Digital photographic grading tool for online visual skin evaluation on images

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Abstract

Background: To assess skincare product efficacy, experts must objectively follow skin feature evolutions. They usually grade cutaneous attributes using visual scales. No online tool for image grading already reaches a consensus among experts, although remote image grading is convenient, especially for multicentric studies.

We propose new digital scales for pore, vascular and pigmented dark circle gradings, in European female population. We also present Photoscale®: a user-friendly online image grading system which enables several raters to easily grade images with regards to interactive digital scales or to run image paired comparison.

Methods: We acquired multi-modalities ColorFace® photographs. Data were pre-processed with color registration and targeted cropping. 60 images were selected per clinical sign, well distributed in terms of criterion (pore visibility, dark circle color intensity and surface) evolution ranges.

Three experts compared the images by pairs, using a specific mode of Photoscale®, that provided rankings. Using image analysis correlated to visual assessments, scale images were chosen to show smooth linear evolutions.

Results: Our photographic scales illustrate representative evolutions. For dark circles, bi-directional scales are designed to represent both surface and color intensity aspects. In online Photoscale® interface, experts can select the reference they judge the closest to the graded

image by examining at both images side by side. The corresponding score is automatically assigned to the graded image.

Conclusion: Our tool opens a complementary standardized way to grade specific areas, in reference to photographic scales of these exact same regions, side by side. It can be enlarged to other clinical signs.

Keywords: Digital images; Clinical grading; Online grading; Product efficacy; Photographic scales;

Introduction. Quantifying skincare product efficacy is a challenge. It needs an objective visual evaluation of skin attribute evolutions. In most cases, experts are asked to examine the subject's skin *in vivo*. Their grading must be objective, quick, precise, reliable, repeatable and expert-independent. To harmonize and standardize skin assessment, visual grading tools are used as references. With a strong training background, the experts learn how to compare the reference illustrations and the subject ’s skin and how to conclude to a quantified grading. The process has been well documented, especially for wrinkle evaluations [1, 2, 3, 4, 5, 6, 7, 8, 9]. They allow natural ageing characterization and product or environment effects measurement for some clinical signs [10, 11, 12].

However, there is still room for improvement, in particular for digital image grading. Indeed, online image grading has several advantages. The first one is flexibility: in contrary to *in vivo* grading, digital image grading does not require the presence of both enrolled subjects and experts at the same time on site. It can be done once all the panel images are done, and remotely. Moreover, one same rater can grade subjects’ skin from multicentric studies, or several raters around the world can remotely assess the same subjects’ skin. Image can also be prepared to meet specific evaluation protocol. For example, skin views and cropped regions of interest (ROI) from different timepoints can be precisely compared. Using high resolution imaging system enables to get reliable images of the skin, that can be comparable to in vivo visualization of the skin. In this context of higher quality, digital image evaluation can be simpler to implement because there is not anymore the same pejorative gap between

a printed photograph and the real skin *in vivo*. Displaying two images on the same screen guarantees that the information is conveyed in the same manner. Besides, it promotes a higher level of training and standardization, complementary to skin *in vivo* grading. Even so, no online tool is already widely accepted by experts. QuantifiCare proposed the Digital Viewing Interface [13], but it doesn't allow synchronizing the cropping between the subject's photographs and the digital scales, that may affect the comparability.

In this project, we developed a complete online grading system for reliable skin evaluation from digital images. This article details the digital scale creation process. We focused on pore and vascular and pigmented dark circle gradings, in European female population. We chose these clinical signs because they are not yet well described in existing published references. In particular, they are not available for Caucasian ethnic group in the main standard [1]. Obviously, the method can be adapted to other skin attributes that will be considered in the next steps. This paper also introduces an innovative online image evaluation system, called Photoscale® [14]. Several raters can evaluate or compare clinical images at the same time. The interface integrates the newly created digital image scales in live display to ease the assessment.

