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Analysis of Sasang constitutional types using facial features with compensation for photographic distance

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ABSTRACT

Background: Facial features are regarded as representative and reliable characteristics for diagnosing a person's Sasang Constitution (SC). However, the description of these features tends to depend on the interpretation and the opinion of the doctor that follows the SC approach. In this paper, we performed a facial feature analysis of SC types in an objective and quantitative manner. Here, site-to-site variability can be an obstacle to properly analyzing facial features when images are taken from various sites, which may have different experimental environments. A compensation technique to reduce the site-to-site variability was proposed before performing the feature analysis.
Methods: The frontal and profile images of 1464 patients recruited from various oriental medical clinics (19 sites) were used. Candidate feature variables were created, which were inspired by the facial characteristics of the SC types described in the Sasang constitutional medicine literature. To resolve the problems involved in processing data collected from various sites with heterogeneous experimental environments, a compensation technique was proposed. Statistical analysis techniques were employed to observe the differences among the SC types and to demonstrate how effectively the site-to-site variability was reduced.
Results: The facial features that were significant for diagnosing the SC types were identified by a statistical analysis, and it was verified that the compensation technique reduced the site-to-site variability produced by the differences in photographic distance.
Conclusion: It is noted that the significant facial features represent common characteristics of each SC type in the sense that we collected extensive opinions from many Sasang constitutional medicine doctors with various points of view. Additionally, a compensation method for the photographic distance is needed to find the significant facial features. We expect these findings and the related compensation technique to contribute to establishing a scientific basis for the precise diagnosis of SC types in clinical practice.

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1. Introduction

Sasang constitutional medicine (SCM) is a unique Korean constitution-based medicine, which was devised by Jae-Ma Lee and systematically theorized in his book *Dong-Yi-Soo-Se-Bo-Won* (*The Principle of Life Preservation in Oriental Medicine*) in 1894. According to the SCM perspective, human beings can be classified into four constitutional types: Tae-Yang (TY), So-Yang (SY), Tae-Eum (TE), and So-Eum (SE). These types have typically distinct characteristics in terms of equilibrium among internal organ functions, external appearance, personality traits, and their responses to drugs and treatment.[1–6] The constitutional approach of SCM has received attention because of its utility for individualized therapy; SCM can help patients avoid unnecessary side-effects while increasing efficacy by prescribing the appropriate medicine for each constitutional type.[1,2] Before prescription, therefore, the patient's constitution is diagnosed in a noninvasive way based on an analysis of factors, such as external appearance, voice, and personality traits, by SCM doctors' five senses.[5,6] Facial features, in particular, have been firmly regarded by SCM doctors as representative and reliable characteristics for distinguishing among Sasang constitutional (SC) types.[7] The facial characteristics of the SC types have been described in the classical SCM literature, but these descriptions are rather subjective, abstract, and nonquantitative.[8–16] For these reasons, SCM classification tends to depend on the interpretation and opinion of the SCM doctor.[6]

In an effort to establish a quantitative standard for SC diagnosis, many recent studies have attempted to analyze the facial features of each SC type using objective methods.[17–20] Yun[17] divided 1035 participants into six subgroups according to age and gender and identified significant facial features for each group among 629 feature candidates; the participants were recruited from two oriental hospitals. Koo et al.[18] acquired 493 patients from five oriental hospitals without considering any subgroups, and they found statistically significant features from a large number of feature candidates only in frontal face images. Pham et al.[19] analyzed the frontal face images of 911 participants by examining the differences in widely-used facial metrics; the SC type was determined by two experienced SCM specialists. These previously described results may not, however, reflect the overall generality of the approach, in the sense that the participants demonstrating the different facial appearances among the SC types were collected from very few sites. In particular, differences might occur in the determination of SC types based on the subjective response of patients after taking constitution-specific pharmaceuticals or on SCM doctors' subjective opinions and experiences.

The purpose of this study was to identify the significant facial features of the SC types without subjective bias and to suggest a standard for the precise diagnosis of SC types by analyzing frontal and profile images acquired from various oriental medical clinics (19 sites in total). A large amount of data acquired from various sites is helpful to reflect the overall generality of facial characteristics for each SC type; however, the site-to-site variability can be an obstacle to properly analyzing facial features. To reduce the systematic errors caused by the differences in the data acquisition environments at different sites, we compensated for the conversion errors from pixels to millimeters in calculating the feature variables. The candidate features were taken from the SCM literature, and a statistical data analysis was performed on subgroups divided according to age (30–49 and 50–69) and gender.

