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Skin Age Index: Development of a Convenient and Quantitative Indicator of Facial Skin Aging and Its Application to Evaluation of the Efficacy of Three Anti-Aging Skin Care Products Containing GFF (Pitera)

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Abstract

Background Facial appearance is regarded as a typical index of aging. However, people of the same age do not necessarily show the same aging in terms of their facial appearance. There is thus a need for an easy-to-understand indicator representing visible facial skin aging in comparison with that of individuals of a similar age. Objectives The purpose of this study was to develop a simple and accurate index of skin to understand the degree of facial skin aging. Methods Facial skin images were taken with two simple and convenient facial imaging devices (Magic Scan, Magic Ring) in 110 Asian women aged 20 - 60 years, and texture, pores, wrinkles, and dullness (skin unevenness) were quantified as parameters of visual skin aging. Regression analysis was performed on each skin aging parameter and age, and the variation of change in skin aging parameters over time for each subject was calculated. The ratio of each measured skin aging parameter to the mean variation of that same parameter among individuals of the same age as the subject and that ratio was converted into a delta (Δ) age value. Skin age for each skin aging parameter was then calculated by adding or subtracting the Δ skin age to the subject's chronological age. The average skin age for all four parameters was defined as the overall facial skin age (Skin Age Index). The Skin Age Index was then compared to the results of visual grading of facial skin aging. We also determined the correlation between Skin Age Indexes determined using Magic Scan or Magic Ring. Furthermore, Galactomyces Ferment Filtrate (GFF, Pitera) containing

anti-aging skin care products' treatment efficacy was performed on 21 healthy Asian women to determine the change in skin age. Results Determined Skin Age Index, together with all visible skin aging parameters of texture, pores, wrinkles, and dullness, were highly correlated with actual age. Notably, a high correlation was also observed between visually evaluated comprehensive facial skin aging and Skin Age Index (r = 0.6801 with Magic Scan, r = 0.5668 with Magic Ring). This showed that the degree of skin aging and the apparent skin aging were approximate. The Skin Age Indexes obtained using the two different facial skin imaging devices showed a high correlation (r = 0.8295), suggesting the possibility of calibrating skin age using different image measurement devices. The three GFF-formulated anti-aging skin care products achieved improvements in texture, pores, and wrinkles, and resulted in a skin age that was 5.92 years younger after 1 week of treatment. Conclusions From this study, a method for measuring facial skin age was developed. This Skin Age Index showed an excellent correlation with the subjectively evaluated visible facial skin aging. Furthermore, this Skin Age Index has been shown to be a useful indicator of the effectiveness of applying anti-aging skin care products.

Keywords

Skin Age Index, Facial Skin Aging, Texture, Pore, Wrinkle, Dullness, GFF (Pitera)

1. Introduction

Facial skin aging is a psychophysical and social concern in humans, especially women. Such aging involves changes in the skin with increasing age, such as wrinkles, hyperpigmented spots, roughness, and loss of elasticity [1]-[4]. Wrinkles are known to increase more rapidly and more conspicuously in Caucasian than in Chinese women. Meanwhile, hyperpigmented spots are more apparent in Chinese than in Caucasian women [4]. Skin barrier function also tends to be impaired by facial skin aging, as assessed by decreased skin hydration and increased transepidermal water loss (TEWL) [1].

The intensity and speed of the aging process differ markedly between individuals [1]. Therefore, some women look younger than their actual age, while others look much older [1]. Among various skin aging parameters, wrinkles, hyperpigmented spots, and skin roughness are considered to be particularly representative of an older appearance of the female face [1].

When looking at a person for the first time, we tend to estimate their age based on appearance, including body type, hairstyle, and facial appearance. In particular, facial skin condition, such as wrinkles, surface roughness (*i.e.*, "texture"), visible follicles at the skin surface (*i.e.*, pores), and skin tone, significantly influence the estimated age [1]-[5]. In various medical fields including dermatopathology, esthetic dermatology, and epidemiology, it is essential to understand the changes that take place in aging facial skin. In previous skin aging studies, facial skin con-

