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# Repeated measurements of facial skin characteristics using the Janus-III measurement system

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## Abstract

**Background:** For personalized skin care, noninvasive quantitative methods to evaluate facial skin characteristics are important. Janus-III is one of the most widely used imaging analysis devices in the skin care industry in Korea. Janus-III generates values for a range of skin characteristics. Due to the convenience of obtaining results for a variety of skin characteristics in a single measurement, the use of Janus-III in cosmetic stores and research institutes has been recently increasing. However, the consistency of skin measurements of Janus-III has not been elucidated yet.

**Materials and Methods:** In this study, we repeated skin measurements three times for 70 different subjects and compared each numerical value in order to assess the consistency of the Janus-III. For this purpose, we compared between-sample distances and within-sample distances.

**Results:** We found important patterns for future analyses in terms of consistency. First, the average values of skin measurement categories were more reliable than individual part values of facial segments. Second, center part values such as forehead and nose were more reliable than side part values such as left and right part segments.

**Conclusion:** If researchers who use Janus-III for studies of facial characteristics analyze average and center part values first, they can obtain relatively reliable patterns of facial skin characteristics.

KEYWORDS

facial skin characteristics, Janus-III, pigmentation, pore, porphyrin, repeated measurements, sebum, skin color, wrinkle

## 1 | INTRODUCTION

Following the remarkable upsurge in the interest for managing facial skin aging, and to support personalized skin care, devices for proper measurement of skin status are beneficial. Due to the continuous demand for noninvasive quantitative methods to objectively evaluate facial skin, many skin measurement devices using different measuring principles and algorithms have been proposed. For example, face wrinkles have been generally evaluated using a direct three-dimensional photographic analytical instrument such as Phase shift rapid in vivo measuring of human skin (PRIMOS®).[1] Also, casual sebum levels can be determined with a photometric device, Sebumeter, which measures the transparency of an opaque plastic tape pressed onto the skin to collect the sebum.[2] Skin elasticity

can be evaluated with Cutometer, one of the most commonly used instruments, which can obtain quantitative values using a suction method.[3] All of the above instruments can measure skin properties in a quantitative and reproducible manner.

With the development of digital imaging technology, skin imaging analysis instruments capable of quickly measuring a subject's overall skin conditions have been recently introduced in cosmetic dermatology.[4] Janus-III, manufactured by PIE Inc, is one of the most widely used imaging analysis devices in the skin care industry in Korea. Janus-III uses a high-resolution digital camera (Canon) to capture the entire face and in seconds generate three independent facial images using three light sources (normal light, polarized light, and ultraviolet light). The images, obtained from a single measurement, are analyzed with an internal algorithm and converted into numerical values that represent overall skin characteristics, such as skin color, wrinkle, pore, pigmentation, elasticity, sebum, and porphyrin. Due to the convenience of obtaining results for a variety of skin characteristics in a single measurement, the use of Janus-III in cosmetic stores and research institutes has been increasing recently.[5-9] However, the consistency and reliability of the numerical values generated by Janus-III for each skin characteristic still need to be confirmed.

In this work, we carried out measurements in 70 subjects, with measurements done in triplicate for each subject. These results were used to investigate the consistency of the Janus-III system, more specifically by comparing both between- and within-sample distances. Our findings show that the average values of categories are more reliable than individual part values of facial segments. Further, center part values such as forehead and nose segments are more reliable than side part values such as left and right segments. Therefore, if researchers using Janus-III for facial skin studies first perform analysis of average or center part values and then proceed with the comparison analysis of individual and side values, they can obtain relatively reliable patterns of facial skin characteristics. After, they can carry out analysis on detailed characteristics of facial skin.

## 2 | MATERIALS AND METHOD

### 2.1 | Subjects

A total of seventy healthy Koreans, including males and females, were recruited in January 2019. The gender and age of the participants were not included in the data collection as they were not considered essential for the experiment as it only analyses within-sample distances and between-sample distances. Every subject was fully informed about the research and signed an institutional review board (IRB)-approved written informed consent form.

