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Applications of the new Aeva-HE™ imaging system: Its link with the visual evaluation of facial wrinkles and its potential in screening tensile products

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Abstract

Objectives: To evaluate, in vivo, a recently developed imaging system (Aeva-HE™), based on fringe projection methodology: (i) its correlation with expert's assessments and real age of 85 French Caucasian women and (ii) its potential, as a screening tool, in rapidly selecting prototypes of tensile cosmetic products.

Materials and Methods: First, the bare faces of 85 differently aged French/Caucasian women were photographed under standard conditions and further analyzed by the Aeva-HE™ device. An expert aesthetician graded the severity of wrinkling on a fixed scale, helped by the use of a dedicated Skin Aging Atlas. A panel of 15 judges performed the same task on full-face standard photographs. The Aeva-HE™ software yielded various wrinkle's parameters (density, volume, mean depth, etc.) on different facial locations, according to age-groups. Second, seven women, balanced in age and wrinkling severity, were recruited in a separate study. These women applied at Day 1 a prototype of the tensile product and at Day 2, they applied another prototype of the tensile product. The whole faces (before and after products application) of the seven studied women were captured and analyzed by the Aeva-HE™ system.

Results: The density of wrinkles was significantly highly correlated with the aesthetician scores and, unsurprisingly, with age. Some parameters (volume, depths) of different wrinkles (glabellar, crow's feet, cheeks) were quantified, showing different absolute values and of statistically different progressions with age. The amplitudes of the rapid effects brought by the two prototypes of tensile products were clearly differentiated.

Conclusion: The recently developed device Aeva-HE™ is an efficient system for rapidly establishing a faithful and precise status of facial wrinkles, in vivo and seems like a precious tool in the rapid screening of tensile products, possibly performed on a rather limited number of subjects.

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KEYWORDS
AEVA-HE, aging, clinical assessments, fringe projection, wrinkles

1 | INTRODUCTION

Facial skin aging is the object of abundant literature[1–12] that covers most of its aspects (causes, biological mechanisms, management, quantitative methodologies, etc.) among which the severity of wrinkles plays a central part. The slow process of facial aging (by decades) goes beyond changes in the skin structures and functions as it brings strong psychological and psychosocial impacts ("I/he/she looks old today," "he/she seems older or younger," etc.), self-esteem and attractiveness Included. A precise evaluation (grading) of the global severity of facial signs is a difficult task for three major reasons: (i) facial skin aging gather wrinkles of different locations (forehead, crow's feet, glabellar, upper-lip, etc.), resulting from different causative or aggravating factors (chronological and/or Photo-induced, pollution, lifestyles habits, etc.);[3–10] (ii) their own progressing intensity (length, depth, etc.) is gender-genetically and ethnically driven; and (iii) some other facial signs (ptosis of the lower face, cheek folds, dark spots, etc.) greatly contribute to the global perception of an aged face.

From a methodological viewpoint, clinical/visual assessments or gradings, performed under face-to-face conditions or from high-quality photographs, by trained experts or aestheticians became the gold standards in such approach. However, for the reasons exposed above, each facial sign had to be considered as unique, focused, with its own extent of development (i.e., grading scale) along lifetime. Such necessity was successfully fulfilled by the creation of Skin Aging Atlases in both genders from different ethnic groups[13–17] based on 15–20 focused facial signs, thus affording a specific grading scale for each sign (0–4, 0–6 up to 0–9. A global grading (sum and average) of facial aging can therefore be attributed to a given subject of a given age, gender, and ethnicity. This methodology—or other comparable approaches—led to works that shed much light of the relationships between the progressive aging process and various factors such as gender, ethnicity, impact of solar exposure, influence of seasonality, fatigue, and so forth.[18–26] A recent and clever approach of image analysis used an AI-based software operating in Smartphones equipped with high-resolution cameras (>5 Megapixels, that analyzes and quantifies the severity of facial signs from selfie's images. This procedure allows a vast number of individual data to being rapidly collected on-line, found correlated with expert's assessments.[27,28] Physicists, looking for a more detailed evaluation of facial signs (e.g., fine lines, skin pores, etc.), successfully developed a method based on fringe projection that comprises a projector of several phase-shifted stripe patterns deformed by the skin topography and a camera unit, positioned at a different angle from the projector that captures the shifted fringe images. The generated images are used to create a 3D mapping of the skin topography, thus collecting several features such as profile roughness/deepness, wrinkle features, and volume parameters. These high-resolution 3D devices and their dedicated software allow a robust and precise characterization of the skin relief that, as example, can demonstrate the effect of a smoothing product on a less marked relief.[29,30] The most used system relying on this technology is the DermaTOP (DermaTOP®, Eotech, Marcoussis, France),[31] now modified and improved by a new system (Aeva-HE™) that captures, in one acquisition, the full-face details.[32]

Technically speaking, the Aeva-HE™ system uses fringes projection combined with stereometry technology and has four possible Fields of View (FOV). On our studies, the focus is made on 160 fields of view to capture the full face with the higher resolution. This technology integrates a high-resolution camera and its accuracy depends on the pixel distance on the FOV instead of fringes distance.

