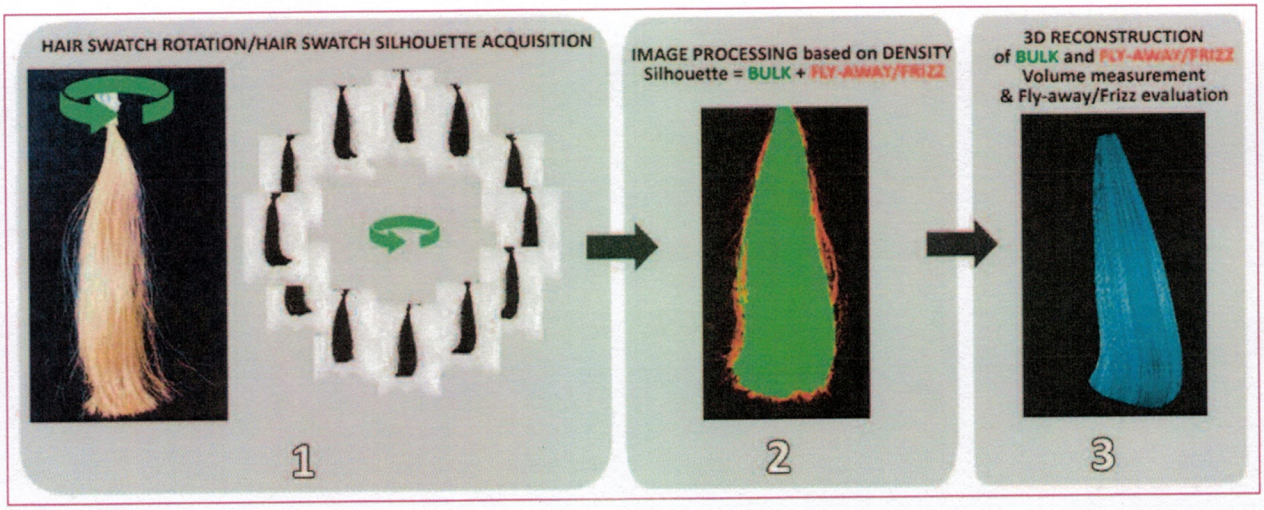

Figure 1

the nature of the hair swatch, image processing based on density evaluation is needed to decompose the silhouette of the hair swatch into the bulk part with clear boundaries and the fly-away/frizz part mainly composed of individual fibers. The bulk part of the hair swatch presents a high density of hair fibers and blocks the back light illumination, contrary to the fly-away/frizz part that presents a low density of hair fibers and enables part of the light to go through. The bulk part can be considered a continuous area and therefore we can use the 3D reconstruction technique using the rotation of silhouette. The fly-away/frizz is not a continuous area. Similar to the bulk, we can estimate a fly-away/frizz continuous area in order to reconstruct its 3D volume. The principle of the reconstruction process is presented in Figure 1.

The 3D reconstruction is decomposed into three consecutive steps:

1. Rotation of the hair swatch and acquisition of its silhouette for each angle;
2. Image processing based on density evaluation for each pixel in order to decompose the image into a bulk image and a fly-away/frizz image (FAF);
3. 3D reconstruction of the hair swatch bulk and FAF followed by an evaluation of their volume and fly-away/frizz %.

The experimental set-up is composed of a monochrome camera, a rotation stage where the hair swatch to be measured is mounted and a LED panel. The LED panel is placed behind the hair swatch for back light illumination configuration. The camera and rotation stage are connected to a computer where a dedicated software allows the rotation of the hair swatch, the acquisition of the images, the density processing to identify the bulk and the fly-away/frizz, the 3D reconstruction and the visualization of the results. Acquisition of a set of images takes 15 seconds. Image processing and 3D reconstruction of the hair swatch lasts around 30 seconds. Point clouds of the bulk and FAF are calculated and saved, allowing measurements of the bulk volume, FAF volume and total volume.

EXPERIMENTAL VALIDATION

Before measuring hair swatches, we started with a simple object to be reconstructed, a plastic bottle. Contrary to a hair swatch, the boundaries of the item are well defined and no density processing needs to be applied.