### 2.2 | Janus-III Measurements

All subjects visited the skin evaluation center of LG Household & Health Care, where they asked to wash their face to remove any makeup or skin care regimen. After facial cleansing, the subjects waited in a room kept at 22 ± 2℃ and 45 ± 5% RH for 30 minutes to equilibrate their skin status. Then, subjects were photographed with a high-resolution Canon 100D camera using a Janus-III measurement system. All measurements were conducted three times per subject, and the consistency of the measurement values was analyzed. The Janus-III measurement system is illustrated in Figure 1.

Firstly, subjects were photographed with their forehead and chin fixed. Figure 1A shows the overall setup for the study, with the exception of a black blanket that was used during the real study in order to prevent unknown interferences during photographing. When obtaining facial images, three different light sources on Janus-III were used: normal light, polarized light, and ultraviolet light. Therefore, for each subject a set of three frontal images were generated, as shown in Figure 1B-D. Figure 1E shows the segments of the face that are automatically determined by the Janus-III system. The width, height, and position of the segments are then adjusted by a senior skin researcher. Segments consist of forehead (①), nose (②), corners of

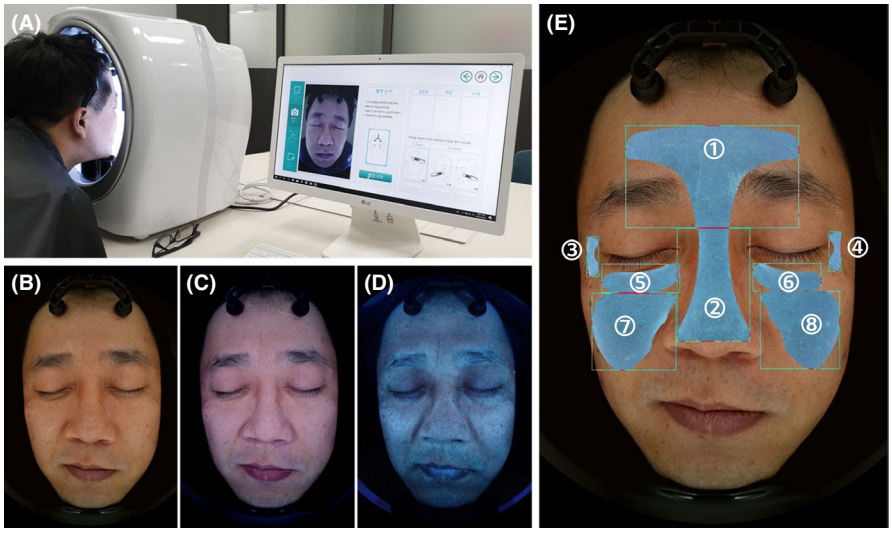


**FIGURE 1** Janus-III measurement system. A, Image acquisition, B, image with normal light, C, image with polarized light, D, image with ultraviolet light, and E, segmentations (①: forehead, ②: nose, ③: left eye corner, ④: right eye corner, ⑤: below left eye, ⑥: below right eye, ⑦: left cheek, and ⑧: right cheek)

left/right eyes (③, ④), below of left/right eyes (⑤, ⑥), and left/right cheeks (⑦, ⑧).

Most of the measurement values are calculated as the product of weights (intensity or degree of color difference) and areas. Area and weights are calculated using color differences between adjacent pixels in an image. With the exception of the color feature, measurement values are transformed into a 0-100 scale. The scale for the color feature is 0-255. Depending on the measurement category, different light sources and different combinations of face segments are used for calculating measurement values. Normal light images are used for features such as elasticity, pore, skin color, skin tone, and wrinkle categories. Polarized light images are used for features in the pigmentation category. Finally, ultraviolet light images are used for features in the pigmentation, porphyrin, and sebum categories. Fluorescent spots of ultraviolet light images are divided into "sebum" or "porphyrin" depending on the color threshold of Janus. *L*, *a*, and *b* in the skin color category are LAB-transformed color values for human perception friendly analysis. Features in the elasticity category are calculated based on the degree of pore angles.

