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ORIGINAL CONTRIBUTION

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Appearance of aging signs in differently pigmented facial skin by a novel imaging system

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Abstract

Background: Facial wrinkles, pores, and uneven skin tone are major beauty concerns. There is differential manifestation of aging signs in different ethnic groups. In this regard, studies on Black Africans from the African continent are scarce.

Objective: To investigate facial wrinkles, pores, and skin tone in Black African women from Mauritius Island and elucidate the differences to Caucasian women from France.

Methods: Facial images were taken using the imaging system ColorFace®. Wrinkles and pores were measured by their length, depth, surface, volume, and number; for skin tone, we measured $L^*a^*b^*$ and calculated ITA, $IWA_{Newtone}$, and color homogeneity.

Results: We found good correlations of wrinkle and pore scores with expert ranking done on ColorFace® images for Caucasians (Spearman's rho = 0.78 and 0.72) and Black Africans (Spearman's rho = 0.86 and 0.65). Caucasians showed more advanced facial signs of aging than Black Africans. Exceptions were vertical lines on upper lip and the depth of pores which were greatest for the Black African subjects. Black Africans had higher heterogeneity scores indicative for uneven skin tone. Luminance (L^*) was significantly higher in Caucasians but a^* and b^* values were significantly higher in the Black African subjects. ITA and $IWA_{Newtone}$ were significantly higher for Caucasians.

Conclusions: The high correlation between expert ranking and wrinkle and pore measurements prove ColorFace® a valid imaging system to study skin aging. Our results show that Africans from the African continent show delayed signs of aging compared to Caucasians. Some exceptions suggest that ethnic differences in facial aging are a complex phenomenon.

KEYWORDS

anti-aging, Black African skin, Caucasian skin, ColorFace®, Ethnic, facial imaging, pores, skin tone, wrinkles

1 | INTRODUCTION

Facial skin aging is of global concern as it is linked to beauty, social acceptance, and status.[1,2] It was identified as one of the most important challenges in global skin health by the International League of Dermatological Societies.[3] However, the perception and manifestation of skin aging differ for different ethnicities.[4-7]

Behavioral habits together with underlying constitutive ethnic skin differences can lead to differences in skin condition and appearance. Contributing factors may be due to differences in structure, composition, architecture, and function of skin of various ethnicities.[8-17] In addition, the aging changes among different ethnic groups may be due to variability in environmental influences depending on geographical location[18,19] and these together with behavioral habits are considered to be important aging factors which have been coined the skin aging exposome.[20,21]

To tackle and counteract ethnic-specific aging phenomena and the resulting unwanted skin conditions, understanding ethnic differences in skin architecture and signs of aging is key. It is generally accepted that the onset of aging begins earlier in less pigmented compared to more darkly pigmented skin.[22,23] One obvious reason is the higher intrinsic UV-protection of darkly pigmented skin, but the molecular and physiological mechanisms are complex.[10,22,24,25] However, key visual consumer concerns are the increasing presence of wrinkles,[26] pores,[11] sagging skin,[27] uneven skin tone,[28] and pigment spots[29] and/or dry rough skin.[30,31] Along those lines, common facial skin aging parameters assessed by dermatologists include surface roughness, wrinkles, mottled hyperpigmentation, lentigines, laxity, and sallowness that are all related to the micro-inflammatory status of skin.[32-36]

Wrinkles are classified into crinkles, glyphic wrinkles, and linear facial wrinkles.[37] Linear facial wrinkles are subdivided into horizontal frown lines on the forehead, crow's feet radiating from the eye's lateral edge, creases from the corner of the mouth to the nose (mouth frown lines and nasolabial folds), and creases on the upper and lower lips.[38] However, many other classifications are described.[39-41] Regarding ethnicity, East Asian females are reported to have the smallest wrinkles, followed by African Americans, Latinos, and Caucasians. The differences in the appearance of wrinkles between African American and Caucasian females are consistent with the earlier studies of Grimes *et al*.[42]

The presence of unwanted and conspicuous skin pores contributes to the appearance of aged skin. Pores are defined as any opening in the skin wider than 0.02 mm^2.[43] They are classified into three different subcategories, namely visible, enlarged, and blackhead embedded pores.[44] Invisible pores also exist and represent the openings of the sweat gland apparatus, while the various visible pores represent enlarged empty funnel-shaped or cylindrical horny impacted openings of pilosebaceous follicles.[45] One of the underlying mechanisms of the cause of the appearance of facial pores is decreased facial elasticity in the presence of hydrodynamic pressure on the pilosebaceous duct opening by sebum.[44] Nevertheless, East Asian subjects (Japan, China, and Korea) are reported to have consistently low numbers of skin pores.[9,23]

Ethnic differences between African American and Caucasian females in the appearance of wrinkles are consistent between studies but not the differences in the number of skin pores. This may be due to methodological differences[46-48] especially as pore volume is reported to be the parameter most highly correlated with the visual assessment of skin pores.[49]

Facial skin color distribution has also been found to correlate with beauty, health, and attractiveness. Specifically, homogeneous skin color distribution was rated younger and more attractive than inhomogeneous skin color distribution of elderly people in both lighter and darker skin types.[7,28,50] Skin homogeneity is inversely correlated with age,[51] manifests as, for example, solar lentigines or age spots due to derailed activity and distribution of pigment cells, and is hence a visible sign of photoaging. Other parameters of age-associated skin tone inhomogeneity are the distribution of skin redness and yellowing of the skin.[52] Abnormalities in UV-induced rete ridge formation and associated blood vessels leading to skin redness and yellowness by the accumulation of advanced glycation end products contribute to this.[53-55] However, a recent study on Japanese women found a positive correlation between cigarette smoking and darker skin tone by increased melanin and erythema indices.[56] In all these studies, skin color was assessed using the red, green, and blue (RGB) color space.

To our knowledge, there are no direct comparisons of skin wrinkles, pores, and skin tone in Black African subjects compared with Caucasian subjects. Thus, we chose to compare these parameters in African females living in Quatre-Bornes, Republic of Mauritius with Caucasian females living in Lyon, France. Equally, we report using a new methodology, the ColorFace® imaging system, to capture digital facial images that is equipped with custom software for the analysis of pores, wrinkles, and skin tone. This device allows the acquisition of full-face images of the volunteers without modifying the shape of facial wrinkles and pores.

2 | MATERIAL AND METHODS

2.1 | Subjects and study design

This cross-sectional study was conducted in accordance with the Declaration of Helsinki Principles. Written and informed consent was obtained from all participants before enrolment.

Ninety-six (96) healthy female volunteers participated in this observation which took place between September to November 2015. Weather conditions during the study were in Lyon, France: min 11.9°C, max 22.1°C, rainfall 138 mm and in Quatre-Bornes, Mauritius: min 21.8°C, max 28.1°C, rainfall 79 mm.