Materials and Methods. We aimed at conceiving digital photographic scales that are:

- dedicated to skin assessment on photographs acquired with ColorFace® (designed to get high resolution images of the skin)
- devoted to online and digital usage
- user-friendly
- linear (with constant illustrated grade gaps)
- precise (with small grade gaps)
- spread out enough to cover the real evolution range of the clinical sign
- adressing the pore visibility, the pigmented or vascular dark circle color intensity or surface

The proposed methodology is made up with six steps: data acquisition, data pre-processing, characterization by visual assessment, characterization by image analysis, scale images selection and scale post-processing.

Data acquisition. We carried out the recruitment of 587 Caucasian women in France (Saint-Étienne and Lyon) and Bulgaria (Sofia). All participants provided written informed consent, including publication of the images. We collected high-resolution full-face photographs (dimension: 4000px x 6000px) of these subjects faces with a ColorFace® system [15, 16, 17]. This system acquires multi-modalities images (standard, cross-polarized, parallel-polarized and UV) of the front face and profile views. Portraits acquisitions went from October 2020 to July 2021 to obtain a large and representative data set.

Data pre-processing. Firstly, we made a color image registration by analyzing the colors rendered on a color chart positioned just below the face. It enables us to correct small variations in illumination.

Then, we selected the more suitable polarization and view, for each studied clinical sign. Pores are the most visible on parallel-polarized front face images. The parallel polarization sheds light on skin micro-relief, allowing for good visualization of pore depth and demarcation. On the contrary, dark circles are easiest to see on cross-polarized front face images. The cross polarization faithfully transcribes the skin colors, and so the dark circle shades.

Afterwards, the images were cropped around the Regions Of Interest (ROI): a rectangle (dimension: 764px x 932px) on the cheeks for the pores and a rectangle (dimension: 823px x 810px) near the eyes for the dark circles. The ROI sizes were set so that the most marked clinical signs can entirely be included, and the surrounding context is sufficient to easily identify and reposition the ROI. We manually put the crop region in place for the first subject. Spatial rigid registration based on image intensities was used to automatically position the ROI on all other images. We did a visual quality control in order to guarantee that the registration is reliable and precise.

Characterization by visual assessment. Firstly, three experts did a quality control of the whole database. They classified all cropped pore images into “image to be rejected” (if the image contains an imperfection like blur, hair presence, acne, age spot…), “image without visible pore” or “image with visible pores” classes. In the same way, they categorized all cropped

dark circle images twice. The first set of classes assessed the dark circle surfaces: “image to be rejected”, “image without dark circle”, “image with a dark circle whose surface is smaller than a third of the under-eye zone”, “image with a dark circle whose surface varies between a third and two thirds of the under-eye zone” or “image with a dark circle whose surface is bigger than two thirds of the under-eye zone”. The second set of classes focused on dark circle colors: “image to be rejected”, “image without identifiable color”, “image with a vascular dark circle (blue shade)” or “image with a pigmented dark circle (brown shade)”. Thanks to this clustering, we selected 60 images per criterion that were aesthetic and diverse in terms of clinical sign evolution.

Next, the images were sorted in ascending criterion order, using Photoscale®. The three experts compared all images by pairs. Photoscale® was used to sequentially display all image pairs in a random order. By looking at both images side by side, it is easy to identify the one with the most visible pores, the most colored dark circle, or the biggest dark circle. The obtained median rankings illustrate smooth evolutions of the clinical signs. They provide visual scores for each studied aspect.

Characterization by image analysis. The visual perception is essential to describe the clinical sign evolution in a natural way. However, it is not the most convenient indicator because it contains a part of subjectivity. The attributes that contribute most to the decision are not explicit. We performed image analyses to find objective parameters that would be well correlated with the visual perception.

First of all, we had to segment the objects of interest to precisely distinguish them from surroundings. For pores, we applied a blob detection algorithm in a specific ROI. We obtained a precise segmentation whose each connected component corresponded to an individual pore. For dark circles, we made semi-automatic segmentations: skin and dark circle markers were positioned, and a super-pixel graph cut computed the fine frontiers. A surrounding segmentation was also defined to analyze contrast parameters. A small square was placed inside the under-eye zone, but outside the dark circle.