2. Methods

2.1. Participants

A total of 1847 patients ranging in age from their thirties to their sixties were recruited from 19 sites (oriental medical clinics) between 2007 and 2010. The patients' SC types were confirmed by SCM doctors who observed their improvements after the administration of constitution-specific pharmaceuticals over one month. The procedure of determining SC types is described specifically by Song,[20] and all data containing clinical information were stored in the Korea Constitution Multi-center Bank at the Korea Institute of Oriental Medicine.

2.2. Data acquisition

The subjects were photographed with a neutral expression in both frontal and profile views under the following standard conditions: the hair should be pulled back with a hair band; the center points of the two pupils and the two points connected between the facial contour and upper auricular perimeters should be on the same horizontal line; and a ruler should be placed approximately 10 mm below the chin to convert pixels into millimeters. This process was approved by the Korea Institute of Oriental Medicine Institutional Review Board (I-0910/02-001).

2.3. Candidate feature variables

Candidate feature variables were determined to express the facial characteristics described in the SCM literature. The variables were limited to ones that could be easily quantified. The facial characteristics delineated in the SCM literature and the feature variables are described in Tables 1 and 2, respectively, and the positions of the numbered facial points are shown in Fig. 1.

2.4. Measurement

The *x* and *y* coordinates of 16 points in a frontal image and 12 points in a profile image were marked and recorded in pixel units by a well-trained operator with self-developed software. The reliability of the operator's marking process was verified by a test–retest on 15 randomized images, which showed a low coefficient of variation (0.40 ∼5.53%).

2.5. Compensating for the conversion error

In the cases in which the location of the ruler was not aligned to the line representing the width of the face contour, such as FW33 and FW43 (see Fig. 2), the value of the variable converted from pixels to mm using only the ruler information

Table 1 – Facial characteristics according to Sasang constitution types described in Sasang constitution medicine literature.[8]

	TE	SE	SY	TY
Face shape	Broad jaw, grave[10] Broad face and head, broad jaw[15]	Roundish[11] Mostly roundish or long face[10] Curly hair[14] Moon-shaped, oval face[15] Long or roundish face[16]	Bulging head or small roundish head[10,12] Stiff and coarse forelock[14] Small or bulging head[15]	Clear-cut face[10,11,15] Well-developed head[11] Prominent cheekbones, roundish face[13] Large head[15]
Forehead	Flat[15]	Slightly bulging[13,15]	Broad[15] Bulging toward the center[16]	Broad[13,15]
Eye	Jet-black eyes[12] Big, upward slanting tiger-like eyes[13] Big eyes[15]	Smiley eyes[13] Downward slanting, small eyes[15]	Clear eyes[10] Glittering, protruding eyes[12] Bright eyes[13] Big and cheerful eyes[15]	Bright eyes[13,15]
Nose	Upturned nose with large nostrils[12] Big nose[13,15] Bulbous nose[14,15]	Small nose[15]	High-bridged nose[15]	High-bridged nose[15]
Mouth	Thick lips[11,13,15]	Big mouth[12] Small mouth[15]	Thin lips[10,11,12,13] Small mouth[13]	

SE, So-Eum; SY, So-Yang, TE, Tae-Eum; TY, Tae-Yang.

was different from the actual length. The difference is given in Equation (1).

$$y' = \frac{d+x}{d} y \qquad (1)$$

We found that the distance (d) between the camera and the subject was different at each site and could vary whenever the photographic location was changed because of spatial limitations. If the photographic distance was not long enough, it could significantly affect the difference between the actual length (y') and the length (y) determined using only the ruler information. The values of the converted length variable might exhibit site-based variability because of the different photographic distances in the absence of compensation for this difference during the conversion.

To compensate for the conversion error given by Equation (1), the photographic distance (d) and the distance between y and y' (x) were required.

The photographic distance (d) from an image could be calculated using the following equation:

$$d = \frac{100_{mm}}{Ruler_{mm}} \cdot f \qquad (2)$$

Table 2 – Feature variables expressing the facial characteristics.