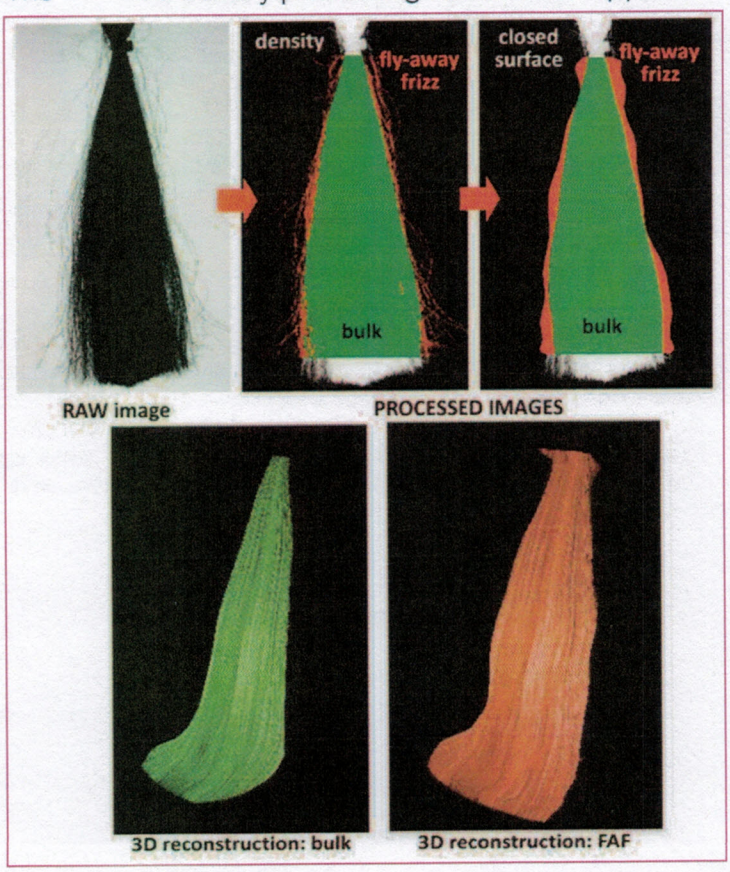

Figure 2

Its simple shape will also allow the validation of the calibration of our system by comparing the volume measured to its theoretical value as our system is calibrated. The volume measured was 523 cm^3, in accordance with the theoretical value of 520 cm^3. We can conclude that the system is pretty accurate and well calibrated.

We then placed a hair swatch in the measurement system. The hair swatch was 20 cm long and weighed around 20 g. Some examples of the images are shown on Figure 3. The raw image is processed, and the bulk in green and the fly-away/frizz in red are shown after density evaluation. The white parts correspond to the un-processed part of the image. Because of the volume reconstruction requirement, the bulk and fly-away/frizz are to be closed surface. An additional processing step is necessary, shown in the last image on the right. The 3D reconstruction process can then be applied to the bulk and to the fly-away/frizz. The images shown on Figure 2 present the 3D reconstruction of the bulk and the fly-away/frizz. Figure 3 shows raw images of diverse hair swatches (from straight to curly) and their corresponding processed images, leading to volume calculation for the bulk, the fly-away/frizz and the total volume. This illustrates the versatile capabilities of this new technique to proceed to 3D reconstruction of volume of any kind of hair swatches.

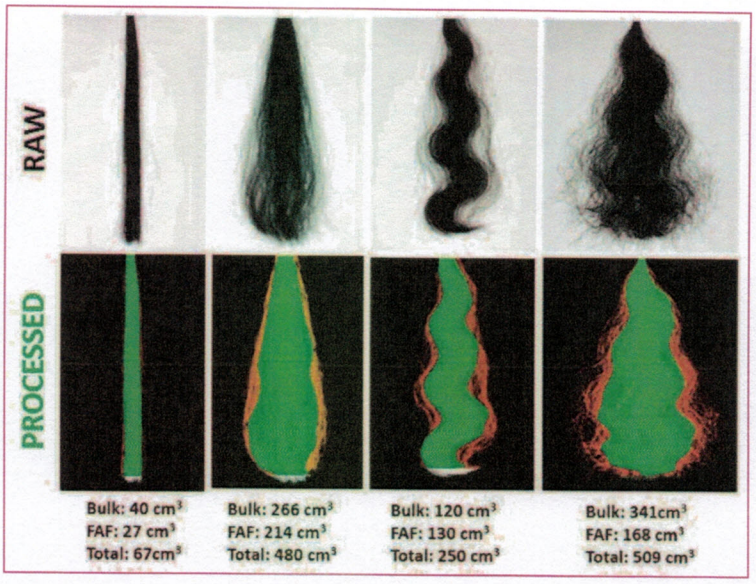

Figure 3

Application of this technique to claim substantiation is presented in the following.