### 2.3 | Statistical analysis

We carried out an analysis of comparison, both within- and between-sample differences. A within-sample difference (W) is a mean value of SD (standard deviation) values of three measurements from a single individual, and a between-sample difference (B) is a SD value of mean values for an individual's three measurement values. The W/B ratio is calculated as a within-sample difference divided by a between-sample difference. Thus, a low W/B ratio implies that the measured values are relatively reliable (consistent). All computations and statistical analyses were performed on R version 3.5.1. For the significance test of difference comparisons, we used a Wilcoxon signed-rank test, Kruskal-Wallis test, and *t* test.

## 3 | RESULTS

For each feature, we calculated within (W)- and between (B)-sample differences, ratios (W/B), and rank of the ratios and summarized the results in Table 1.

The ratio values represent the consistency of repeated measurements with low ratio values indicating a high consistency. Of the 77 features, 29 have ratio values lower than 0.1 and 61 have ratio values lower than 0.2. We found some interesting patterns in this table. Firstly, the ratio values of averages are relatively low (consistent) compared with the other features in the same categories. Secondly, the ratio values of some features using side segments (left/right) are relatively high (inconsistent). Therefore, we compared ratio values of groups based on different criteria as summarized in Figure 2.

In Figure 2, we used three different criteria for grouping: type of light source (A), average features, or the others (individual segments such as forehead or nose) (B) and center vs left vs right (C). Figure 2A shows that ratio values of ultraviolet lighted features are relatively lower than features lighted by normal and polarized light, but without statistical significance (the difference between ultraviolet and normal is not statistically significant using Wilcoxon rank-sum test but is statistically significant using t test). Differences are caused not only by differences in light source but also by differences in measurement algorithms. Specifically, pigmentations using polarized light show relatively lower ratio values than pigmentations using ultraviolet light, but the two categories measure different depth of pigmentations.

In Figure 2B, ratio values of segments' averages are lower than that of individual segments (the others). We inferred that this difference is due to the average being less sensitive to outlier values (smaller SD) compared with individual segment features. When carrying out a Wilcoxon rank-sum test, the difference is not statistically significant since this test only uses rank information. However, when carrying out a t test, the difference is statistically significant (*P*-value: .021, log-transformed *P*-value: .091), but the distribution of the ratio is not well matched to a normal distribution and well-matched distribution is unknown.

In Figure 2C, ratios of center segments (forehead and nose) are significantly lower than that of left or right segments as shown in Figure 2C. We inferred that features using center segments are relatively consistent because the Janus-III system uses only frontal facial images. Therefore, we hypothesize that features using the left or right side of face have a relatively large proportion of measurement errors.

In addition, we found some interesting patterns such as correlations between features. First, for the interpretation of the patterns, we represented values of repeated measurements for each sample using the same color and shape combinations in Figures 3 and 4. In Figure 3, the *x*-axis represents the average of sebum number and the *y*-axis the porphyrin average. Repeated measurement values are located relatively close (low ratio, consistent). We found some interesting patterns in Figure 3. Firstly, sebum number and porphyrin number show a strong positive correlation, which has also been previously reported.[10] As mentioned in the study, the red fluorescence in ultraviolet images is not only due to Propionibacterium acnes but also due to the secretion of sebum on the face. Therefore, "porphyrin" results using Janus should be interpreted with care. Secondly, we observed that samples divided into two groups, leaned to porphyrin or sebum. In order to confirm and further analyze this pattern, a study using a larger sample size is needed. Further analysis should include a detailed comparison of color difference between groups. Thirdly, we observed that the average sebum values in the "leaned to porphyrin" group were relatively consistent but that the average porphyrin values are relatively inconsistent, such as top pink and green snow pattern dots. Similarly, in the "leaned to sebum" group, average porphyrin values are relatively consistent, but sebum averages are relatively