ditions were evaluated for various age groups to comprehensively characterize their skin aging [6]-[14]. However, in those studies, it was not possible to exclude the variability caused by individual living environment, lifestyle, and genetic background [15]-[18]. Such variability must be minimized in order to precisely elucidate skin aging. Hillebrand *et al.* conducted an 8-year study to quantify changes in wrinkles by age and ethnicity [19]. Their study classified the skin conditions conferring susceptibility to wrinkles, and clinically demonstrated that long-term repetition of the generation of expression-related wrinkles (e.g., smiling wrinkles) eventually settled into permanent wrinkles. Miyamoto *et al.* also evaluated skin changes in the same subjects in various age groups over a period of 11 years [20] [21]. These studies identified facial skin parameters that contribute to the subjective impression of overall age and characterized the degree of skin aging by tracking individual skin conditions over a long period of time. These studies revealed the degree of skin aging based on visual impressions of the face; however, the applied method requires specialized knowledge about the mechanism of aging of the skin. Against this background, we investigated whether it would be possible to create an aging index that can be easily understood by non-professionals. Using a database of facial skin aging measurements classified by chronological age of the subjects, we developed and applied an index called Skin Age Index, which classifies the degree of visual aging of the skin by comparing it with the average for individuals of the same age. In addition, three anti-aging skin care products containing *Galactomyces* ferment filtrate (GFF, Pitera™) were applied twice a day for 1 week, and their effects were evaluated using the Skin Age Index. GFF functions as a potent antioxidative agonist for the aryl hydrocarbon receptor. It is known to increase the expression of filaggrin, caspase-14, and claudin-1, which may facilitate the production of natural moisturizing factors (NMFs) and promote the integrity of tight junctions [22] [23]. It also potentiates the anti-inflammaging system in epidermal keratinocytes. In parallel with this, clinical studies have revealed that the daily application of Pitera increases skin hydration and decreases the TEWL of facial skin [24] [25].

2. Material and Methods

2.1. Study Subjects

The first skin evaluation study was carried out on 110 healthy East Asian females who were employed (working indoors; those working outdoors were excluded) or were housewives, and lived in Akita City, Japan, in September 2021. The evaluation occurred in an examination room maintained at a constant temperature and humidity (20˚C ± 2˚C, relative humidity 50% ± 5%). The age of the subjects ranged from 20 to 60 years old [mean ± standard deviation (SD): 34.9 ± 11.4]. In terms of the age groups of the subjects, 44 were in their 20s (24.0 ± 2.75), 33 were in their 30s (34.8 ± 2.69), 23 were in their 40s (45.1 ± 3.05), and 23 were in their 50 s (54.0 ± 2.77). None of the subjects had undergone any type of esthetic treatment such as laser cosmetic procedures prior to participation in the study.

2.2. Facial Optical Imaging and Objective Image Analysis

The subjects washed their faces using the prescribed cleansing foam and then spent 20 min becoming accustomed to the environment of the measurement room. Each subject's face was photographed using two different image capture systems (SK-II Magic Scan and Magic Ring; P&G, Kobe, Japan) (**Figure 1**). Magic Scan and Magic Ring image capture systems were described previously [26] [27].

Figure 1. Magic Scan (left) and Magic Ring (right) facial imaging systems. Each subject's face was photographed using Magic Scan and Magic Ring.

In short, Magic Scan is a portable facial image-capturing system in which a number of 5600-K light-emitting diodes (LEDs) are mounted on the left and right sides of the system. A high-resolution complementary-symmetry metal-oxide-semiconductor digital camera, capable of generating 1980 (vertical) × 1024 (horizontal) effective picture elements (pixels), is also mounted in the imaging module. Meanwhile, Magic Ring is another facial imaging system that consists of a portable image-capturing module that can be positioned on either the left or the right side of the subject's face in a reproducible manner. Illumination is provided by a number of 5600-K LEDs mounted in the imaging module. A high-resolution complementary-symmetry metal-oxide-semiconductor (CMOS) digital camera, capable of generating 2592 (vertical) × 1944 (horizontal) pixels, is also mounted in the imaging module, and images are digitally transferred to a computer. A neutral 8.0 gray color board (GretagMacbeth GmbH, Munich, Germany) was used for white balancing of the camera for both imaging systems.

The region of interest (ROI) of the images obtained from both Magic Scan and Magic Ring imaging systems was from the lower edge of the eyes to the cheek, and the following characteristic objects were extracted by measuring the contrast in the shape and pixels using an image analysis algorithm. Wrinkles were defined as ≥ 5 mm in length, perimeter/length ratio ≤ 2.5, and circularity (perimeter^2/area) ≥ 34, and the total wrinkle area fraction [total wrinkle area (pixels)/ROI (pixels)] was quantified. Dullness (skin unevenness) was defined as areas of ≥ 5 mm^2 in size with color contrast DeltaE ≥ 3 when compared to the surrounding skin region, and circularity (perimeter^2/area) ≥ 20; total dullness area fraction [total dullness area (pixels)/ROI (pixels)] was also quantified. As an index of skin surface roughness, total textured area fraction [total textured area (pixels)/ROI (pixels)] was quantified as areas of ≤3 mm^2 in size, aspect ratio ranging from 0.5 to 2, and color contrast Delta E ≥ 1.5, while pores were defined by being ≤ 4 mm^2 in area, color contrast DeltaE ≥ 2, and circularity (perimeter^2/area) ≥ 20; total

pore area fraction was quantified as follows: total pore area (pixels)/ROI (pixels) (**Figure 2**) [26] [27]. Measurement reproducibility and accuracy of all the image analysis parameters of wrinkle, dullness, texture and pores comparing subjective visual grading at Magic Scan and Magic Ring were examined and validated prior to the study placement [26] [27]. In addition, the subjective impression of the subject's facial skin from the periorbital region including the eye area to the cheek region was visually evaluated on a color-calibrated monitor by 10 examiners, who scored it on a 20-point scale from −10 (looks much older than the actual age) to 10 (looks much younger than the actual age) compared with the chronological age. The mean values of the resulting data from the 10 evaluators were analyzed.