APPLICATION TO CLAIM SUBSTANTATION

The objective of this study is to evaluate the efficacy of products on anti-frizz and anti-volume properties. Five different products were tested:

- Sodium lauryl ether sulfate (SLES Reference)
- Shampoo (anti-frizz)
- Conditioner (anti-frizz)
- Leave-in (anti-frizz)
- Olive oil

Caucasian wavy hair is used for this study. The tresses weight is 2.6 g and their length is 20 cm. For each tested product, six tresses are used. Four different treatments are carried out on hair tresses namely:

- SLES (Sodium lauryl ether sulfate at 10%, pH 7)
- Olive oil (commercial oil)
- Shampoo + conditioner (SH + CND)
- Shampoo + conditioner + leave-in conditioner (SH + CND + LIC)

All tresses are washed using the SLES (surfactant) which also acts as the reference. The procedure used to wash the swatches is the following: The tress is wetted under running tap warm water (30°C). We comb the fingers through the tress during 10 seconds times. The quantity of SLES used for each swatch is 1 g. The product is applied along the swatch and gently massaged during 30 seconds. The swatch is rinsed under tap water by running fingers through the hair for 40 seconds. Then the swatch is combed and passed between 2 fingers to remove excess water. The swatch hair hangs during drying on a specific support.

The olive oil is applied on wet hair just after the washing by SLES (procedure described above). The quantity used for each swatch is 0.12 g. The application is done from roots to tips gently massaged until the product seems homogeneous. The swatch hair hangs during drying on a specific support.

The shampoo is applied (1 g for each swatch) by the same procedure used for the SLES. Each swatch is placed in a watch glass during 2 minutes.

The conditioner is applied (1 g for each swatch) after rinsing the shampoo. The same procedure is used, with a 5 minutes waiting time. The leave-in product is applied (0.12 g). After rinsing the conditioner, the swatch hangs on a specific support during drying.

The swatches are evaluated according to the procedure described below.

- The drying phase is carried out in a climatic cabinet at 20% Relative Humidity (20% RH) during at least 12 hours;
- The measurement is run after drying which is the beginning of the test: T0;
- Then the climatic chamber rises to 80% RH. A first measurement is done after 1 hour at 80% RH, then after 3 h at 80% RH, 7 h at 80% RH and 24 h at 80% RH.

The swatches are placed outside the regulated cabinet for 1 minute during the images acquisition with the system. The physical quantities calculated are the followings:

- The volume of hair Bulk (in cm^3) which represents the higher volume hair density in the swatch.
- The volume of Fly-away/Frizz (in cm^3) which represents the independent hair flying around the Bulk.
- The total volume (in cm^3) which is the sum of the bulk and the Fly-away/Frizz (Total Volume = Bulk + FAF)

RESULTS AND DISCUSSION

Figure 4 shows the images (from top to bottom, raw, processed, 3D bulk and 3D FAF) after drying and after 24 h at 80% RH for the four tested products. The processed