Then, we computed analysis parameters. Pores were characterized by the conspicuous number (i.e. the number of distinct elements in the segmentation), the area (i.e. the total number of pixels in the whole segmentation), the average area (i.e. the average number of

pixels in one individual pore segmentation), the density (i.e. the area divided by the number of pixels in the complete ROI), the conspicuous depth (i.e. the difference of intensity between the pores and the surrounding) and the conspicuous volume (i.e. the multiplication of the area and the conspicuous depth). Dark circles were characterized by the area, the CIE Lab parameters [18] inside the segmentation, the CIE Lab contrasts between the segmentation and the surrounding, the ITA (i.e. Individual Typological Angle defined by $\arctan\left(\frac{L^*-50}{b^*}\right)$), the ITA contrast between the segmentation and the surrounding , the IWA (Individual Whitening Angle defined by $\arctan\left(\frac{L^*}{\sqrt{a^{*2}+b^{*2}}}\right)$), the IWA contrast between the segmentation and the surrounding.

We studied the correlations between the computed parameters and the median visual rankings. For each attribute, the parameter with the highest level of correlation was selected among all the analyzed ones: the average area for pore visibility, the area for dark circle surface, the IWA for pigmented dark circle color and b* for vascular dark circle color. Each image is now graded with this set of mathematical parameters.

Scale images selection. We defined target parameter values so that:

- the first ones correspond to the minima
- the last ones correspond to the maxima
- the number of intermediate values is sufficient to create detailed scales
- the differences between two consecutive values are constant

Afterwards, we chose the images whose parameters were closest to the target values. We obtained the final digital photographic scales. By definition, the designed scales are linear in regard of the chosen mathematical parameters.

Scale post-processing. To ease the pore grading, we added reticle on scale images. It helps clinical experts to focus their attention on the ROI and not to be disturb by the surroundings. The reticle is fixed size and positioned just below the cheek bone. For dark circles, we did not include a reticle because the shapes of dark circles are too various: the reticle is more disturbing than helpful in this particular case.

We also applied small image corrections, using Photoshop®, to remove some age spots and to make the shadow less visible on the upper eyelid in the dark circle scales. No modification is done on the dark circles not to alter the grading region of interest.

Results.

Pores. We designed a six-point digital photographic scale for pore visibility grading [Figure 1]. The average area parameter varies from 30 to 65 with a step of 7. The result is visually harmonious. Thank to mathematical linearity, the increase in pore visibility looks regular. We decided to create our scale with six photographs in order to illustrate clear differences between two consecutive images. Obviously, the method would enable us to create a scale including as many sub-grades as it is desired.

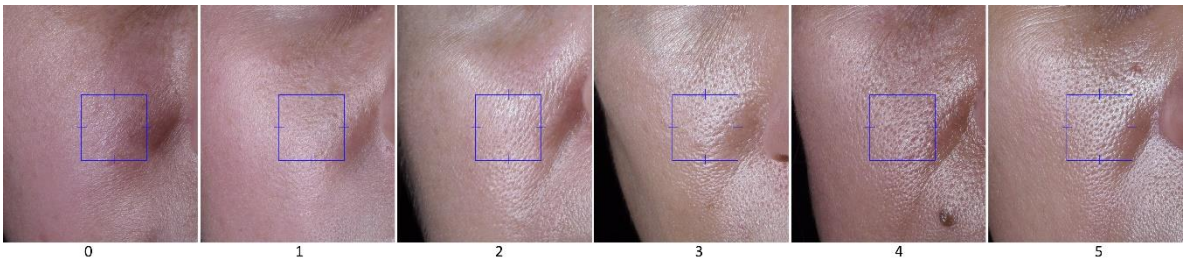

FIGURE 1: Photographic scale for pores.

Dark circles. Dark circle scale development is more challenging because both color and surface are important to be considered in the dark circle characterization. To completely describe this duality, we introduced two dimensional scales [Figures 2 and 3]. On a row of these scale tables, the illustrated dark circles have the same color but variable areas. On the contrary, on a column, they have the same area but variable colors. We only illustrated the table diagonal because none of database subject has small colored or large pale dark circles. For pigmented dark circle, the number of pixels in the segmentation (the area parameter) goes from 6000 to 62000 with a step of 14000 while IWA varies from 70 to 50 with a step of -5. For vascular dark circle, the computed area takes values between 6000 to 48000 (step of 14000) while b* varies from 20 to 8 with a step of -4. It means that the dark circle surface grades are equivalent for pigmented and vascular dark circles. A grade (0, 0) without any dark circle is added to finalize the scales. This grade is the same for both pigmented and vascular dark circles.