A previous paper[33] showed that this recently developed device[34] provides data of a good similarity with those obtained by the Dermatop™ Instrument. Accordingly, the potential of this new Aeva-HE™ device to correlate with expert's evaluations and to being integrated in the screening process of prototypes of anti-aging products, needed to be explored. The results of these applied studies are the objects of the present study.

2 | MATERIALS AND METHODS

2.1 | Subjects

The study involved the same 85 French Caucasian women who participated in the first study.[33] These women were clustered in age-groups: 25–39 y (N = 7), 40–49 y (N = 18), 50–55 y (N = 23), 56–60 y (N = 15), and 61–71 y (N = 22). All women were recruited and selected, through the visual assessment of crow's feet graded by an aesthetician for presenting the largest variability in the scoring of wrinkles severity (0 to 6, 0: absent, 6: very intense).

Subjects were informed about the respective purpose and protocol of the study and signed an informed consent. Prior to photographic shootings, one day of wash out was requested to all subjects to avoid the impact of their usual cleansing routines and skin care products on the result of the study.

2.2 | Protocol

When coming in our facility, subjects were asked to rest for 15 min, and went further into our shooting room (standard photographs and Aeva-HE™ device) as shown in Figure 1. Prior to shootings, the bare faces of all subjects were gently wiped off with a dry cotton pad to avoid shine from sebum or sweat. Acquisitions were performed in a dark room to avoid altering the contrast between fringes.

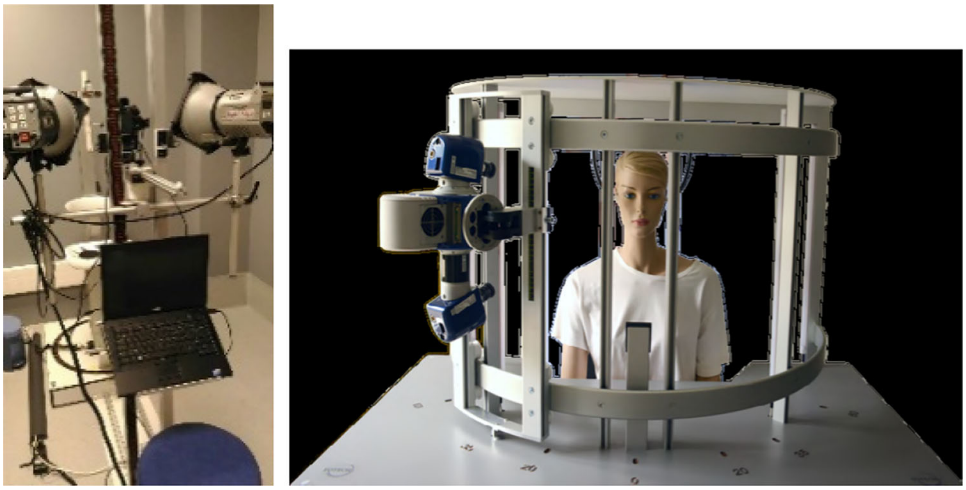

FIGURE 1 Devices used in the vivo study. From left to right, Orion table, Aeva-HE.

A 3D full face acquisition is performed on the bare skin of each volunteer using the Aeva-HE™ system. Then, 2D photos were taken with the following device: Left and right lateral photographs are taken under standard conditions of lightning composed of Nikon D300 digital camera (aperture F22, speed 1/60, ISO 400) and two symmetrically positioned flashes, using an Orion table (Figure 1).

Subjects were further seen by an esthetician to score their crow's feet wrinkles, using a referential Skin Aging Atlas, and their global wrinkles severity was evaluated through a 0–6 scale.