**TABLE 1** Results of repeated measurements

| Light source | Category 1 | Category 2 | Area 1 | Area 2 | SD of means (*B*) | Mean of SDs (*W*) | Ratio (*W*/*B*) | Rank |
|---|---|---|---|---|---|---|---|---|
| Normal | Skin_color | L | | | 3.53 | 0.46 | 0.13 | 39 |
| | | a | | | 2.18 | 0.33 | 0.15 | 50 |
| | | b | | | 2.52 | 0.22 | 0.09 | 25 |
| | Skin_tone | Blue | Left | Cheek | 10.86 | 1.26 | 0.12 | 37 |
| | | | | Eye_below | 10.76 | 1.74 | 0.16 | 53 |
| | | | Right | Cheek | 11.21 | 1.22 | 0.11 | 36 |
| | | | | Eye_below | 10.42 | 1.78 | 0.17 | 55 |
| | | | | Forehead | 10.81 | 1.01 | 0.09 | 29 |
| | | | | Nose | 8.93 | 0.95 | 0.11 | 33 |
| | | | | Average | 9.88 | 1.06 | 0.11 | 35 |
| | | Green | Left | Cheek | 10.03 | 1.42 | 0.14 | 44 |
| | | | | Eye_below | 9.81 | 2.07 | 0.21 | 63 |
| | | | Right | Cheek | 10.76 | 1.40 | 0.13 | 40 |
| | | | | Eye_below | 10.24 | 2.01 | 0.20 | 61 |
| | | | | Forehead | 11.00 | 1.14 | 0.10 | 31 |
| | | | | Nose | 8.80 | 1.29 | 0.15 | 47 |
| | | | | Average | 9.51 | 1.27 | 0.13 | 43 |
| | | Red | Left | Cheek | 7.11 | 1.19 | 0.17 | 54 |
| | | | | Eye_below | 7.49 | 1.93 | 0.26 | 67 |
| | | | Right | Cheek | 7.62 | 1.32 | 0.17 | 56 |
| | | | | Eye_below | 8.05 | 2.10 | 0.26 | 69 |
| | | | | Forehead | 11.52 | 1.04 | 0.09 | 28 |
| | | | | Nose | 5.65 | 0.98 | 0.17 | 57 |
| | | | | Average | 7.29 | 1.10 | 0.15 | 49 |
| Ultraviolet | Porphyrin | Number | Left | Cheek | 73.12 | 4.32 | 0.06 | 11 |
| | | | Right | Cheek | 70.26 | 3.33 | 0.05 | 3 |
| | | | | Forehead | 207.33 | 11.80 | 0.06 | 10 |
| | | | | Nose | 102.61 | 6.75 | 0.07 | 14 |
| | | | | Average | 105.36 | 4.34 | 0.04 | 2 |
| | | Ratio | Left | Cheek | 20.40 | 6.92 | 0.34 | 75 |
| | | | Right | Cheek | 18.02 | 8.63 | 0.48 | 77 |
| | | | | Forehead | 13.85 | 3.59 | 0.26 | 68 |
| | | | | Nose | 15.64 | 4.68 | 0.30 | 71 |
| | | | | Average | 13.04 | 2.52 | 0.19 | 60 |
| | Sebum | Number | Left | Cheek | 93.02 | 6.17 | 0.07 | 18 |
| | | | Right | Cheek | 90.16 | 4.30 | 0.05 | 4 |
| | | | | Forehead | 264.88 | 14.77 | 0.06 | 8 |
| | | | | Nose | 102.79 | 6.81 | 0.07 | 16 |
| | | | | Average | 130.51 | 5.03 | 0.04 | 1 |

(Continues)