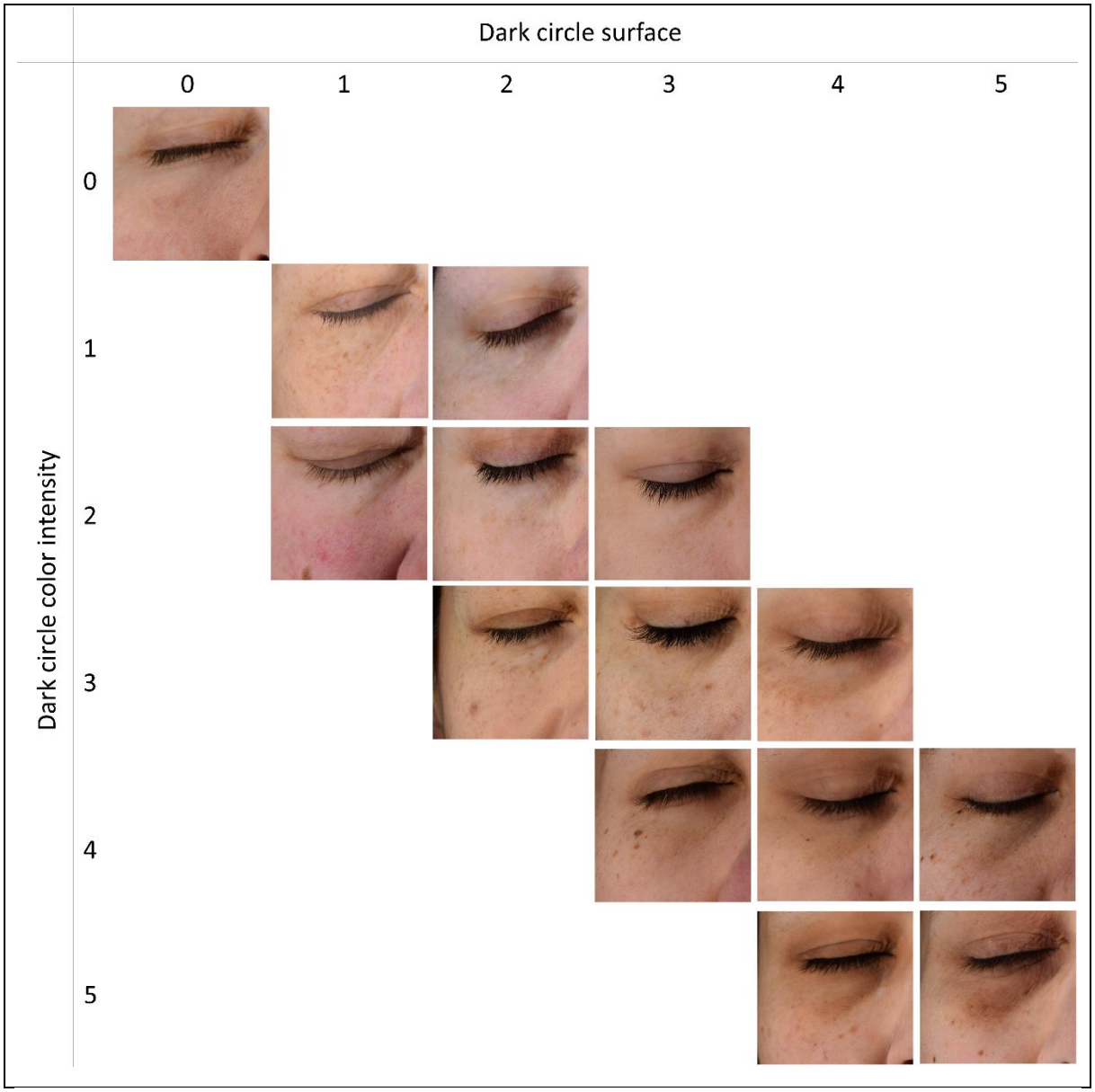

FIGURE 2: 2D photographic scale for pigmented dark circles.