	Size-related variables	Shape-related variables
Face shape	Width: FW33*, FW43 Height: FD(47,51)†, FD(52,51)	Ratio: FW33/FD(47,51), FW33/FD(52,51), FW43/FD(47,51), FW43/FD(52,51) Angle: FA(33,43,51)¶
Forehead	Height: PDV(6,9)§, PDV(7,9), PDV(6,7), PDV(6,9)	Angle: PA(6,7,9)¶, PA(9,7)‖, PA(9,6), PA(9,12) Ratio: PD(77,9)†/PD(6,9), PDV(7,9)/PDV(6,9) Distance: PD(7,77)
Eye	Width: FDH(18,25)‡ Height: FDV(17,26)§	Angle: FA(25,18)‖, FA(25,17), FA(25,26), FA(17,18), FA(18,17,25) Ratio: FDV(17,26)/FDH(18,25)
Nose	Width: FW35, PDH(12,14)‡ Height: PDV(12,14) Distance: PD(12,14) Area: PR(12,14,21)**	Angle: PA(14,12), PA(14,21), PA(12,14,21) Ratio: FD(52,49)/FW35
Mouth	Width: FW40	Height: FDV(38,50)

* FWn: distance from a point n to the central vertical line in a frontal image.
† FD(n_1, n_2) (or PD(n_1, n_2)): distance between point n_1 and n_2 in a frontal (or profile) image.
‡ FDH(n_1, n_2) (or PDH(n_1, n_2)): horizontal distance between n_1 and n_2 in a frontal (or profile) image.
§ FDV(n_1, n_2) (or PDV(n_1, n_2)): vertical distance between n_1 and n_2 in a frontal (or profile) image.
‖ FA(n_1, n_2) (or PA(n_1, n_2)): angle between the line through two points, n_1 and n_2, and a horizontal line in a frontal (or profile) image.
¶ FA(n_1, n_2, n_3) (or PA(n_1, n_2, n_3)): angle between three points, n_1, n_2 and n_3, in a frontal (or profile) image.
** PR(n_1, n_2, n_3): area of the triangle formed by three points, n_1, n_2, and n_3, in a profile image.

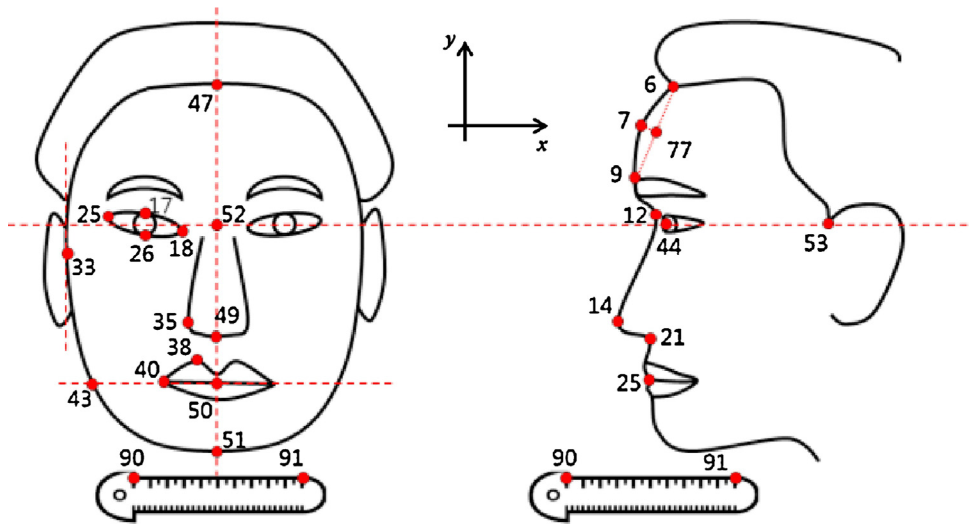

Fig. 1 – Facial points used to calculate candidate feature variables.

where

$$Ruler_{mm} = Ruler_{pixel} \cdot \frac{CCD\_width_{mm} \cdot \sqrt{\frac{E\_pixels}{T\_pixels}}}{Image\_width_{pixel}}, \quad (3)$$

in which:

- $Ruler_{mm}$: length of a 100 mm gradation on the ruler projected on the charge coupled device (CCD) in mm;
- $Ruler_{pixel}$: length of a 100 mm gradation on the ruler in the image (pixels);
- CCD_Width_{mm}: CCD width of the camera in mm;
- E_pixels: the number of effective pixels for the camera;
- T_pixels: the number of total pixels for the camera;
- $Image\_width_{pixel}$: the width of the image (pixels); and
- f: focal length when the image was taken in mm.