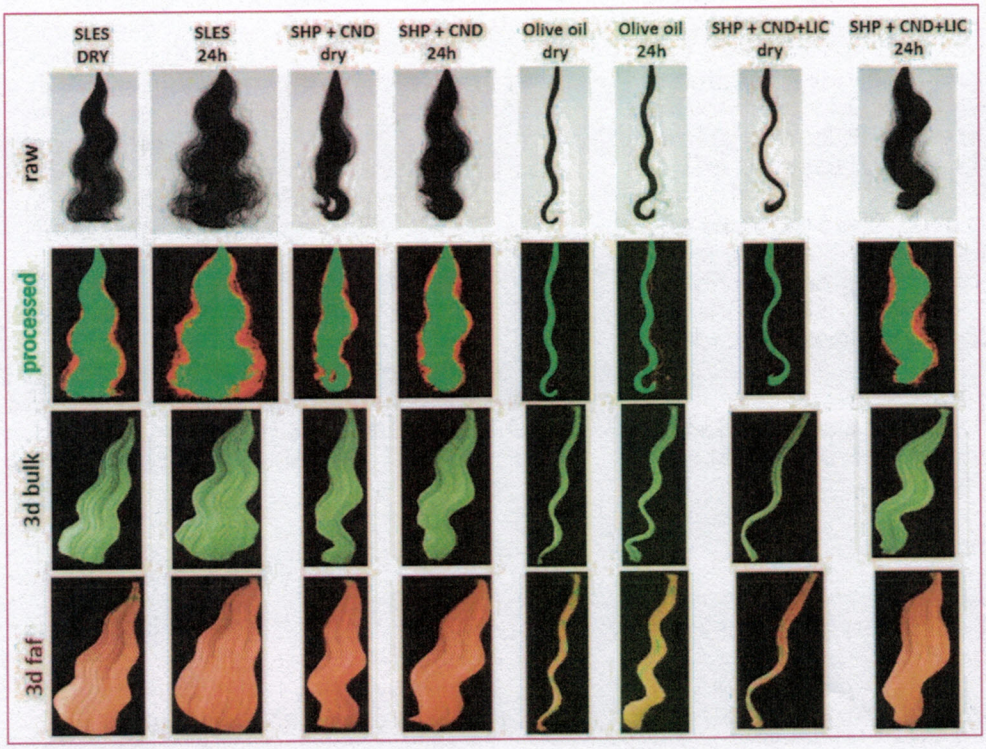

Figure 4

images shows the bulk in green and the fly-away/frizz in red.

The table presented on Figure 5 represents the volume of the BULK, Fly away, and Total Volume for the four cases studied, after drying, and after 1 h, 3 h, 7 h, and 24 h at 80% RH (Mean value, standard deviation and covariance). The displayed values are averaged on six swatches. Several charts can also be plotted. The three physical volumes parameters, i.e. the bulk, the FAF and the total volume are plotted on Figure 5.

Bulk Volume

SLES has important impact on the bulk of the swatches. The bulk volume is around 200 cm^3 after drying. It reaches 285 cm^3 after 1 hour and 317 cm^3 after 24 h at 80% RH; it increases from 53% to 71%.

The treatment with shampoo and conditioner presents a bulk volume of 100 cm^3 after drying. It goes up to 134 cm^3 after 1 hour and 150 cm^3 after 24 hour at 80% RH. The growth is 27% to 42%.

The trinomial hair care routine (shampoo + conditioner + leave-in conditioner) has a bulk volume of 18 cm^3. It reaches 56 cm^3 after 1 hour and 78 cm^3 after 24 hour at 80% RH. The increase is 217% after 1 h and 343% after 24 h.

The treatment with olive oil has no obvious impact on hair. The bulk volume is 8 cm^3 after drying and goes up to 12 cm^3 after 24 hour at 80% RH. Nevertheless this growth is not obvious visually (from 41% to 60%).

FAF Volume

The SLES impacts also the FAF of swatches compared to other products. The FAF volume is around 160 cm^3 after drying. It reaches 350 cm^3 after 1 hour (an increase of 120%) and 420 cm^3 after 24 h at 80% RH (an increase of 160%).

The treatment with shampoo and conditioner presents a FAF volume of 75 cm^3 after drying. It increases to 100 cm^3 after 1 hour and 125 cm^3 after 24 hour at 80% RH. The growth is 40% after 1 h and 66% after 24 h.

The trinomial hair care routine (shampoo + conditioner + leave-in conditioner) has a FAF volume of 8 cm^3, goes up to 35 cm^3 after 1 hour (an increase of 350%) and 60 cm^3 after 24 hour at 80% RH (an increase of 680%).

The treatment with olive oil has no obvious impact on hair concerning the FAF volume. It is only 2 cm^3 after drying; it reaches 8 cm^3 after 24 hour at 80% HR.

Total Volume

The total volume is the sum of the bulk volume and the fly-away frizz volume. SLES shows the most important impact on the hair swatches volume. The volume is around 345 cm^3 after drying. It increases to 635 cm^3 after 1 hour at 80% RH (an evolution of 84%) and