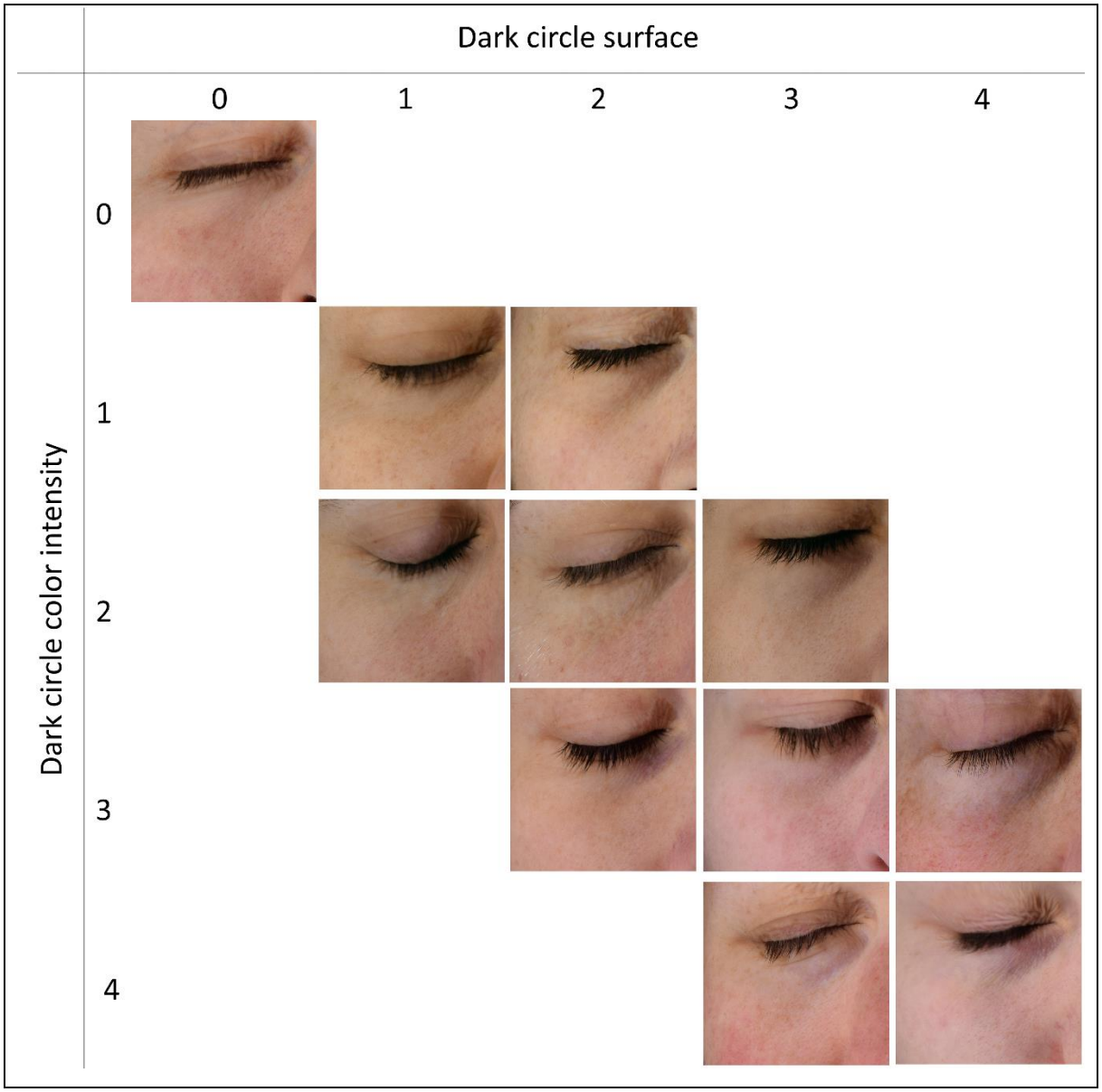

FIGURE 3: 2D photographic scale for vascular dark circles.