There were two ethnically different groups of Caucasian women living in Lyon, France (n = 50, 46.2 ± 3.6 years old, Fitzpatrick skin phototype II-III[57]) and Black African women living in Quatre-Bornes, Mauritius (n = 46, 56.5 ± 4.5 years old, Fitzpatrick skin phototype V-VI[57]). Noninclusion criteria included pregnant or nursing women, menopausal women, women with facial cutaneous pathologies like eczema, women who had injections on the face, for example, botulinum toxin or fillers. Before the start of the study, subjects were

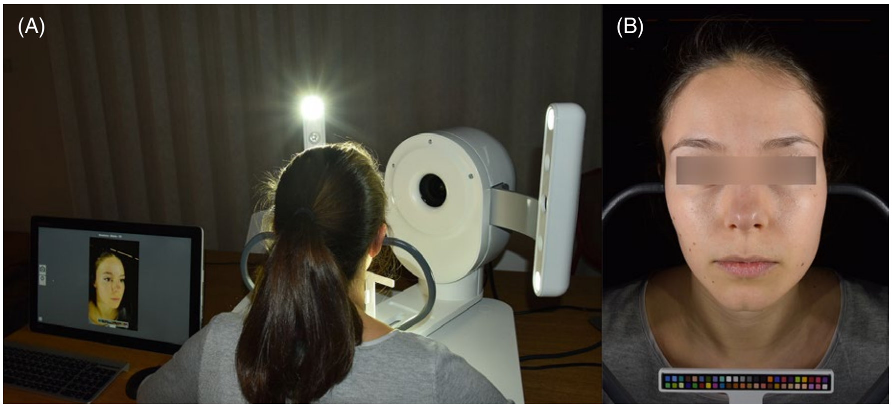

FIGURE 1 Image acquisition. Photographing using Colorface® (A) and an example of image acquire in "No-filter" mode (B). One can see the absence of facial deformation due to ear support and the color chart for color consistency purpose

asked to refrain from the use of anti-aging products for 1 month and any cosmetic products for 7 days.

Upon arrival at the laboratory, the subject's skin free of makeup was cleansed with a cotton pad soaked with water at ambient temperature and allowed to dry for 30 minute. Subjects were acclimatized for 30 minute before any measurements were performed in a room at a 22 ± 2°C and 45 ± 10% relative humidity. Expert grading of skin wrinkles underneath the eye, at the crow's feet area, and on the forehead together with skin pores was performed using the 9-point scales of Bazin®.[58] Parameters had a minimum acceptance grading of 2-5 for under eye wrinkles, 1-5 for crow's feet wrinkles, 1-6 for forehead wrinkles, and 1-5 for visible pores.

Self-assessment of normal, dry, greasy, or combination skin was also performed (Table 1).

2.2 | Image acquisition

High-resolution full-face photographs were taken using a ColorFace® (Figure 1) (Newtone Technologies, Lyon, France). This device allows highly reproducible acquisition using white LED lights with a color rendering index of 87%, a 24 M pixels built in DSLR camera, and a computer vision-based repositioning system with acquisition software for data recording and storage. Three photographs (4000 × 6000 pixels in JPEG fine format (lowest compression)) were taken successively with the eyes lightly closed from prefixed angles (left and right oblique angles at 45° and full face at 0°). Standard light images were taken to analyze wrinkles, and parallel-polarized light images were taken to analyze pores. The possible environment lighting variations between acquisitions leading to color variations between images were corrected using a RAL standardized color chart and a built-in color consistency algorithm. Images were analyzed by a specifically designed software to detect wrinkles, pores, and skin tone. Software efficiency was assessed by correlating results with visual ranking from two experts.

TABLE 1 Number of volunteers with respective skin type

Skin type	Black Africans	Caucasians
Dry	0	10
Normal	0	7
Combination	31	33
Greasy	15	0

2.3 | Image analysis of wrinkles

To extract only wrinkles of a distinct facial site, a user-defined region of interest (ROI) was identified around the sites on each image for each subject (forehead, crow's feet, mouth frown, upper lip, and nasolabial folds). The ROI extracted area had the same size for all subjects but was different for each site: 2081 × 997 pixels (~83 × 40 mm) for the forehead, 1328 × 1386 pixels (~53 × 55 mm) for the eye, 455 × 561 pixels (~18 × 22 mm) for the mouth frown, 983 × 478 pixels (~39 × 19 mm) for the upper lip, and 694 × 1122 pixels (~28 × 45 mm) for the nasolabial folds. On the obtained image, we defined an analysis area to keep only the wrinkles on the site of interest. Note that this area had the greatest possible size (Figure 2A,C,E,G,I).

Wrinkle segmentations were obtained using a segmentation pipeline including wrinkle highlights, segmentation, and false-positive cleaning (Figure 3). To highlight wrinkles, pixel values were converted to a specific grayscale accentuating wrinkles and mitigating other skin imperfections (Figure 3B). Overall, facial shades were removed using a low-frequency cut filtering[59] (Figure 3C). Segmentations were performed using a Hessian-based vesselness filtering[60] combined with thresholding (Figure 3D). This allowed elongated structures to be identified within the region of interest (Figure 3E). False-positive cleaning was performed using morphological mathematics criteria[61] with a minimum wrinkle size of 6 mm and elongation factor greater than 5 (length/width ratio) (Figure 3F). Results are shown in Figure 2B,D,F,H,J.

2.3.1 | Wrinkle lengths (mm)

It is necessary to define wrinkle length since at this stage wrinkles are defined as 2D shapes obtained from the segmentation. To perform this measurement, the 2D shape skeleton, defined as the central element of unit width, is extracted at each point of segmented wrinkles (Figure 4). Quantification of the length of this skeleton will define the length of wrinkles at a distinct site. The length matches with the number of pixels of the skeleton. This value is converted into millimeters using a known scale in the image. When the length decreases, wrinkles are less visible.

FIGURE 2 Image acquisition of the various facial sites and determination of regions of interest to measure wrinkles and pores: A-B, forehead wrinkles, C-D, crow's feet, E-F, nasolabial folds, G-H, mouth frown lines, I-J, vertical lines on upper lip, K-L, pore area on cheeks, M, skin tone analysis. For details, see Material and Methods section. In brief, A, C, E, G, I, K, and M represent regions of interest. B, D, F, H, J, L, and M represent actual measurement area in each region of interest

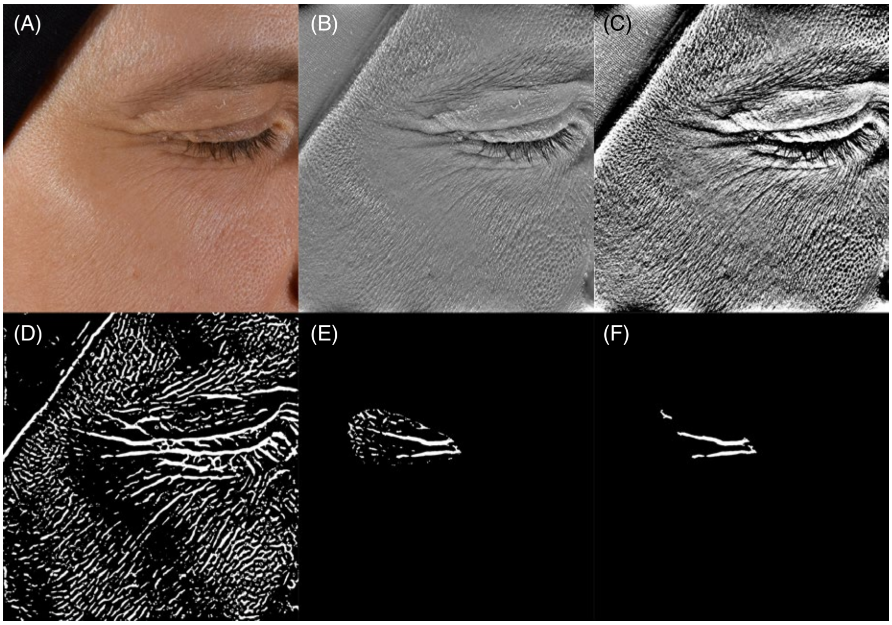

FIGURE 3 Wrinkle segmentation starting from the original image (A), a specific grayscale is used (B) and shadings are removed (C). After thresholding (D) and masking by the region of interest (E), false positives are removed by mathematic morphology (F) to obtain the final segmentation