Time		SHP + CND BULK Volume (cm3)	SHP + CND FAF Volume (cm3)	SHP + CND TOTAL Volume (cm3)	SHP + CND + LIC BULK Volume (cm3)	SHP + CND + LIC FAF Volume (cm3)	SHP + CND + LIC TOTAL Volume (cm3)	OLIVE OIL BULK Volume (cm3)	OLIVE OIL FAF Volume (cm3)	OLIVE OIL TOTAL Volume (cm3)	SLES BULK Volume (cm3)	SLES FAF Volume (cm3)	SLES TOTAL Volume (cm3)
DRY 20% RH	Mean	105.9	75.2	181.1	17.6	7.6	25.2	7.9	2.2	10.1	185.7	159.9	345.6
	std	31.2	31.9	62.9	18.3	8.2	26.0	1.9	1.6	3.4	16.0	48.3	63.3
	Cvr	29%	42%	35%	104%	107%	103%	25%	75%	34%	9%	30%	18%
80% RH after 1h	Mean	134.3	105.2	239.5	55.9	34.3	90.2	11.2	3.6	14.8	284.6	351.6	636.2
	std	39.2	50.6	89.1	21.3	14.6	35.1	2.7	1.7	4.1	28.7	94.3	118.9
	Cvr	29%	48%	37%	38%	43%	39%	24%	49%	28%	10%	27%	19%
80% RH after 3h	Mean	139.7	110.4	250.1	65.8	41.2	106.9	11.6	3.9	15.6	298.5	385.2	683.7
	std	41.3	48.3	89.3	26.7	18.6	44.9	2.9	1.1	3.5	27.5	85.3	108.5
	Cvr	30%	44%	36%	41%	45%	42%	25%	28%	23%	9%	22%	16%
80% RH after 7h	Mean	143.6	117.5	261.1	73.4	54.2	127.7	11.9	5.4	17.3	305.4	407.2	712.6
	std	40.0	52.0	91.5	32.0	30.1	60.9	2.9	2.0	4.6	28.1	77.6	101.7
	Cvr	28%	44%	35%	44%	56%	48%	25%	38%	27%	9%	19%	14%
80% RH after 24h	Mean	150.7	125.0	275.7	78.0	59.4	137.4	12.6	7.7	20.3	317.2	420.3	737.5
	std	41.4	55.7	96.7	33.9	33.4	66.2	3.2	2.8	4.6	40.6	89.4	124.8
	Cvr	28%	45%	35%	43%	56%	48%	25%	36%	23%	13%	21%	17%

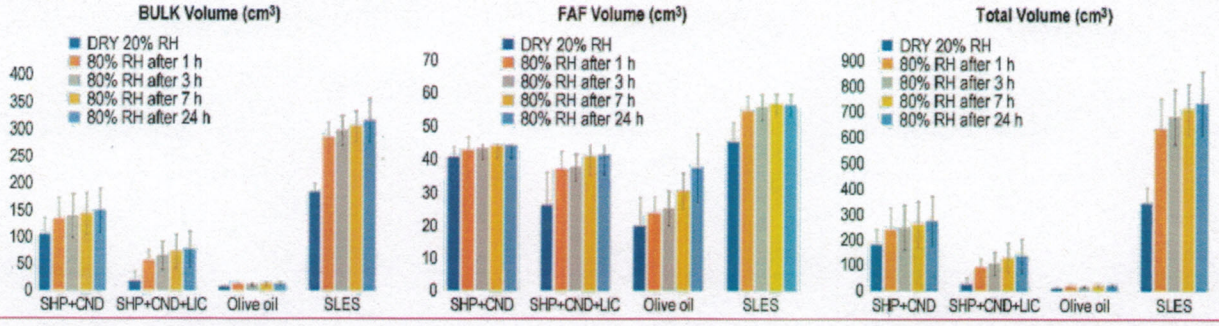

Figure 5

735 cm³ after 24 hours (a growth of 113 %).

The treatment with shampoo and conditioner presents a total volume of 105 cm³ after drying. It reaches 134 cm³ after 1 hour (a growth of 32%) and 150 cm³ after 24 hour at 80% RH (an evolution of 52%).

The trinomial hair care routine (shampoo + conditioner + leave in conditioner) has a total volume of 25 cm³. It goes up to 90 cm³ after 1 hour which represents an increase of 250% and 137 cm³ after 24 hour at 80%RH (a progression of 440%).

The treatment with olive oil has no impact on hair concerning the total volume. It is only 10 cm³ after drying, reaches 15 cm³ after 1 hour and 20 cm³ after 24 hour at 80% RH.

Results Summary

The results show that the volume and fly away frizz of hair tresses increase with high humidity whatever the products used.

The hair tresses washed with SLES lead to higher level of volume and FAF. The surfactant washed strongly the surface of the hair. It did not generate any coating to prevent hair to swell by absorbing water at high humidity.

The treatment with hair care routine (shampoo + conditioner + leave-in) generates less volume and FAF compared to the treatment with only shampoo and conditioner.

The leave-in conditioner brings clearly an anti-volume/anti-frizz effect. However, the two hair care treatment (shampoo + conditioner and shampoo + conditioner + leave-in conditioner) are not significantly different.

The olive oil brings a coating on the hair which confers to hair a hydrophobic property. Furthermore it stops hair to absorb water during 24 hour. That is why the volume on tresses treated with olive oil never increases significantly.