Standardized 2D photos were cropped on the crow's feet region and were scored by a panel of 15 people of various ages (25–55 y), using the images of the crow's feet region illustrated in the Skin Aging Atlas dedicated to Caucasian women.[13]

3D image analysis was performed by Aeva-HE™ V3 software, allowing a robust and flexible quantification of the micro-structure (micro-relief), assessed by the Surface roughness (Stm parameter) and the mid structure wrinkles and fines lines, assessed by parameters like the Profile roughness (Sa), and the mean depth of wrinkles.

2.3 | Products

Seven women from the 45–65 y group were selected to test two prototypes of products (P1 and P2) coming in our offices at two occasions in the same week. These prototypes were chosen according to their tensile property, that is, smoothing most facial signs in a very short time. Accordingly, after photographic shootings and picturing with Aeva-HE™, P1 was applied onto the whole face in Day 1 and P2 in Day 2, at standard amounts of 2 mg/cm^2. Immediately after product application, the faces of all subjects were re-captured while ensuring a good repositioning, adopting the most neutral expression with the Aeva-HE™ device. After photographic shooting, the face is cleaned with the same makeup removal. Before and after product application, images of all subjects were analyzed by the Aeva-HE™ V3 software.

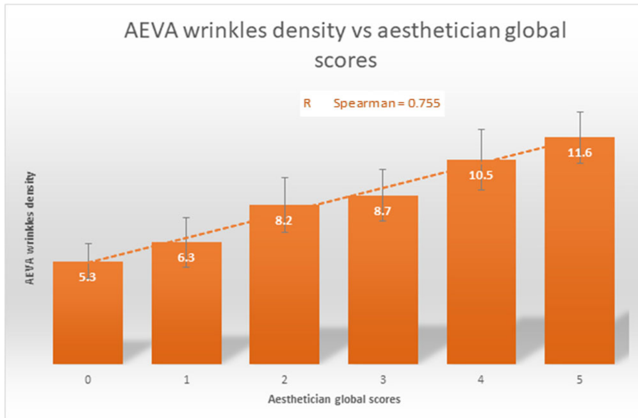

FIGURE 2 Wrinkles density as a function of the grading scores established by the aesthetician (mean ± C.I 95% confidence interval).

2.4 | Statistics

All statistics were performed using IBM® SPSS® Statistic version 23, and a $\alpha = 0.01$ level was considered a significant threshold. The normality of the data was checked using the Shapiro-Wilk normality test. Data were compared using the Tukey test when the analysis of variance show an age class effect. Comparing the effects of P1 and P2 was carried out under Anova analysis.

3 | RESULTS

3.1 | Global density of wrinkles versus aesthetician's scores

The wrinkle density is calculated by the ratio of detected features divided by the total surface of the face. Figure 2 illustrates the histogram of the average density of wrinkles as a function of aesthetician

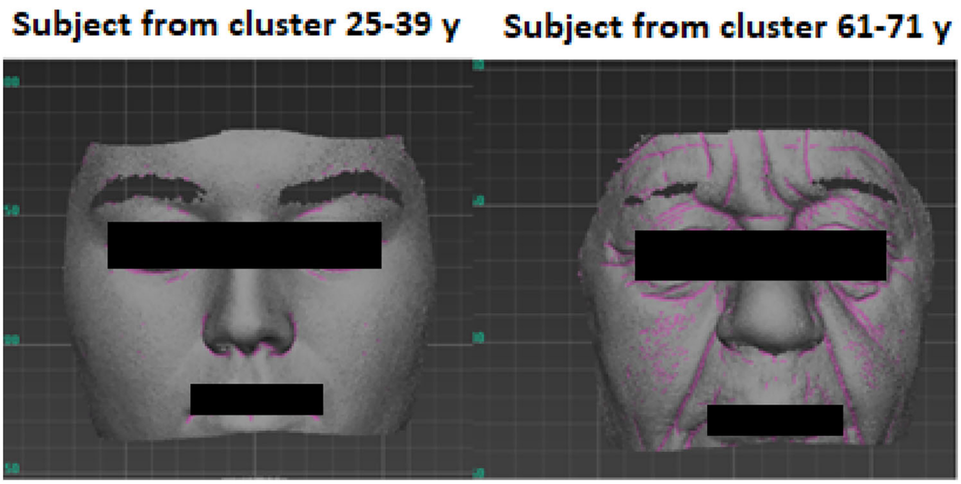

FIGURE 3 Illustrations of Aeva-HE pictures (wrinkles density) between two differently-aged women.

grading scores. A good correlation is observed (Spearman coefficient: 0.755). Of note, the finest lines detected by the Aeva-HE™ were not observed by the aesthetician.