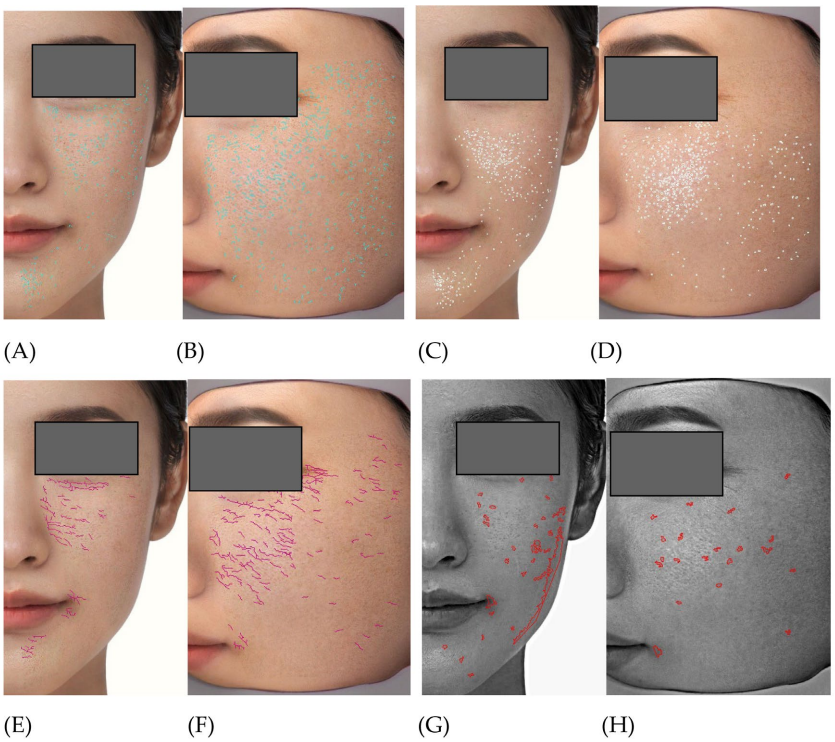

Figure 2. Examples of image analysis of skin aging parameters. Texture [Magic Scan (A) and Magic Ring (B)], pores [Magic Scan (C) and Magic Ring (D)], wrinkles [Magic Scan (A) and Magic Ring (B)], and dullness [Magic Scan (G) and Magic Ring (H)].

2.3. Skin Aging Index

Facial skin images were taken with two simple and convenient facial imaging devices (Magic Scan, Magic Ring), and texture, pores, wrinkles, and dullness were quantified as parameters of visual skin aging using skin image analysis methods. Regression analysis was performed on each skin aging parameter and age, and the difference in Δ skin aging parameters from the average value for each age was estimated. An equation for estimating the age of skin was established as follows. First, the degree of skin aging was obtained from the ratio of each individual aging parameter value relative to the mean variation of that same aging parameter

among individuals of the same age as the subject. Then, the degree of skin aging was converted to Δ age value from the slope of a linear equation. Finally, skin age was calculated by adding or subtracting the Δ age from the subject's actual age. The average of the texture age, pore age, wrinkle age, and tone age calculated as described above was defined as the overall facial skin age (Skin Age Index). In other words, the Skin Age Index can objectively and easily show how much a subject's visual skin aging has progressed relative to their actual age. In addition, the overall degree of skin aging was visually graded using the captured facial images, and its relationship with the Skin Age Index was determined.

For example, if the chronological age of a subject is 35 years old, the measured texture value as an aging parameter is 5.0, the estimated average texture value at the age of 35 is 6.0, the degree of variation of the texture at that age is 1.5, and the range of variation is 11 years, the subject's texture skin age is estimated as 27.6 years (texture skin age = $\{[(5-6)/1.5] \times 11\} + 35 = -7.3 + 35 = 27.6$ years) (Figure 3).

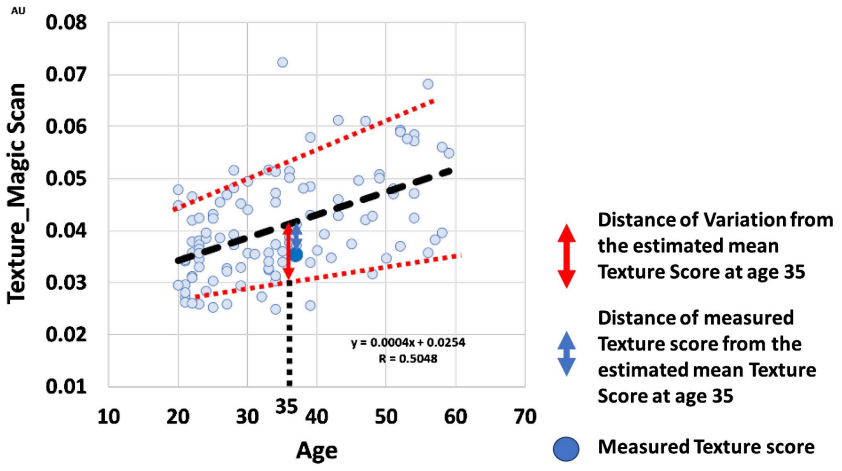

Figure 3. Example of a skin aging parameter (texture). Black dotted line represents mean texture by age. Distance between the red dotted lines shows the variation of skin aging parameter by age. Relative ratio of the distance (blue) between measured texture score and mean texture score to the variation of texture score.