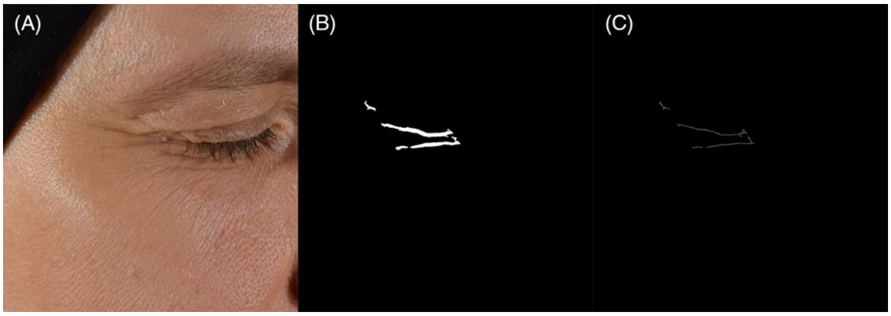

FIGURE 4 Wrinkle length value is computed from the original image (A) after segmentation (B). The skeleton is extracted as the central structure of unitary width (C) allowing to obtain the wrinkle length

2.3.2 | Wrinkle surface area (mm^2)

Using the segmented images, it was possible to calculate the surface area of wrinkles. For this, we determined the number of segmented pixels on the image and convert this value into millimeters using a known scale in the image. A decrease in the size of wrinkles results in a decrease in the surface area.

2.3.3 | Wrinkle conspicuous depth (arbitrary units)

Using the segmented images, we could estimate the depth of wrinkles as the contrast between the pixel values calculated on wrinkles and the pixel values calculated on the region surrounding wrinkles. The higher this contrast is, the more visible the wrinkles are.

2.3.4 | Wrinkles conspicuous volume (mm^2 × arbitrary units)

We calculated the conspicuous volume of wrinkles: volume = surface*depth. This is not a true mm^3 volume but an apparent volume.

2.4 | Image analysis of pores on cheeks

We defined the ROI adjacent to the nasolabial fold (Figure 2K,L) on each image for each subject. The extracted area was 946 × 1203 pixels (38 × 84 mm) and had the same size for all subjects similar to that for the wrinkle measurements. Segmentation pipelines, similar to the one defined for wrinkles, were used (Figure 5). To highlight pores, pixel values were converted to a specific grayscale accentuating pores and mitigating other skin imperfections (Figure 5B). Overall facial shades were removed using a low-frequency cut filtering[59] (Figure 5C). We applied a "K-Means" algorithm to optimally partition the grayscale image in five classes based on the image histogram and we kept only the darkest classes which mainly represents pores (Figure 5D). Only the structures in the region of interest are kept (Figure 5E). To remove false positives, we established the following morphological criteria on pores: Pores were defined by a maximum width (100 pixels = 4 mm) and pores had a length/width ratio smaller than 5 (Figure 5F). After having applied all these treatments, we could apply the mask of segmented pores on original images (Figure 2L).

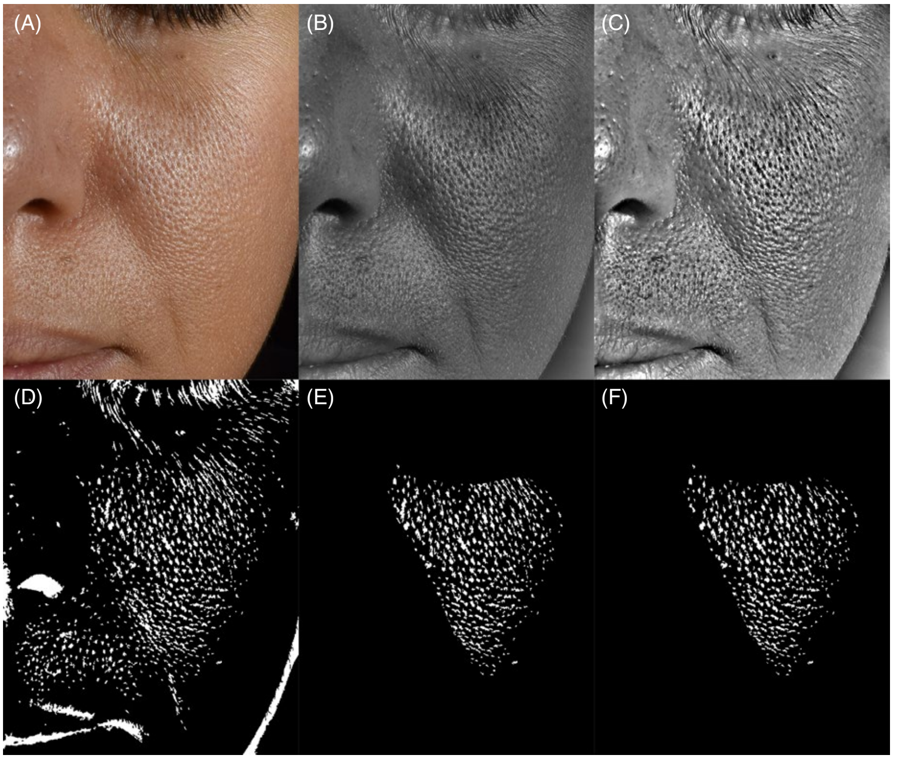

FIGURE 5 Pore segmentation starting from the original image (A), a specific grayscale is used (B) and shadings are removed (C). After k-means algorithms used to keep darker structures (D) and masking by the original region of interest (E), false positives were removed by mathematic morphology (F) to obtain the final segmentation

2.4.1 | Number of pores

This number is defined as the number of connected components in the segmented image.

2.4.2 | Surface area of pores (mm^2)

Using the segmented images, it was possible to calculate the surface area of conspicuous pores. For this, we determined the number of pixels on the segmented images pores and convert this value into millimeters using a known scale in the image.

2.4.3 | Depth of pores (arbitrary unit)

It was possible to estimate the depth of pores which is the contrast between the pixel values calculated on pores and the pixel values calculated on the region surrounding pores. The higher this contrast is, the more visible pores are.

2.4.4 | Volume of pores (mm^2 × arbitrary unit)

It was possible to calculate the conspicuous volume of pores as follows: Volume = surface*depth. Like the wrinkle analysis, this is not a true mm^3 volume but an apparent volume.

2.5 | Image analysis of color

We defined the ROI adjacent to the cheek on each image for each subject (Figure 2M). The extracted area fitted the size of the cheek of each subject. The average cheek surface was 1.05 MPixels (~1680 mm^2). For each pixel, RGB colors were converted to CIELab colors following CIE recommendation.[62] CIELab L^*, a^*, and b^* of the ROI is computed by averaging the L^*, a^*, and b^* of all the pixels in the ROI.

ITA, which stands for individual typological angle, is a measure of skin pigmentation degree[63] using skin luminance (L^*) and yellowness (b^*), and is defined according to the following formula:

$$\mathrm{ITA} = \arctan\left(\frac{L^* - 50}{b^*}\right)$$

A decrease of the pigmentation results in an increase of ITA.