3.2 | Crow's feet wrinkles parameters versus grading scores

Aeva-HE™ results were compared to judges scores established on Orion photos (crow's feet region). Correlation results for four parameters were the following: Sa (0.59), Stm (0.57), Volume (0.54), and mean depth (0.56). All parameters included, the data provided by Aeva-HE™ present a total correlation coefficient >0.54, Sa parameter seems to be the most correlated ($r = 0.59$) with the perception performed from standard photographs.

3.3 | Wrinkles density vs age

Figure 3 shows, as examples, the images provided by the Aeva-HE™ device between two differently aged women.

Data from full-face wrinkles yield to a global evaluation of aging signs as shown by Figure 4 which unsurprisingly illustrates a good correlation (Spearman correlation coefficient $r = 0.7$) between the density of wrinkles and the age of all subjects (N = 85). The five age clusters appear well separated.

3.4 | Differentiation of age clusters using Aeva-HE™ wrinkles parameters on facial zones

Seven zones were defined in each subject, as facial regions: crow's feet, glabellar, under eyes and cheek areas, left and right sides, as shown in Figure 5. The Valley thresholding method was used to detect wrinkles entities and to generate descriptive parameters such as volume (in mm^3), mean depth (in mm), area (mm^2).

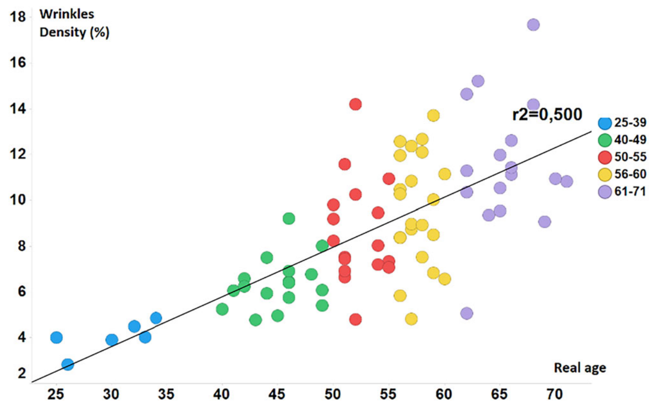

FIGURE 4 Wrinkles density (Aeva-HE data) as a function of age.

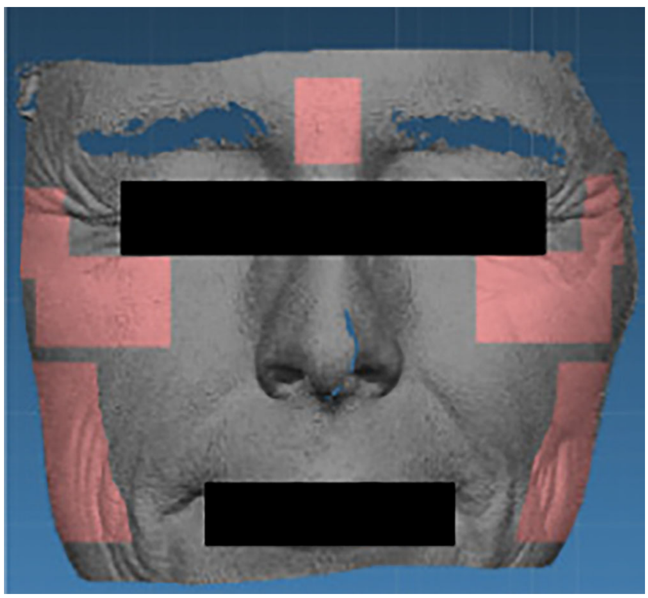

FIGURE 5 Extracted zones (in pink) in a 3D subject's face: Glabella, crow's feet, under eyes and cheek areas, left and right sides.