Next, we examined the correlation between the subjectively assessed skin age obtained by visually evaluating an image of the facial skin and the difference in the Skin Age Index from the chronological age. We also assessed the correlation between the Skin Age Indexes obtained from measurements using the two different imaging systems.

2.4. Treatment Efficacy Study of Anti-Aging Skin Care Products

In Study 2, a facial skin care treatment study was carried out in January 2025 in Kobe, Japan, in which 21 healthy Asian women (mean age 37.4, SD 12.60) were enrolled and applied three GFF (Pitera) formulated anti-aging skin care products (Facial Treatment Essence, Genoptics Infinity Essence, Skin Power Advanced Cream) to their faces twice a day for 1 week. Using the facial skin imaging methods, aging

parameters such as texture, pores, wrinkles, and dullness were measured before and after treatment with the products to determine the Skin Age Index.

Both studies were conducted in accordance with the tenets of the Declaration of Helsinki and approved by P&G Ethics Committee. Data acquisition and analysis were performed in compliance with protocols approved by the Ethical Committee of Global Product Stewardship in P&G Innovation Godo Kaisya (ethics approval numbers ES21-002 and KIC25-001). Written informed consent was obtained from all subjects prior to enrollment in the study.

3. Statistical Analysis

All statistical analyses were performed using JMP® Pro 16.1.0 (SAS Institute Inc., Cary, NC, USA). Pearson's correlation coefficients (r) between all four visual skin parameters (image analysis data on texture, pores, wrinkles, and the skin dullness) and age were examined using facial images obtained with the two different imaging systems. To estimate the age from each visual aging parameter, the least squares regression analysis was performed to estimate the Skin Age Index using each aging parameter and chronological age as explanatory variables. Notably, to avoid excessive shine that could appear on some images from influencing the results, measurement values with SD of 3 times or more of the upper limit were excluded as outliers from the measurement data. Pearson's correlation coefficient was also determined to evaluate the relationship between the Skin Age Indexes determined using the four skin aging parameters as described above. We determined the correlation of the difference between Skin Age Index and chronological age and the skin age estimated by subjective visual assessment. To evaluate the efficacy of treatments with the GFF-formulated skin care products, quantitative comparisons were also carried out for the four skin aging parameters (image analysis data on texture, pores, wrinkles, and dullness) after 1 week of treatment with the three GFF-containing formulas versus the baseline in Study 2 using two-way ANOVA. A P-value of less than 0.05 was considered to reflect statistical significance.

4. Results

All visible skin aging parameters (*i.e.*, texture, pores, wrinkles, and dullness) that were quantified by skin image analysis algorithms using the facial images taken with the two imaging devices, Magic Scan and Magic Ring, were significantly correlated with actual age (Magic Scan: r = 0.5048, 0.3277, 0.6456, and 0.3479; Magic Ring: r = 0.7688, 0.5758, 0.4823, and 0.6129, respectively) (**Table 1**, **Figure 4**).

Table 1. Correlation coefficients (r) of skin aging parameters and actual age.

	Texture	Pores	Wrinkles	Dullness	Facial Imaging Device
Correlation coefficient (r) with actual age	0.5048*	0.3277*	0.6456*	0.3497*	Magic Scan
	0.7668*	0.5758*	0.4823*	0.6129*	Magic Ring

*: $p < 0.05$.