The $\mathrm{IWA}_{\mathrm{Newtone}}$ is an index developed by Newtone Technologies to evaluate the whiteness of the skin that takes into account the amount of melanin (like ITA) and hemoglobin. It is defined as follows:

$$\mathrm{IWA}_{\mathrm{Newtone}} = \arctan\left(\frac{L^*}{C}\right) = \arctan\left(\frac{L^*}{\sqrt{a^{*2} + b^{*2}}}\right)$$

where L^*, a^*, and b^* are the three color components of the system defined by the International Commission of Lighting (CIE). C (Chroma) is the second component of the color defined by the International Commission of Lighting (CIELCH). A whitening effect results in an increase of this parameter.[64]

For a given ROI, homogeneity is defined as the degree of color (L^*, a^*, b^* values) dispersion within this ROI in regard to the average L^*, a^*, b^* value (μL, μa, and μb) of this same ROI. It is defined as follows:

$$H_{76} = \frac{1}{N}\sum_i \sqrt{(L_i - \mu L)^2 + (a_i - \mu a)^2 + (b_i - \mu b)^2}$$

When a region of interest is homogenous, H_{76} has a value of 0 and increases with color dispersion, hence heterogeneity.[64,65]

2.6 | Statistics

All data were collected in Microsoft Excel 2013. The samples were checked for normality using the Shapiro-Wilk test (https://sdittami.altervista.org/shapirotest/ShapiroTest.html, link copied 6th February 2017[66]). A positive result at $P < 0.05$ was considered displaying normality. In case both groups showed a normal distribution, the *t* test for unpaired samples was used to calculate *P*-values. In case one or both ethnic groups did not show a normal distribution, the Mann-Whitney *U* test (https://www.socscistatistics.com/tests/mannwhitney/, link copied 6th February 2017[67]) was used to calculate *P*-values.

2.7 | Expert ranking

Expert ranking on crow's feet and pores on images was performed to correlate computed data with visual assessment of images. The ranking was performed using series of paired comparison tests procedure (also called 2-AFC test for 2-Alternative forced choice, ISO 5495:2005). These tests allow to rank a large number of samples by comparing all the sample pairs. A Spearman's rho coefficient[68] was computed to correlate the ranking with the values obtained by the image analysis. This coefficient is especially designed to evaluate rank correlation.

3 | RESULTS

3.1 | Correlation between visual ranking and measurements

Analysis of wrinkles and pores was assessed by visual ranking of two experts, and correlation coefficient was computed to conspicuous surface. There is a strong correlation for Caucasian ethnicity measurement ($r = 0.78$ for crow's feet wrinkles and $r = 0.72$ for pores). This correlation is similar for African ethnicity on crow's feet wrinkles ($r = 0.86$) but a little weaker on pores ($r = 0.65$).

3.2 | Effect of ethnicity on forehead wrinkles

Measuring length, surface, and volume of forehead wrinkles, we found no difference between Caucasian and Black African volunteers (Figure 6A,B,D). There seemed to be a trend towards less wrinkle volume in Black Africans, but this was not significant. However, measuring conspicuous depth of forehead wrinkles we found a

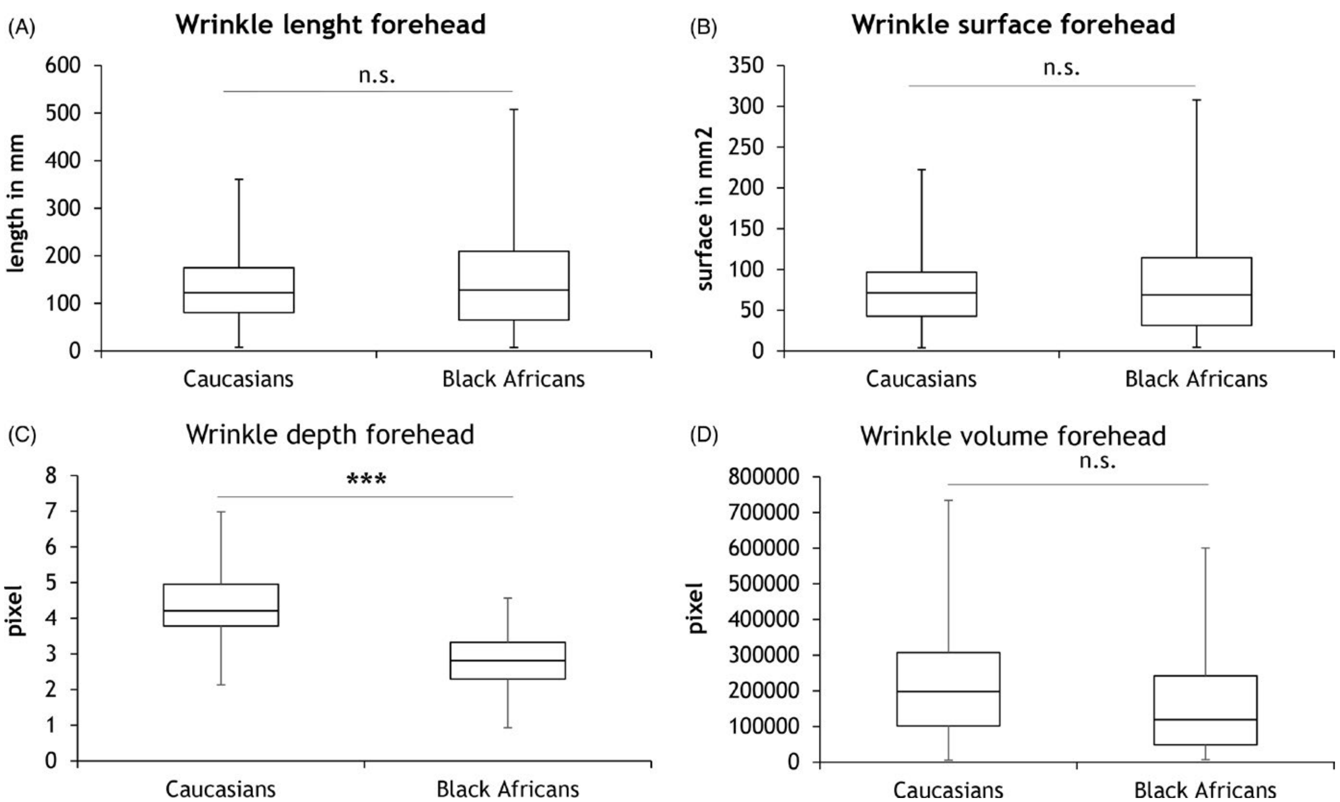

FIGURE 6 Wrinkles on forehead in Caucasians and Black Africans. While the difference in wrinkles on forehead measured by length (A), surface (B), and volume (D) was not significant, depth (C) yielded a significant result showing deeper wrinkles in Caucasians. ns, not significant; $^{***}P < 0.001$ by Mann-Whitney *U* test (A, B, D) and Student's *t* test (C)