**TABLE 1** (Continued)

| Light source | Category 1 | Area1 | Area 2 | SD of means (*B*) | Mean of SDs (*W*) | Ratio (*W*/*B*) | Rank |
|---|---|---|---|---|---|---|---|
| Normal | Elasticity | Left | Cheek | 15.53 | 1.05 | 0.07 | 19 |
| | | Right | Cheek | 14.94 | 0.96 | 0.06 | 13 |
| | | | Average | 15.07 | 0.77 | 0.05 | 6 |
| | Pore | Left | Cheek | 11.86 | 0.80 | 0.07 | 20 |
| | | Right | Cheek | 11.60 | 0.73 | 0.06 | 12 |
| | | | Forehead | 9.07 | 0.96 | 0.11 | 32 |
| | | | Nose | 7.90 | 0.67 | 0.08 | 24 |
| | | | Average | 9.12 | 0.49 | 0.05 | 7 |
| | Skin_tone | Left | Cheek | 3.51 | 0.53 | 0.15 | 51 |
| | | | Eye_below | 3.56 | 0.79 | 0.22 | 66 |
| | | Right | Cheek | 3.72 | 0.49 | 0.13 | 41 |
| | | | Eye_below | 3.62 | 0.76 | 0.21 | 62 |
| | | | Forehead | 4.16 | 0.45 | 0.11 | 34 |
| | | | Nose | 2.91 | 0.39 | 0.13 | 42 |
| | | | Average | 3.36 | 0.49 | 0.14 | 45 |
| | Wrinkle | Left | Eye_corner | 11.21 | 2.10 | 0.19 | 59 |
| | | | Eye_below | 9.78 | 2.13 | 0.22 | 65 |
| | | Right | Eye_corner | 10.34 | 1.81 | 0.17 | 58 |
| | | | Eye_below | 9.94 | 3.03 | 0.30 | 72 |
| | | | Average | 8.89 | 1.35 | 0.15 | 52 |
| Polarized | Pigmentation | Left | Cheek | 9.23 | 0.61 | 0.07 | 17 |
| | | | Eye_corner | 9.60 | 3.01 | 0.31 | 73 |
| | | | Eye_below | 7.54 | 1.10 | 0.15 | 46 |
| | | Right | Cheek | 9.86 | 0.65 | 0.07 | 15 |
| | | | Eye_corner | 9.26 | 3.64 | 0.39 | 76 |
| | | | Eye_below | 6.67 | 1.42 | 0.21 | 64 |
| | | | Forehead | 9.11 | 0.82 | 0.09 | 27 |
| | | | Nose | 10.32 | 0.58 | 0.06 | 9 |
| | | | Average | 6.93 | 0.70 | 0.10 | 30 |
| Ultraviolet | Pigmentation | Left | Cheek | 11.70 | 0.79 | 0.07 | 21 |
| | | | Eye_corner | 12.92 | 3.40 | 0.26 | 70 |
| | | | Eye_below | 11.08 | 1.37 | 0.12 | 38 |
| | | Right | Cheek | 11.85 | 0.81 | 0.07 | 22 |
| | | | Eye_corner | 11.99 | 4.04 | 0.34 | 74 |
| | | | Eye_below | 9.95 | 1.46 | 0.15 | 48 |
| | | | Forehead | 8.81 | 0.65 | 0.07 | 23 |
| | | | Nose | 13.55 | 0.67 | 0.05 | 5 |
| | | | Average | 9.59 | 0.82 | 0.09 | 26 |

inconsistent, such as red and sky blue rhombus with diagonal line pattern dots. In further studies, we will aim to understand hidden or uncertain characteristics of facial skin.

In Figure 4, the *x*-axis represents the average of wrinkles, while the *y*-axis is the average of polarized pigmentations. The positive correlation between wrinkle and pigmentation is shown in Figure 4, but it is not as clear compared with the positive correlation pattern shown in Figure 3. We inferred that the relatively weak correlation is caused by differences in light source and difference in segments for two features. In Figure 3, the sebum average and the porphyrin average are calculated using the same four categories of ultraviolet light images. In the wrinkle category, only four segments

(around eyes) are measured, while in the polarized light pigmentation category, all eight segments are measured. We hypothesized that the highest proportion of this positive correlation is caused by common factors that affected both "wrinkle" and "pigmentation," such as age or lifestyle (eg, hours of outdoor activity and degree of skin care).