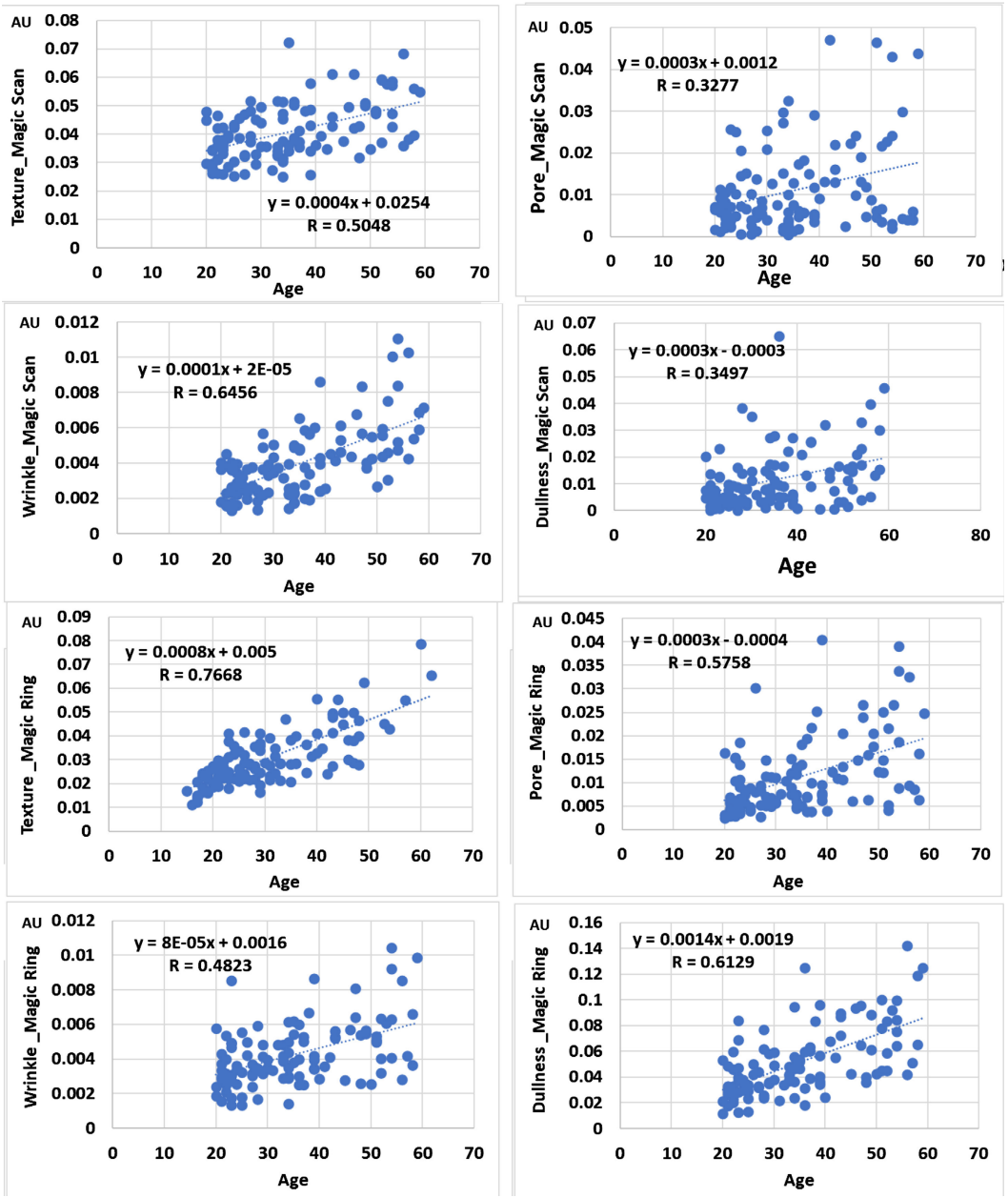

Figure 4. Correlations between skin aging parameters (texture, pores, wrinkles, and dullness) and actual age with Magic Scan (top four graphs) and Magic Ring (bottom four graphs).

The degrees of variation of the Δ skin aging parameters of texture, pores, wrinkles, and dullness from the estimated mean of those skin aging parameters at each age were obtained. Overall, variation of the skin aging parameters became larger with increasing age (**Figure 5**).

By converting the relative ratio of the difference in measured skin aging parameter values to the degree of variation values into an age range, it became possible to estimate the Δ age of each skin aging parameter, thus enabling quantification of the skin age. In the age database, the correlation coefficients with actual age were r = 0.7169 (Magic Scan) and r = 0.7891 (Magic Ring) (**Figure 6**).