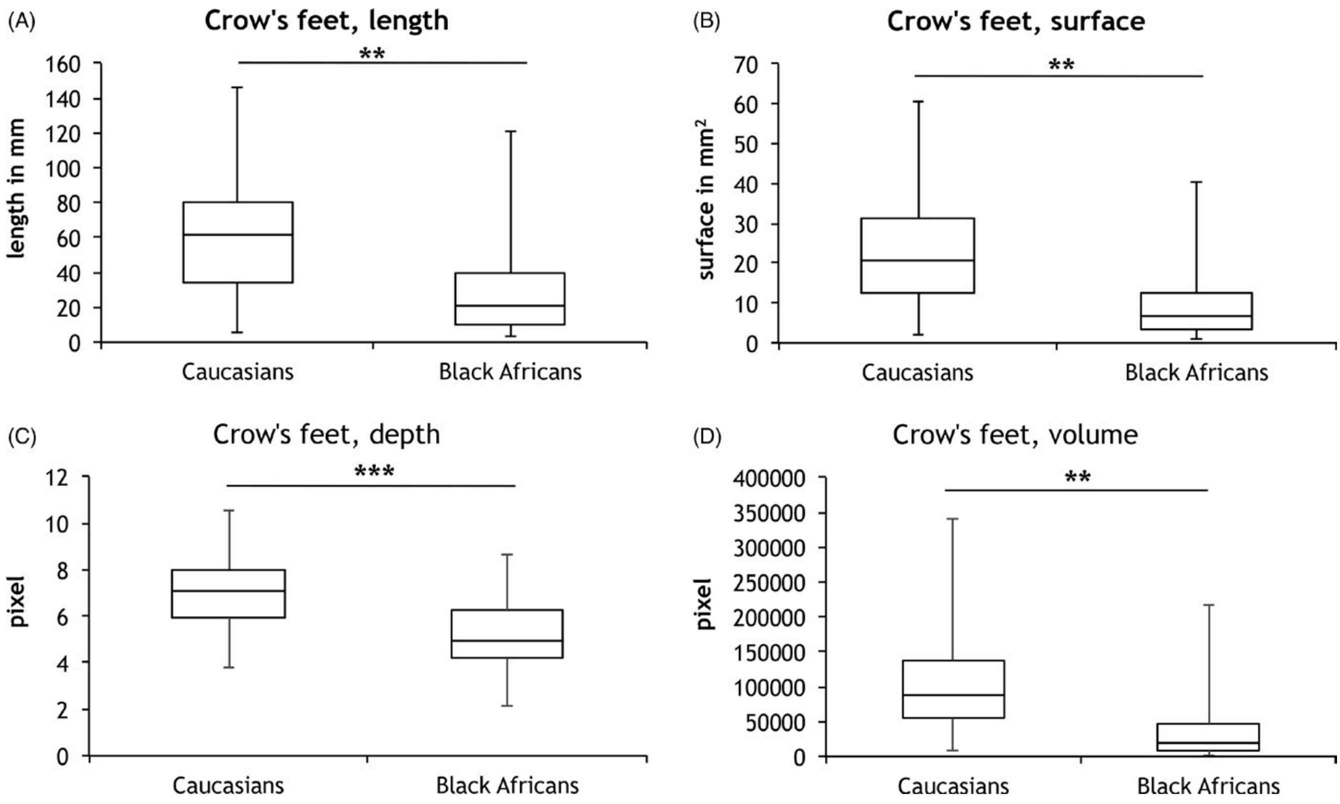

FIGURE 7 Crow's feet wrinkles in Caucasians and Black Africans. All measured parameters yielded significantly more crow's feet in the Caucasian cohort. ** $P < 0.01$ by Mann-Whitney *U* test (A, B, D), and *** $P < 0.001$ by Student's *t* test (C)

significant decrease for Black African compared to Caucasian volunteers ($P < 0.001$; Figure 6C).

3.3 | Effect of ethnicity on crow's feet

Black African volunteers showed significantly less advanced crow's feet wrinkles than Caucasian volunteers ($P < 0.01$; Figure 7A,B,D). This was even more pronounced for depth ($P < 0.001$; Figure 7C).

3.4 | Effect of ethnicity on mouth frown lines

Measuring length of mouth frown lines, we did not find any difference between Caucasian and Black African subjects (Figure 8A). However, examining the wrinkle surface and volume parameter there was a significant increase in Caucasian subjects compared with the Black African subjects ($P < 0.01$; Figure 8B,D). This increase was even more pronounced when we were measuring depth of mouth frown lines ($P < 0.001$; Figure 8C).

3.5 | Effect of ethnicity on vertical lines on upper lip

Length, surface, and volume of vertical lines on upper lip revealed significantly more advanced aging in African subjects than in Caucasian subjects ($P < 0.01$; Figure 9A), which was even increased when measuring surface and volume ($P < 0.001$; Figure 9B,D). However, examining depth showed no difference between the two ethnic groups (Figure 9C).

3.6 | Effect of ethnicity on nasolabial folds

All four measured parameters length, surface, depth, and volume yielded bigger nasolabial folds in Caucasian compared to Black African volunteers ($P < 0.01$; Figure 10A-D).

3.7 | Effect of ethnicity on pores on cheeks

There were less pores in terms of number surface, and volume for Black African volunteers ($P < 0.001$; Figure 11A,B,D). Surprisingly, Black African volunteers had deeper pores than Caucasian volunteers ($P < 0.01$; Figure 11C).

3.8 | Effect of ethnicity on skin color characteristics

As expected Black Africans had lower scores for L^* (29 vs 43) and ITA (−34 vs −13) values corresponding to their darker skin type than the Caucasians (Figure 12). Interestingly, both a^* for redness and b^* for yellowness were slightly but significantly greater in the Black African group than in the Caucasian group (a^*: 22 vs 21; b^*: 30 vs 26; both $P < 0.001$). Presenting a new color parameter $IWA_{Newtone}$, which includes the a^*values in addition to L^* and b^* as in the ITA parameter, we found a significantly higher score for the Caucasian group. This

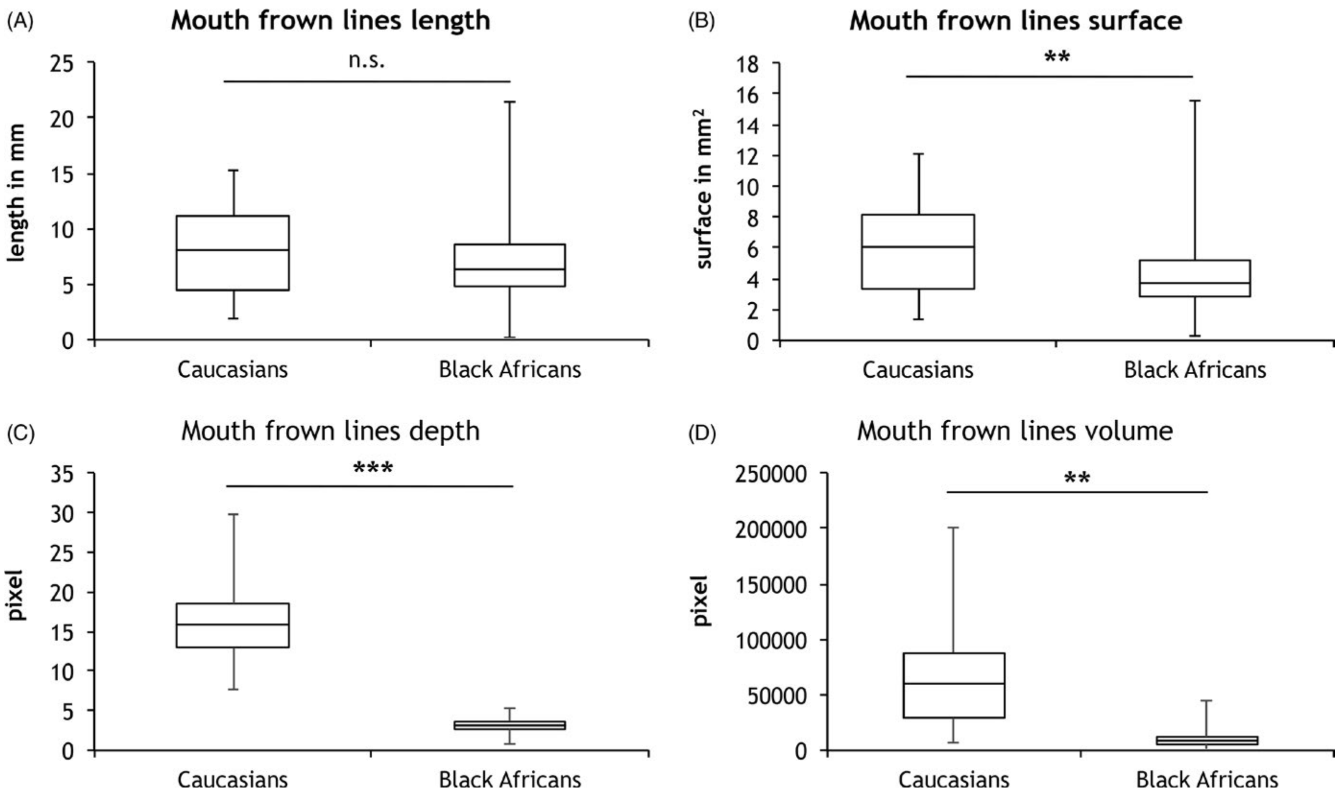

FIGURE 8 Mouth frown lines in Caucasians and Black Africans. Except for length of mouth frown lines which was not significantly different in Caucasians vs Black Africans (A), all other parameters yielded significantly higher scores for mouth frown lines in Caucasians (B, C, D). ns, not significant; $^{**}P < 0.01$ by Mann-Whitney *U* test (A, B, D); $^{***}P < 0.001$ by Student's *t* test (C)