We can conclude that this new technique is relevant to compare different hair care routine, to study the impact of greasy treatment, or a surfactant effect on anti-volume and anti-Fly-Away/Frizz.

Cross Section

The cross section of the hair swatch can also be displayed and measured. A surface in cm² is calculated at a Z position chosen by the operator. Figure 6 shows the diameter at z=750 pixels of a swatch.

On the left figure (profile view) the red line presents the cross section of the tress and on the right figure (the cutting view) the representation of the measured surface. In this case, the area of the cross section is 40 cm². The total surface (bulk + FAF) and the bulk can be measured by this option.

The four graphs show the evolution of the cross section of the tested products at z=750 pixels at different time for the total (Bulk + fly-away/frizz). The SLES has an important hair swatches diameter during the first hour at 80% RH (increase of 165%), after that the cross section area increases slowly (14% to 15%) from 1 to 24 h.

The Shampoo + Conditioner generate a cross section which increases slowly. After 1 hour it goes up 34%, after the section area increases slowly (2 % to 14%) from 1 to 24 h.

The trinomial treatment (shampoo + conditioner + leave-in) presents a cross section which growths strongly after 1 h (increase of 3,050%). It increases constantly from 1 to 24 h (23% to 14%).

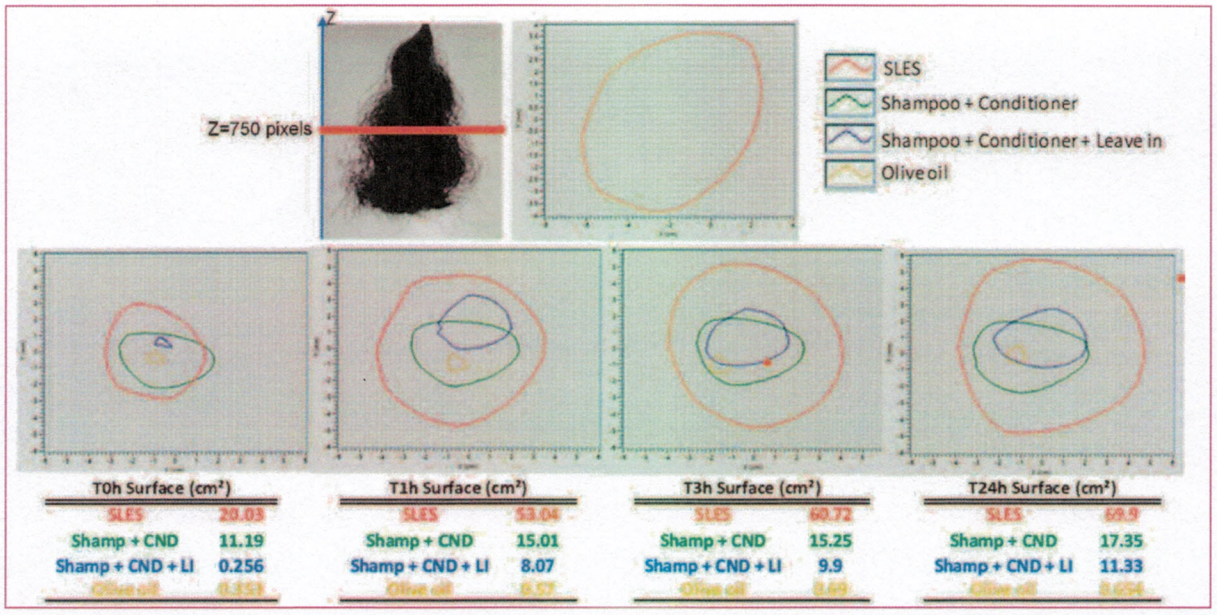

Figure 6

The treatment with olive oil does not impact the hair swatch diameter during the test. The surface did not reach 1 cm^2 during 24 h. According to these charts, a quick visual ranking can be done:
SLES>SH + CND >SH + CND + LI> OLIVE OIL

CONCLUSION

This new technique allows to reconstruct 3D volume of bulk and fly-away/frizz of hair swatches, leading to a complete analysis of the hair swatch. Many representative parameters can be extracted (volume, fly-away/frizz) from these 3D reconstruction along geometric parameters (bulk point clouds, FAF point clouds, slice, etc.).
Application to claim substantiation has been demonstrated for straightening products. We believe that this technique can be used for many applications in hair care product development and claim substantiation.

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