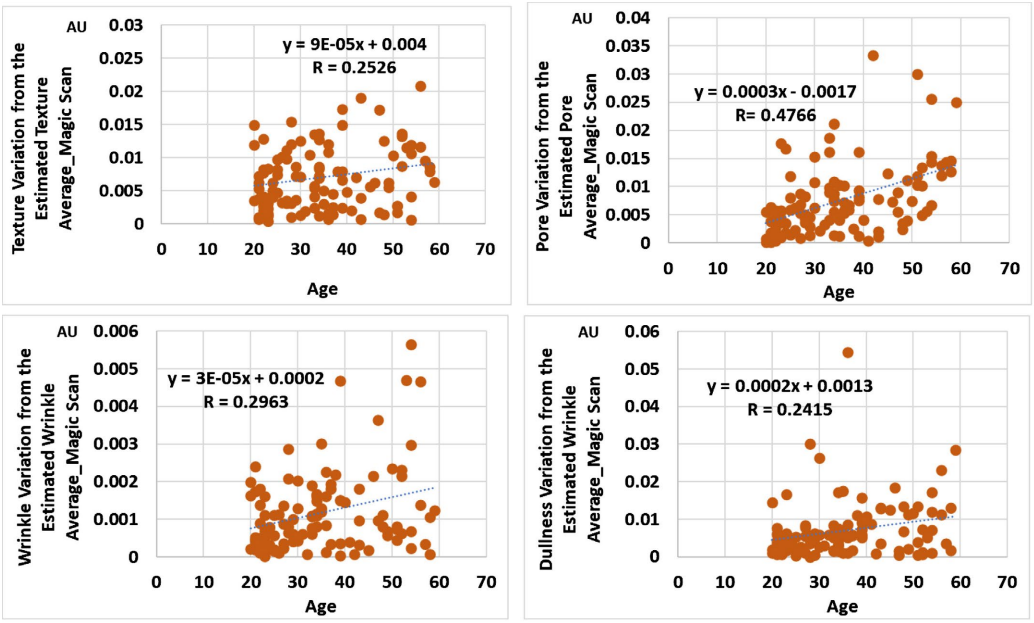

Figure 5. Variation of Δ skin aging parameters (texture: top left, pores: top right, wrinkles: bottom left, dullness: bottom right) from the estimated mean value and actual age (Magic Scan).

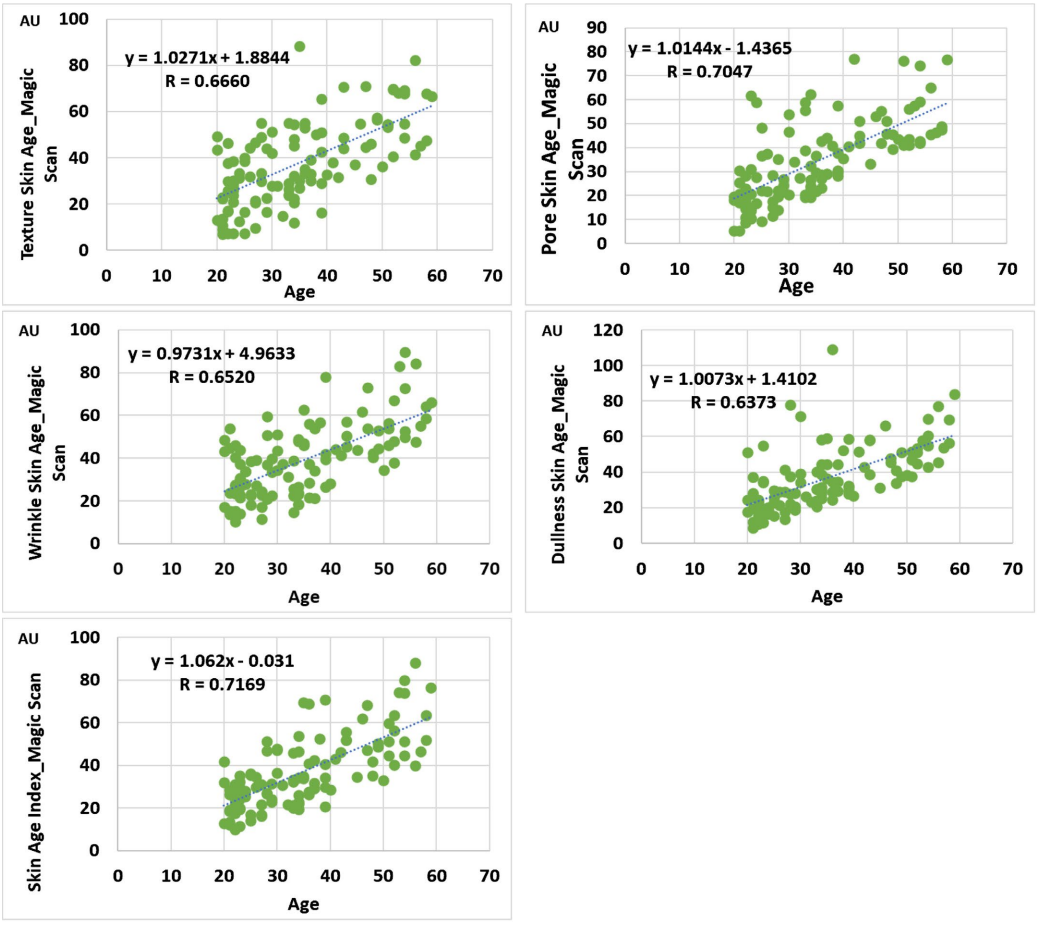

Figure 6. Skin age and age correlation of texture (top left), pores (top right), wrinkles (middle left), and dullness (middle right), and Skin Age Index (overall, bottom) using Magic Scan.

In addition, strong correlations were observed between the subjective visually evaluated rating of skin aging and the Skin Age Index (r = 0.6801 with Magic Scan, r = 0.5668 with Magic Ring) (Figure 7). In other words, the measured degree of skin aging reflected the subjectively determined level of skin aging.

The Skin Age Indexes obtained using the two different facial skin imaging devices showed a high correlation (r = 0.8295), suggesting the reproducibility of determining the Skin Age Index using different image measurement devices (Figure 8).