is due to the higher L^* values for the Caucasians. However, the delta $IWA_{Newtone}$ between the Black Africans and the Caucasian subjects is smaller than for the ITA values (14.74 vs 21.58) taking into account the higher a^* and b^* values for the Black African subjects. We hence propose $IWA_{Newtone}$ a new and more accurate parameter for skin color assessment. Concerning skin color homogeneity, the Black African group had a more heterogeneous color distribution than the Caucasian group (Figure 13; $P < 0.001$).

4 | DISCUSSION

In the present study, we investigated the appearance of facial wrinkles and pores in two cohorts of female Caucasian and Black African subjects from France and Mauritius, examining various mathematically calculated parameters from digitally captured images. These were length, surface, depth, and volume for wrinkles, and number, surface, depth, and volume for pores, as well as $L^*a^*b^*$, ITA, $IWA_{Newtone}$, and heterogeneity for skin color. The calculations were based on image analysis using the ColorFace® system developed by Newtone Technologies. We found crow's feet wrinkle measurement versus ranking correlations of $r = 0.78$ for Caucasians and $r = 0.86$ for Black Africans. In a recent study on Caucasians looking at crow's feet, images taken with a Nikon D7000 camera and correlated with SWIRL-grading similar *r*-values for wrinkles on various facial sites between 0.74 and 0.82 were recorded[47] and again others found a correlation between digitally measured crow's feet area in Caucasian women and expert grading done by two experts of 0.81 (Spearman's correlation coefficient).[69] In addition, our correlation for pore calculations versus expert ranking ($r = 0.72$ for Caucasians and $r = 0.65$ for Black Africans) was in line with a recent study where a correlation between expert grading and Dermascore+® measurements of $r = 0.75$ was calculated[70] for Caucasians. With respect to skin color, we found higher L^* scores for the lighter skin type than for the dark skin type corresponding well with the ITA values. Comparing these values with the reported values in Del Bino *et al*,[71] we are also well in line. However, compared with a multi-ethnicity study by de Riga *et al* our values are below what was measured there by a device called Chromasphere®[52] showing the difference between diffuse lighting used in the Chromasphere and direct lighting used in the ColorFace. Concerning a^* and b^* values, we found small but significant higher values for both a^* and b^* in the Black African subjects. For the b^* values, this is similar to the previous comparison of de Rigal *et al* with African American subjects and Caucasian subjects.[52] Those results validated our method using the novel imaging device ColorFace® suggesting that it yielded relevant and meaningful results.

In the literature, differences in the appearance of wrinkles and pores are reported between African American and Caucasian subjects, albeit with the data on skin pores being inconsistent between two studies. However, as far as we are aware there are no reports

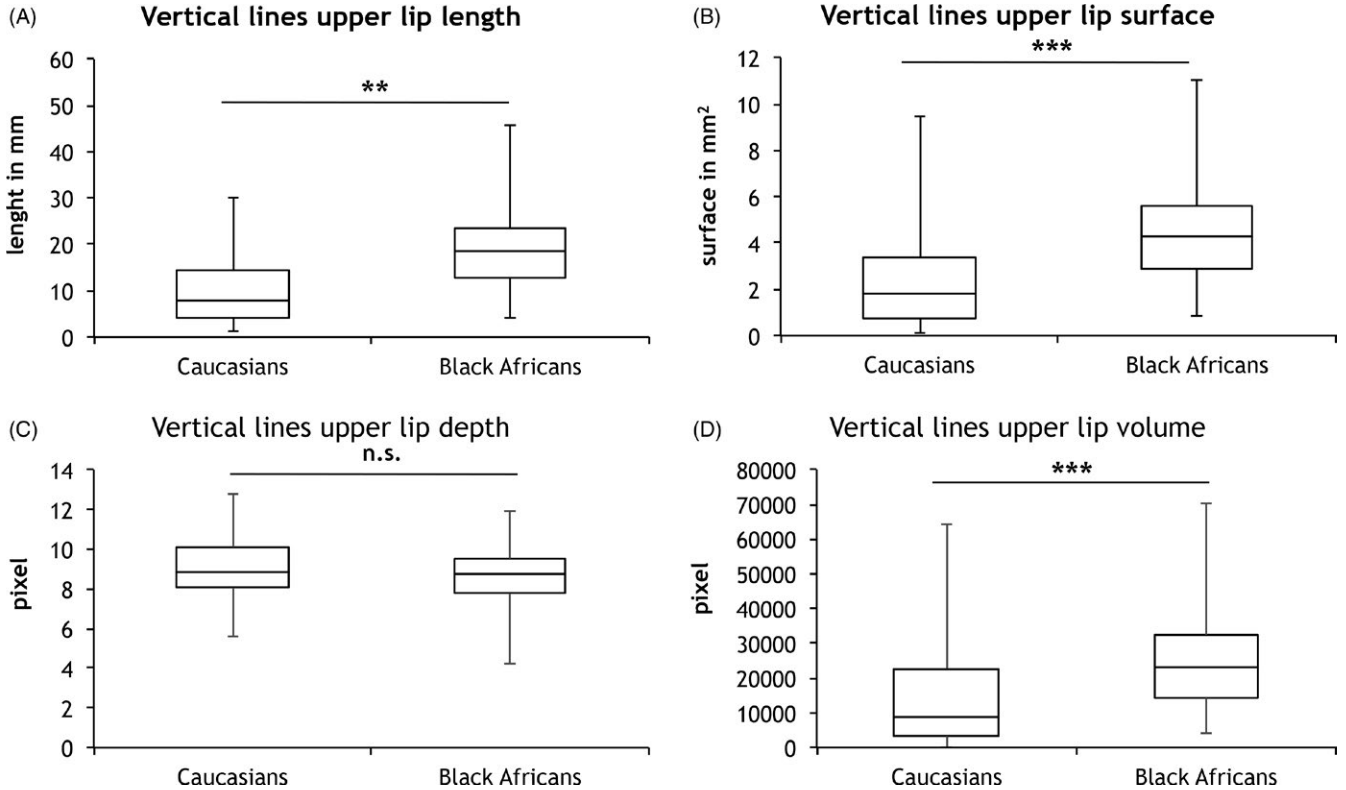

FIGURE 9 Vertical lines on upper lip in Caucasians and Black Africans. The three parameters length (A), surface (B), and volume (D) yielded significantly higher scores for the Black African cohort. However, depth (C) was not significantly different with a small trend towards deeper lip lines in Caucasians. ns, not significant; $^{**}P < 0.01$; $^{***}P < 0.001$ by Mann-Whitney *U* test (A, B, D) and Student's *t* test (C)