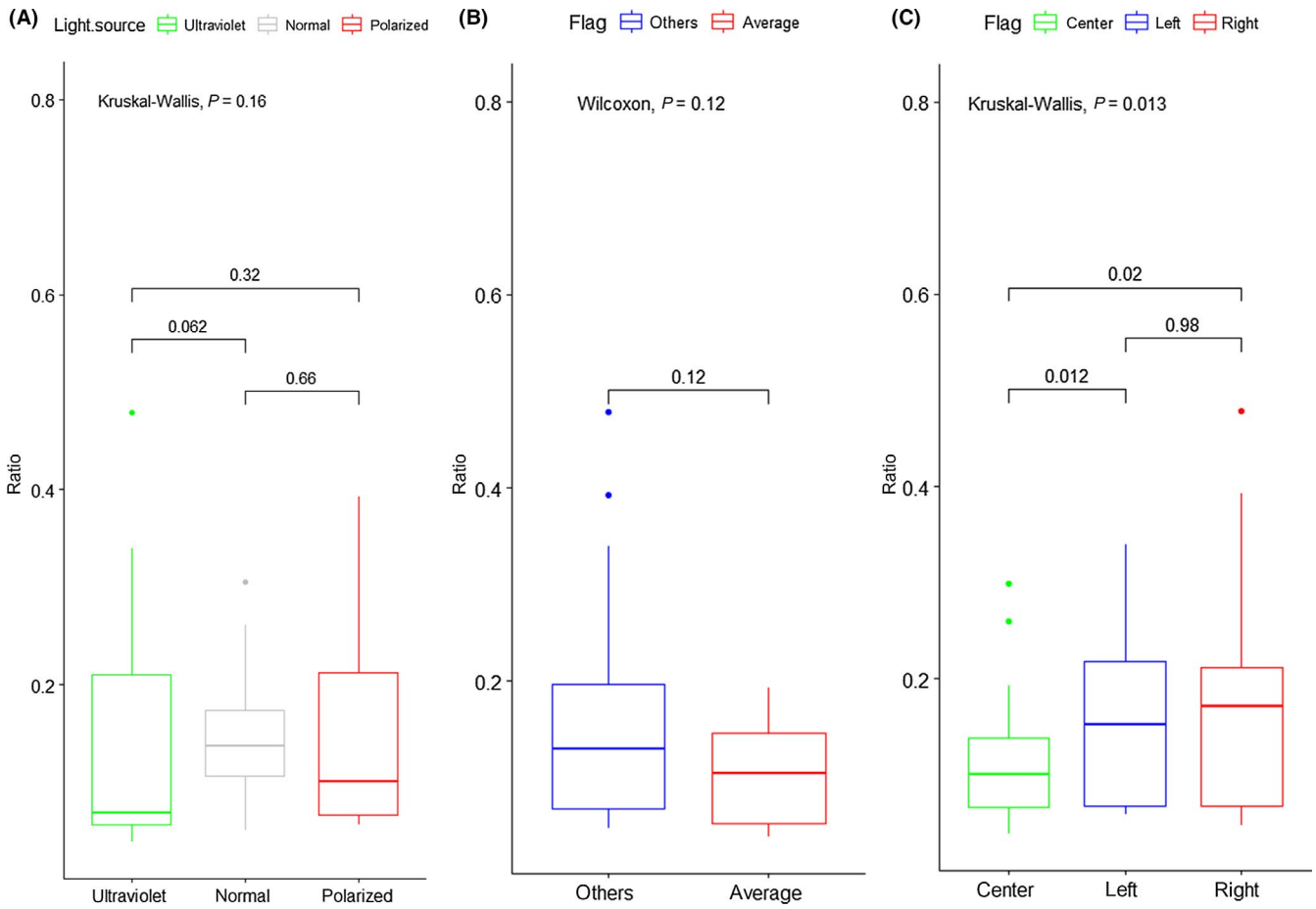


**FIGURE 2** Comparisons of ratio values. A, Different types of light source, B, average values vs other values, and C, left vs center vs right. P-values of the pair comparisons are represented above the line indicating pairs