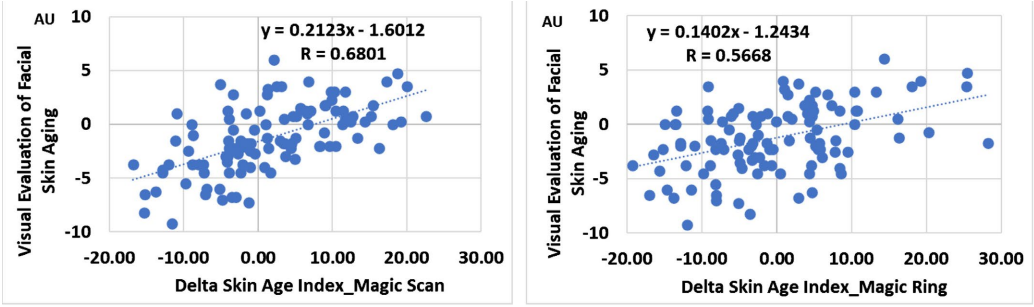

Figure 7. Correlation of subjective visual evaluation of facial skin aging and the Skin Age Index determined with Magic Scan (left) and Magic Ring (right).

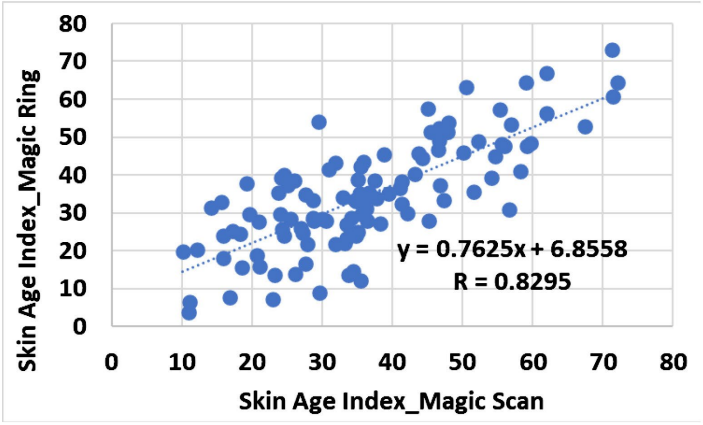

Figure 8. Correlation of skin age indexes determined with magic scan and magic ring.

In Study 2, facial skin treatment evaluation was carried out among 21 Asian female volunteers. The three GFF-formulated anti-aging skin care products achieved improvements in texture, pores, and wrinkles, and led to skin age that was 5.92 years younger after 1 week of treatment. Improvements in Texture, Pore and Wrinkles were relatively mild; however, there was a significant improvement in Skin Age Index as this index was made by the combination of multiple improvement parameters (Table 2, Figure 9, Figure 10).

Example clinical images. Skin Age Index was markedly decreased by 1 week of application of the GFF-containing skin care formulas (SK-II Facial Treatment Essence, Genoptics Infinite Aura Essence, Skin Power Advanced Cream). Images of a subject (aged 37) at baseline (top left) and after 1 week of treatment (top right). Skin Age decreased by 9.1 years. Images of another subject (aged 30) at baseline (bottom

left) and after 1 week of treatment (bottom right). Skin Age decreased by 6.1 years.

Table 2. Texture, pores, wrinkles, and dullness (top) and texture skin age, pore skin age, wrinkle skin age, dullness skin age, and Skin Age (overall, bottom) at baseline and after 1 week of the skin care regimen.

		Texture	Pores	Wrinkles	Dullness	
Mean	Before	3.9330	0.0475	0.0394	0.0185	
	After 1 Week	3.5379	0.0435	0.0265	0.0157	
SD	Before	1.5976	0.0170	0.0375	0.0166	
	After 1 Week	1.2763	0.0151	0.0285	0.0127	
	p	0.06	**0.05**	0.06	0.12	
		Texture Skin Age	Pore Skin Age	Wrinkle Skin Age	Dullness Skin Age	Skin Age Index (Total)
Mean	Before	32.09	20.92	36.89	41.90	32.95
	After 1 Week	28.50	11.89	29.19	38.51	27.02
	Δ Skin Age	–3.59	–9.03	–7.70	–3.39	–5.92
SD	Before	16.54	38.07	23.11	24.03	19.72
	After 1 Week	14.52	34.51	18.28	19.20	16.04
	p	0.06	**0.05**	0.06	0.12	**0.03**

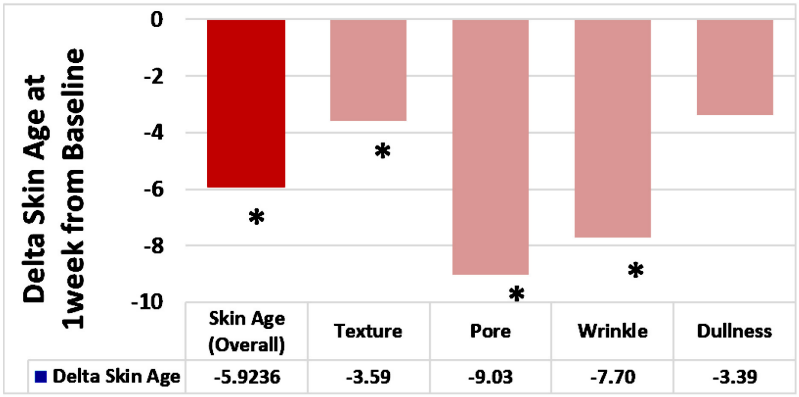

Figure 9. Skin Age Index (overall), texture skin age, pore skin age, wrinkle skin age, and dullness skin age after 1 week of the skin care regimens relative to the baseline.