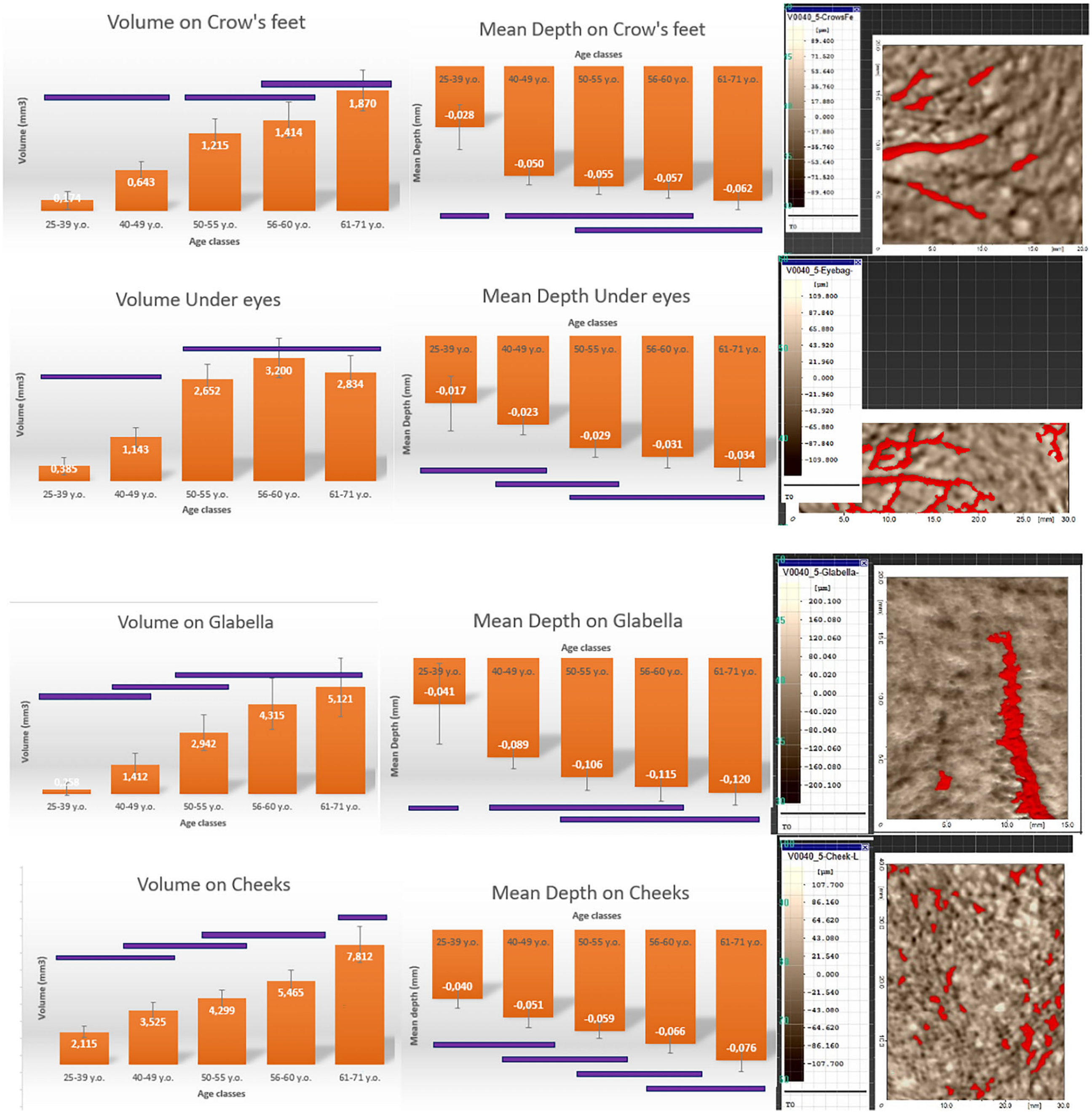

FIGURE 6 Results for, from up to bottom lines, Crow's feet, under eyes, Glabella and Cheek regions; and from left to right, statistic results (mean and confidence interval) on age clusters for volume, statistic results on age clusters for mean depth, (horizontal lines regroup classes with non-significant statistical results); example of wrinkles extraction from one subject (in red: wrinkles detection on the defined facial zones).

Results proved the ability of these parameters to separate the five age groups on four regions, left and right sides being merged in the same analysis. The volume parameter seems to be the most pertinent in significantly separating the younger class (25–49 y) from the older ones (50–71 y) for crow's feet and under eyes. A difference between the 61 and 71 y class and all other age classes is also observed for the cheek region. The mean depth distinguishes the 25–39 y class from the four other classes in the case of crow's feet and glabellar zones.

Figure 6 gathers, region by region, the statistic differentiations (mean ± C.I 95%, confidence interval) obtained, using volume and depth parameters. Non-significant differences for the other attributes and regions could be explained by some "noise" on the wrinkles segmentation which can occur during a slight facial motion.

3.5 | Effect of products on the crow's feet region

Figure 7 shows black and white images given by the texture camera of the Aeva-HE™ system of one subject before and after product

FIGURE 7 Aeva 2D images, left before and right after product application; on the same subject; from up to bottom P1 and P2.

application for both products, illustrating that the crow's feet region is the most smoothed area in both products.