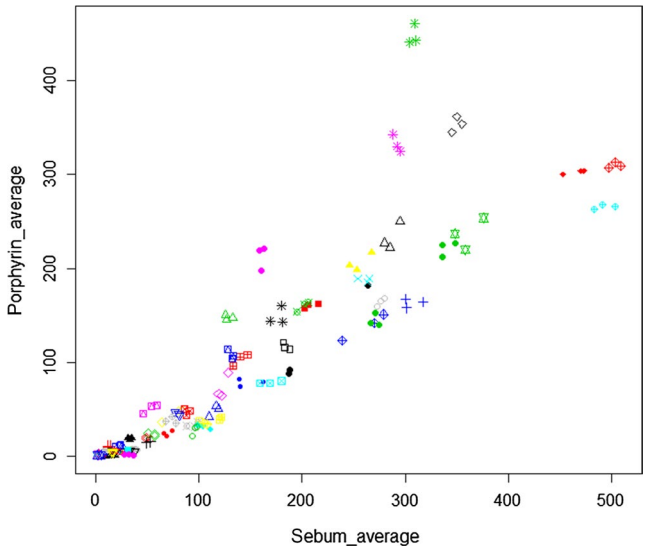


**FIGURE 3** Distribution of sebum average values and porphyrin average values. Color and shapes represent three values for each sample

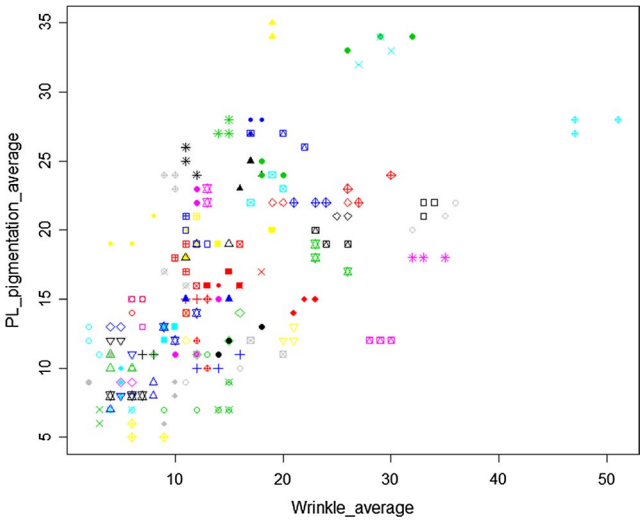


**FIGURE 4** Distribution of wrinkle average values and polarized pigmentation average values. Color and shapes represent three values for each sample

## 4 | DISCUSSION AND CONCLUSION

In recent studies, facial skin has been described as one of the major determinants of life quality. In addition, personalized skin care can be an optimal solution to overcome skin care obstacles due to the diversity of facial skin. For personalized skin care, noninvasive quantitative methods capable of objectively evaluating the characteristics of facial skin are important. In an aim to address this need, many skin measurement devices, using different measuring principles and algorithms, have been presented.

Janus-III is one of the most widely used imaging analysis devices in the skin care industry in Korea. Janus-III uses high-resolution images of the frontal face using three light sources including normal light, polarized light, and ultraviolet light in a single measurement. Images are analyzed with an internal algorithm and converted into numerical values that represent overall skin characteristics, such as skin color, wrinkles, pores, pigmentation, elasticity, sebum, and porphyrin. Due to the convenience of obtaining results for a variety of skin characteristics in a single measurement, the use of Janus-III in cosmetics stores and research institutes has been recently increasing.

The results of this study show that there are relative differences between measured features in terms of consistency. Average values for categories are more consistent than individual part values of categories, and values of central segments such as forehead and nose are relatively more consistent than that of the other segments. The consistency of average values can be explained by smaller variances of average than population variances. The consistency difference in central and side parts measurements are due to the use of frontal face image only, in Janus-III. Therefore, side face imaging can provide good supplementary data and thus enrich the study results.

Janus-III has the possibility of improving the measurement algorithms for skin characteristics. A previous study proposes an advanced algorithm for pore measurement,[11] which uses not only color differences between a pore and its adjacent parts, but also distance similarity between pores. Additionally, segmentation results are often not sufficiently accurate and therefore need to be manually adjusted. Using deep learning schemes, face landmark detectors may improve segmentation algorithms.[12] Janus-III has potential to discover new facial features.

In this study, we also found some interesting patterns using Janus-III, such as positive correlations by simple analysis. Researchers using Janus-III for facial skin studies will obtain reliable results if they concern about the consistency results of this study.

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### CONFLICTS OF INTEREST

All authors have no conflict of interest to declare.

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