Figure 10. Skin Age Index (overall), texture skin age, pore skin age, wrinkle skin age, and dullness skin age after 1 week of the skin care regimens relative to the baseline.

5. Discussion

This study elucidated comprehensive changes in the aging-related appearance of facial skin in order to quantify the Skin Age Index, which represents the degree of skin aging relative to others of the same age. It is suggested that the Skin Age Index is useful as an indicator of overall facial skin aging, which can be easily understood without specialized dermatological knowledge.

In developing the Skin Age Index, we adopted texture, pores, wrinkles, and dullness as representative visual indicators of facial aging. Texture (skin surface roughness) is related to dryness and lack of barrier function of the skin [28]. It has been reported that the levels of certain NMFs produced in the granular layer of the upper part of the epidermis decrease with age, and as we age, the moisture-retaining ability of the stratum corneum decreases and the roughness of the skin surface increases [29] [30]. Although sebum secretion decreases with age, pores become more noticeable as they expand vertically due to sagging facial muscles and gravity. Among the aging-related variables of facial skin, the relationship between aging and wrinkles has been the most widely studied, and it is clear that wrinkles increase in number and severity with age [31] [32]. It is also well known that melanin chromophore pigments, which increase after skin inflammation due to exposure of the face to ultraviolet radiation or post-inflammation of acne, become unevenly distributed in the skin with age, which causes skin dullness. Therefore, the four skin aging parameters were measured in association with age, and the obtained data were incorporated into a database for the development of the Skin Age Index. All parameters used for calculating the Skin Age Index were significantly correlated with each other and increased with age. Regression equations were created to estimate average aging parameters. The difference of each measured aging parameter from the estimated average aging parameter from the regression equation by age was calculated as the variation in skin aging. It was found that the variation in skin aging with regard to texture, pores, wrinkles, and dullness also increased with age. In other words, the differences in skin aging between

individuals become more pronounced with age.

In this way, we calculated whether the measured value of each skin aging parameter of the subject was higher or lower than the estimated average value of individuals of the same age, and the ratio of the difference between the measured value and the estimated average value to the range of variation in skin aging at each age. We then converted this ratio into Δ Skin Age Index and added or subtracted it from the chronological age to define the skin age. Texture skin age, pore skin age, wrinkle skin age, and dullness skin age were determined using the above methods, and their average was used as the Skin Age Index, an index representing facial skin aging.

Importantly, the Skin Age Index strongly correlated with scores obtained by visibly evaluating facial skin aging. In other words, if your skin is more visually aged than that of people of the same age, your skin age will be older than your actual age, in accordance with the degree of skin aging. We also determined the Skin Age Index using two different facial image capture devices, Magic Scan and Magic Ring, and found that these indexes strongly correlated with each other. This suggests that skin age can be measured reproducibly with different facial skin imaging devices, such as VISIA CR® (Canfield Inc.), a commercially available device.

GFF has been reported to have moisturizing and antioxidant effects. It has also been reported that daily treatment with skin care products containing GFF improves skin aging parameters, which was also shown in this research. In this context, it is significant that the degree of improvement resulting from such skin care can be expressed using an easy-to-understand indicator in the form of the Skin Age Index.

This study has some limitations, which should be mentioned here. First, the sample size of subjects used to create the skin ages was relatively small, and the subjects only ranged in age from 20 to 50 years old. Also, among the Skin Age Index determined variables, dullness was the weakest correlation with age, so it is suggested that a smaller sample size in this study. Another limitation is that skin from individuals of different ethnicities and from different geographical regions was not analyzed, so there is a need for wider analysis in future work so that skin age can be measured more accurately in more statistical power and generalizability across a wide range of subjects with more sample size.

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Author Contributions

Conceptualization of this study and clinical investigation was performed by K.M., K.F., W.S., B.D., S.W., L.Y., and S.S. K.M. wrote the first draft of the manuscript, while all authors revised it. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Both studies were conducted in accordance with the tenets of the Declaration of Helsinki and approved by P&G Ethics Committee. Data acquisition and analysis were performed in compliance with protocols approved by the Ethical Committee of Global Product Stewardship in P&G Innovation Godo Kaisya (ethics approval numbers ES21-002 and KIC25-001). Written informed consent was obtained from all subjects prior to enrollment in the study.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this paper are available on request from the corresponding author. The data are not publicly available because of privacy restrictions.

Conflicts of Interest

All authors are employees of P&G Innovation GK.

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