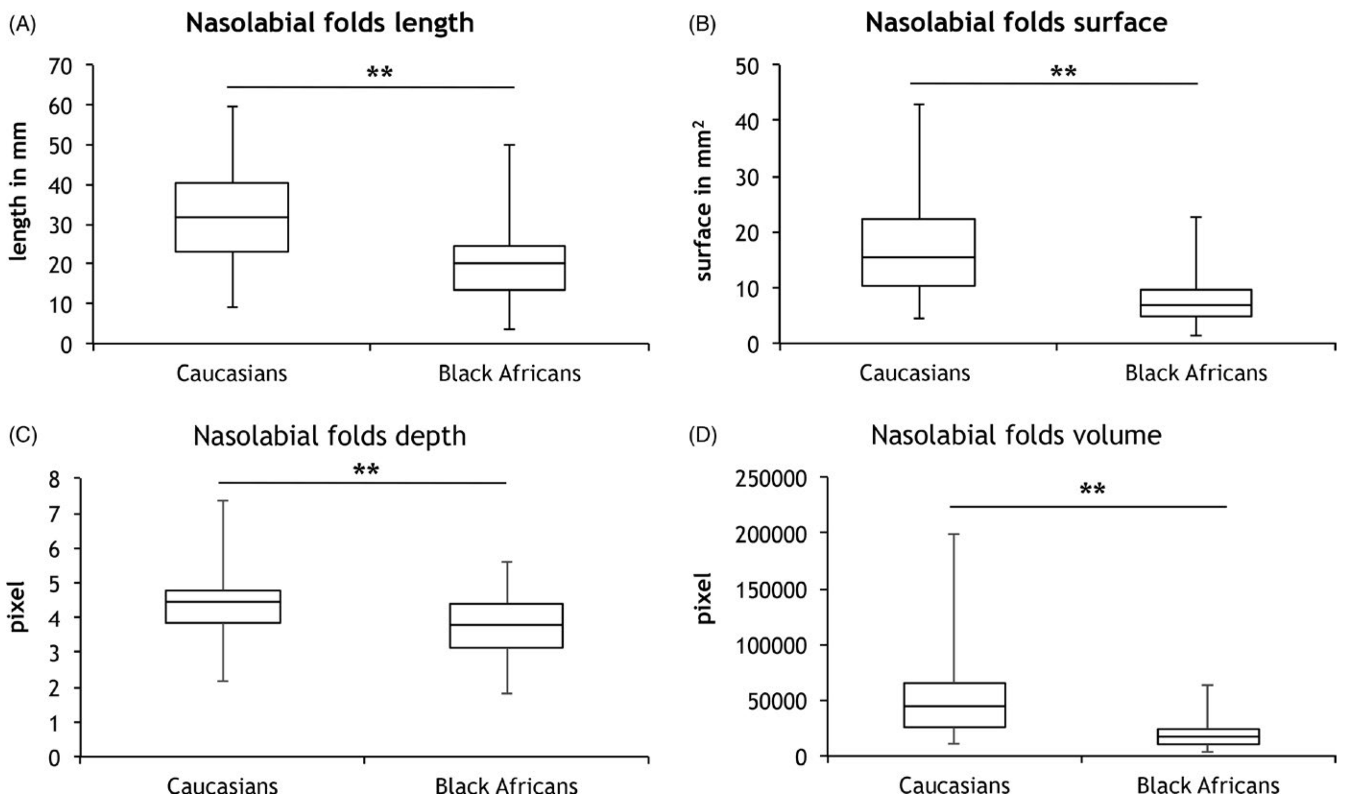

FIGURE 10 Nasolabial folds in Caucasians and Black Africans. All measured parameters yielded significantly increased values in the Caucasian cohort. $^{**}P < 0.01$ by Mann-Whitney *U* test

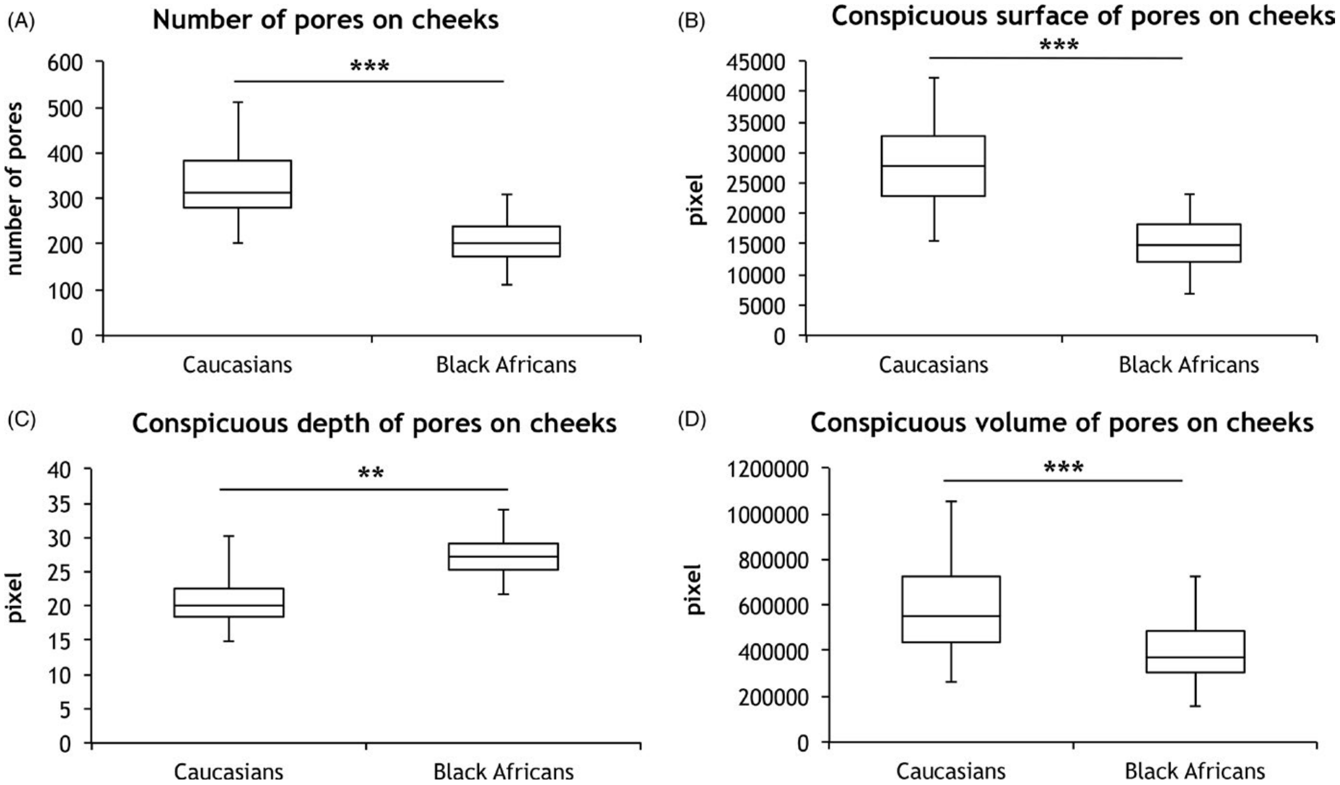

FIGURE 11 Pores on cheeks in Caucasians and Black Africans. While measurement of number (A), surface (B), and volume (D) yielded significantly higher scores for the Caucasian cohort, measurement of pore depth (C) yielded a significantly higher score for the Black African cohort. **$P < 0.01$ by Mann-Whitney *U* test (C); ***$P < 0.001$ by Student's *t* test (A, B, D)

on these parameters between Black African-African females and Caucasian females. Although the Black African subjects were slightly older than their Caucasian counterparts, we found some unexpected and interesting differences between the two ethnic groups.