As explained hereinabove, the upper right and the bottom left corners could not be completed. We wanted to know if it corresponds to a biological reality or if our database was not big enough to include all the possible cases. We found high correlations between the visual evaluations of color and surface [Figure 4]. It implies that a diagonal is sufficient to well describe the dark circle diversity.

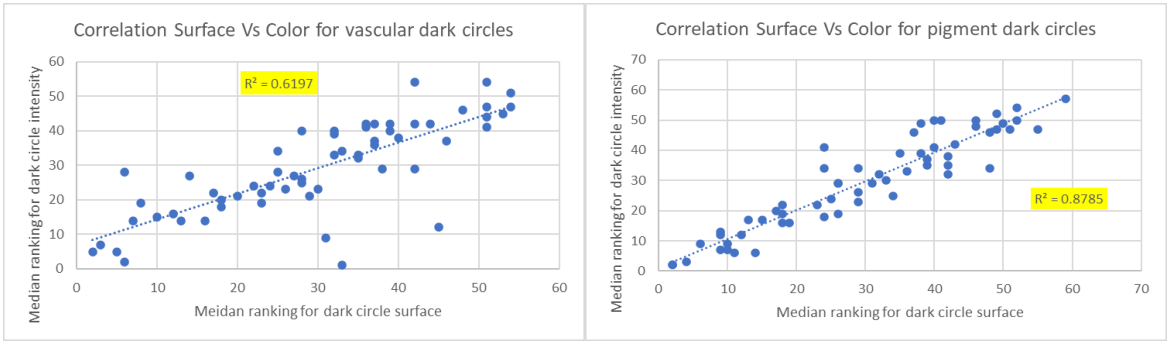

FIGURE 4: Correlations between visual assessments of color intensity and surface.

Moreover, thanks to this result, we could create one-dimensional scales [Figures 5 and 6], based only on the area, that will describe in a more general way dark circle evolutions. For pigmented dark circles, the area goes from 0 to 63000 with a step of 7000. For vascular dark circles, the area varies from 0 to 56000 with a step of 7000.

FIGURE 5: 1D photographic scale for pigmented dark circles.

FIGURE 6: 1D photographic scale for vascular dark circles.

Finally, we created another dark circle scale, only based on b* parameter [Figure 7]. It is not dedicated to grading, but to classification. The idea is to help expert to easily distinguish pigmented and vascular dark circles. For instance, it can be really helpful for subject recruitment in a clinical study.

FIGURE 7: Photographic scale for dark circle classification.

Photoscale® integration. Photoscale® is an online tool dedicated to digital image grading and comparison. When a grading session is configured (the question to be asked, the number of repetitions, the zoom range, the references to be displayed, the images to be evaluated…), the algorithm generates a randomized sequence to display all images to be scored. Raters can display side by side the image to be graded and the reference scale [Figure 8] to easily compare both attributes. They just have to select the reference image that they feel closest to the target. The corresponding grade is automatically assigned to the image to be evaluated. The grading is easy, intuitive and quick. The three experts involved in this project found Photoscale® more convenient and enjoyable than referring to paper references.