The decreases of Wrinkles surface (in mm^2) and depth (in mm) immediately brought by the two tested products for the crow's feet region are expressed in Figure 8. The effect of P2 clearly appears more potent than the one brought by P1. The delta Area, mean depth, SR, and SA parameters are significantly different, the values of P2 being more than twice as those of P1.

4 | DISCUSSION

The present applied studies aimed at exploring the capacity of the recently developed imaging system, Aeva-HE™, in the testing and development of anti-aging products in routine. This device, of easy handling, allows a rapid establishment (<2 min) of most facial signs with high precision, yielding to quantitative values of wrinkles (Volume, Depth, Surface) present at different sites of the face. Consequently, focusing on a region of interest (ROI) could better discriminate some facial signs, the causality of which (chronological, sun-induced) may differ and thus may better orientate the mode of actions of the products. Unsurprisingly, the increased severities of all wrinkles that this new equipment provided appeared well correlated with age. A further objective would in theory assess the differences between the perceived age of the subjects versus their real age. The latter was shown in many cases rather different from the real age (seen "older or younger ..") in previous studies.[20,23,26] Whatsoever, the global severity of most wrinkles was found in very good agreement with the gradings given by the aesthetician, using the referential Skin aging Atlas. The correlation of the data between Aeva-HE™ device and those provided by the naïve panel, although significantly correlated, were found of a lower statistical weight, knowing that this panel had to assess the severity of wrinkles from standard 2D photographs, a projection of what could be observed briefly in real life. However, it has to be kept in mind that such observation is deeply influenced by the lighting and angle of view. In addition, the human vision presents inherent limits in the detection of tiny details such as fine lines that were rapidly detected by the Aeva-HE™ system. From a development viewpoint, this device seems of a

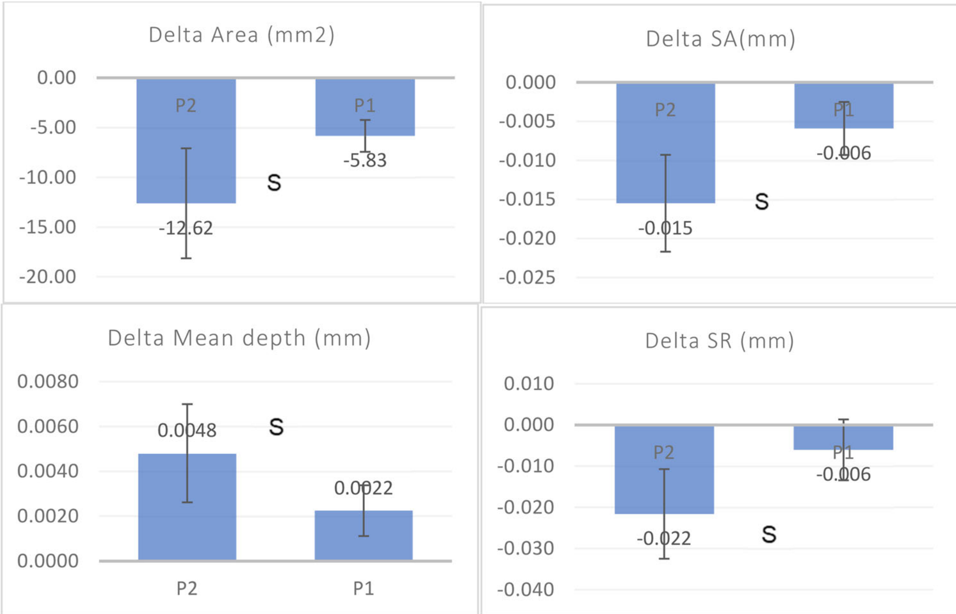

FIGURE 8 Product differentiation on Aeva parameters. S: Statistically significant difference ($p < 0.05$).

great help in the evaluation of the efficacy of anti-aging products often recorded for longer times (months). Here, tensile products were voluntarily selected with regard to their immediate camouflaging effect. The applied study carried out here indicates that such action can be assessed not only rapidly but requires a limited number of subjects, taking the facial aspect at D0 (prior application) as control to best mimic the daily life situation. To summarize, the use of this device, based on fringe projection, seems a key and additional element within the arsenal of various technologies that deal with the skin aging process, in both basic and applied research.

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CONFLICT OF INTEREST STATEMENT

Ayet Shaiek, Muriel Monot, Virginie Rubert, Celine Cornillon, Marco Vicic, Geraldine Decocq and Frederic Flament are employees of L'Oréal group.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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