When we compared the appearance of wrinkles, we found that for all facial sites measured, except upper lip, the Caucasians had more wrinkles than Black Africans despite being on average 10 years younger. Interestingly, the vertical lines on the upper lip were more pronounced in the Black African subjects, at least when measuring wrinkle length, surface, and volume. Our results provide evidence that skin aging manifests differently in the two ethnic groups and this is dependent on facial site and on the measurement parameter. Vierkötter *et al*[18] reported similar findings on extrinsic aging among German, Japanese, and Chinese subjects. While, for example, wrinkle scores on the upper lip and under the eye were highest in German subjects, Chinese showed highest wrinkle scores on the forehead compared to the other two ethnicities. Comparing Caucasians and Black Africans living in Los Angeles, Hillebrand

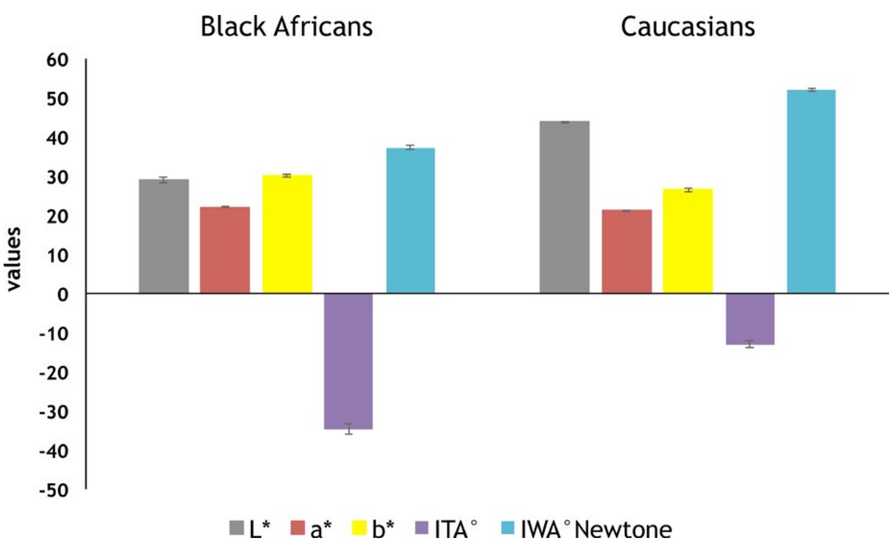

FIGURE 12 Skin color assessment on the cheeks in Black Africans and Caucasians. All parameters are the average of all pixels in the ROI. All parameters are significant at $P < 0.001$ between the two skin types (by Mann-Whitney *U* test)

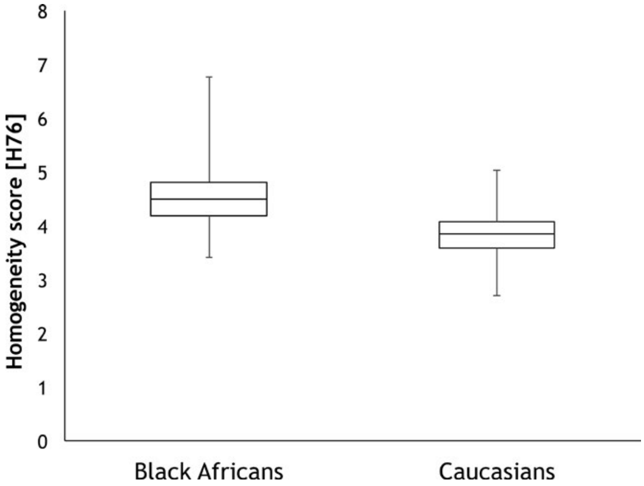

FIGURE 13 Skin homogeneity on the cheeks in Black Africans and Caucasians. Higher score means less homogeneous skin color. ***$P < 0.001$ by Mann-Whitney U test

et al[23] found more facial wrinkling in the Caucasian group similar to our findings with Black Africans living in Mauritius. This is also in line with the fact that photoaging in African Americans does not appear until the late fifth or sixth decade of life.[22] This may explain why aging in our Black African cohort from Mauritius is less pronounced than in the Caucasian cohort although the Black African cohort is older. This is underpinned by molecular studies showing that aging-related pathways, like NF-kB pathway leading to collagen I degradation, are down-regulated in fibroblasts of Black African donors vs. Caucasian donors.[72] Furthermore, Fantasia *et al* showed that the TGF-β1 pathway and elastin fiber synthesis are at a higher expression level in skin of African Americans compared to Caucasians.[73]

Moreover, Hillebrand *et al*[23] found that African Americans had more pores than Caucasians which contradicts the result of our study. Nevertheless, it was reported by others that there was a trend of African Americans having less pores than Caucasians[9] supporting our own data presented here with Black Africans from Mauritius.

Looking at the four parameters used to evaluate pores, we found consistent results for the number, surface, and volume of pores, when comparing the Caucasian to the Black African cohort. Because volume was suggested previously to be a reliable marker for pores and highly correlated with visual assessment,[49] we postulate that Black Africans have indeed less pores than Caucasians. Interestingly, pore depth yielded the opposite result.

Although it is commonly accepted that skin aging signs appear later in life in darkly pigmented skin compared to lightly pigmented skin, it was found that African Americans showed a more heterogeneous skin color distribution than Mexicans, Chinese, and Caucasians.[52] In addition, our results presented here suggest that Black Africans from Africa have a more heterogeneous skin type than Caucasians. So far, an even skin tone corresponding to a homogeneous skin color distribution was mainly known to be of concern for East Asian women compared to Caucasians who rather worry about wrinkles.[74] However, our data together with previously published results[22] suggest that while subjects with darkly pigmented skin may have less concerns with wrinkles, they may have more concern with skin tone, too. More so, because skin homogeneity was found to be a main sign of skin beauty and contributor to facial attractiveness in Black Africans from South Africa.[50]

The difference in age between our Caucasian and Black African cohorts (median age 46 years vs 56 years) could bring into question the comparisons of the two cohorts. Nevertheless, we mostly found that Caucasians displayed more severe signs of aging than Black Africans which is in line with the common understanding that the onset of aging in fair skin starts earlier than in darkly pigmented skin[22] and that there were differences in the appearance of lip lines and facial pores.

There are, so far, only a few studies examining facial aging or facial skin conditions on Black African subjects from Africa.[15,17,75] In other studies, African Americans have been studied.[9,23,76,77] Although our data on facial wrinkles are mostly in line with skin aging data from previous studies despite the relatively small number of subjects (50 for Caucasians, 46 for Black Africans), differences in lip lines and pores are apparent. It has been shown that, for example, for Asians the appearance of wrinkles and pores can be different depending on precise ethnicity, for example, Chinese, Thai, or Japanese.[12,78] Moreover, even within China it was found that there were differences in wrinkle establishment depending on location and regional climate conditions in young women.[79] The same is true for skin color characteristics which were found to differ significantly between Koreans and Cantonese subjects.[80] We can hence assume that also within Caucasians and Black Africans there are significant differences between, for example, Caucasians from Northern and Southern Europe, or between Black Africans from Northern and Southern and sub-Saharan Africa, let alone Black African Americans.

In summary, we provide comparative data on the appearance of facial wrinkles, pores, and skin color characteristics in Caucasian and Black African women from France and Mauritius using a newly developed facial skin imaging system. We show that there were distinct differences between these two cohorts and that these differences were dependent on facial site and the measurement parameter.

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DISCLOSURES

RC, DI, and RV and are employees of DSM Nutritional Products. ST, PS, and CA are employees of Newtone Technologies. AVR is a consultant to DSM Nutritional Products.

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