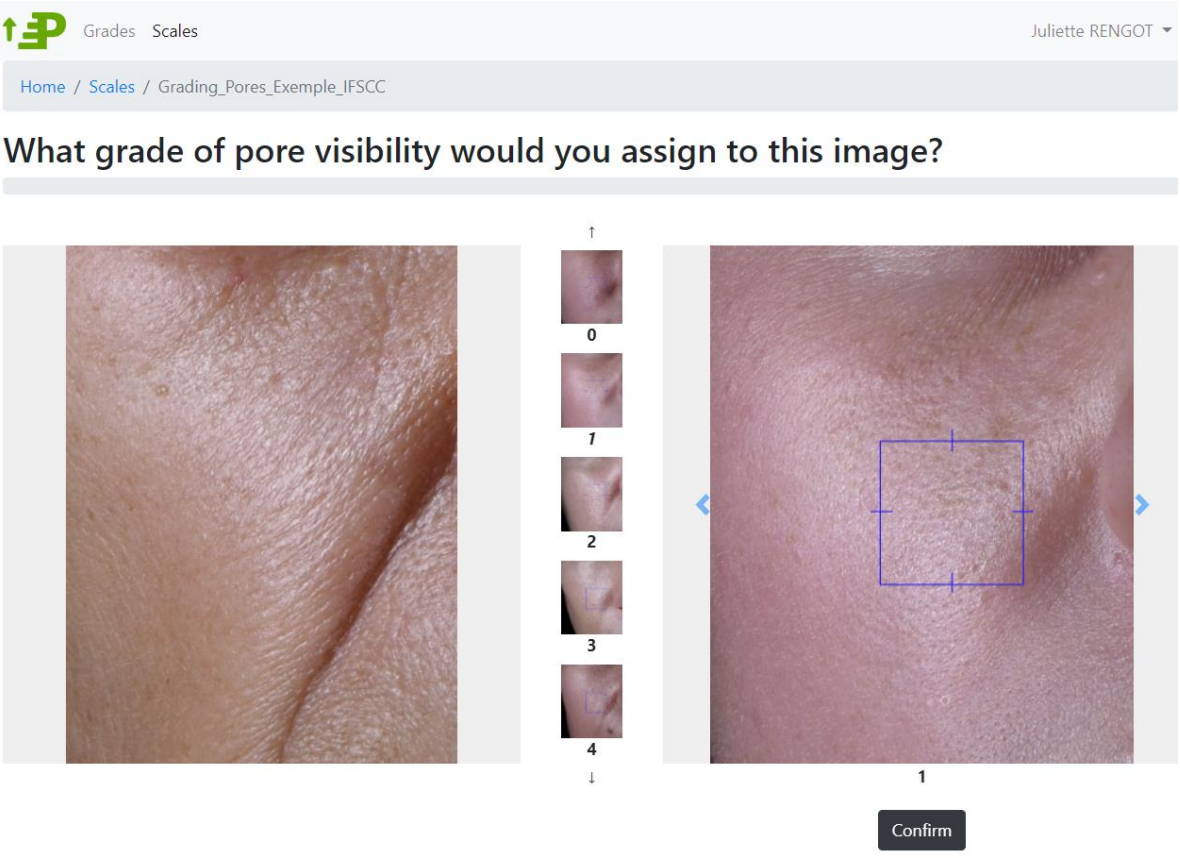

FIGURE 8: Photoscale® integration of digital scale for pore grading.

Discussion. The proposed digital photographic scales provide new opportunities for clinical skin grading in the context of clinical studies involving digital imaging of the skin. They fill a gap of the main reference [1]: pores and dark circles were not included for Caucasian female

population. Without convenient reference, skincare product effects are harder to be proved and quantified.

Being developed using ColorFace® images, our scales can be used in the context of clinical studies where this device is used to acquire the images. Image perspective, polarization and cropping can be exactly identical with the reference scale. Needless to say, the introduced methodology is generalizable to other acquisition systems.

Moreover, the dark circle scales allow experts to comprehend this clinical sign from various angles according to the study objectives. A global grading is possible thanks to one-dimensional scales. A more detailed following can be done thanks to two-dimensional scales. The possibility to follow two different features of dark circles at the same time is innovating. It permits to analyze product effects with a finer understanding.

Last, the Photoscale® integration finalizes the tool. Thanks to a complete digital image grading system, the assessment becomes nicer and easier according to three expert feedbacks.

Conclusion. This article presents a complete digital image grading system. The Photoscale® eases online skin evaluation by displaying side by side the images to be evaluated and reference images. We also have explained how to conceive powerful reference scales. We took the examples of pore, pigmented and vascular dark circles. These photographic scales illustrate linear clinical sign evolution thanks to well-chosen parameter values assigned to images. It is even possible to follow two parameters at the same time thanks to two-dimensional scale format. This methodology can be extended to other clinical signs to feed the digital image grading offer.

In the future, the introduced scales will be put into real clinical conditions to validate the user-friendliness of the Photoscale® and the reliability and repeatability of the photographic scales.

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Conflict of Interest Statement. NONE.

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