Here, $Ruler_{pixel}$ was acquired by manual pointing in the image, and $Image\_width_{pixel}$, f, and the camera model information were obtained from the "*Exchangeable image file format*" (Exif) information stored in the image file. CCD_Width_{mm}, E_pixels, and T_pixels were surveyed separately based on the camera model information.

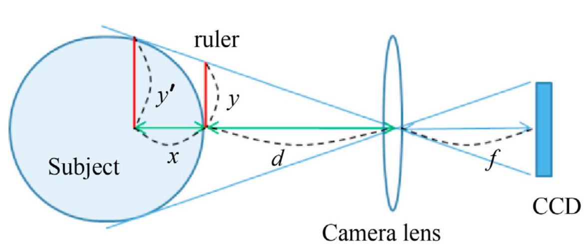

Fig. 2 – Photographing a frontal face image (upper view) where y′ is the actual length of a variable, y the length converted from pixel to mm units with the ruler information, x the distance between y and y′, d the photographic distance, and f the focal length. CCD, charge-coupled device.

To calculate the distance between y and y′ (x), we assumed, heuristically, that x was two-thirds of PDH(44,53) because it was difficult to estimate the exact location of y′ in the image. The descriptive statistics for the photographic distance estimated by Equations (2) and (3) for each site are given in Supplementary table* S1.

2.6. *Data filtering*

Before the facial analysis was conducted using the feature variables extracted from the images of the subjects, the samples that did not satisfy the following conditions were excluded.

First, 250 images were excluded that contained considerable noise due to the photography taking place in a dark location or without following the standard conditions, described in section 2.2.

The subjects of two sites whose SC type was TY ($n = 41$) were excluded because the proportion of TY types was extremely small (according to the SCM literature, TY types are less than 0.1% of the whole population[9]) compared with the number of other SC types in our study, meaning they might skew the normal assumption in classical statistical data analysis.

Seventy-four samples were excluded because the candidate features contained at least one missing value. These omissions occurred because of the ambiguity of marking the predefined points on the images or because the Exif information necessary to estimate the photographic distance was missing.

Eighteen outliers were eliminated from the dataset based on the results of the multivariate outlier detection method, which combines Stahel-Donoho's outlyingness measure[21] and the adjusted boxplot proposed by Vandervieren.[22]

Table 3 – Population distribution of the subjects according to Sasang constitution type.

	Age (y)	Sasang constitution types			
		TE (%)	SE (%)	SY (%)	Total (%)
Male	30–49	109 (41.4)	74 (28.1)	80 (30.4)	263 (52.0)
	50–69	120 (49.4)	43 (17.7)	80 (32.9)	243 (48.0)
	Subtotal	229 (45.3)	117 (23.1)	160 (31.6)	506 (100.0)
Female	30–49	173 (31.6)	162 (29.6)	212 (38.8)	547 (57.1)
	50–69	173 (42.1)	97 (23.6)	141 (34.3)	411 (42.9)
	Subtotal	346 (36.1)	259 (27.0)	353 (36.8)	958(100.0)
Total		575 (39.3)	376 (25.7)	513 (35.0)	1464

SE, So-Eum; SY, So-Yang; TE, Tae-Eum.

Ultimately, the data from 1464 participants from 19 sites were analyzed, and the distribution as a function of the SC type is shown in Table 3.

2.7. Statistical analysis

By treating each candidate facial feature as a response variable, univariate one-way analysis of variance (ANOVA) and a *post hoc* test using Scheffe's multiple comparison method were applied to reveal and identify the differences among the SC types. The significance level in all statistical tests was set at $\alpha = 0.05$.

To demonstrate how effectively the conversion error compensation procedure for certain facial features reduced the site-to-site variability, a variance component analysis using a mixed-effects model[23] was employed.

This analysis addressed the total variation in the dependent variables that could be attributed to fixed factors, random factors, and covariates. Here, FW33 and FW43, influenced by the photographic distance, were used as dependent variables to build the mixed-effect models, and the models incorporated the following factors: *GENDER* (male and female), *SC* (TE, SE, and SY types), and *AGE* (30–49 and 50–69 years) as fixed factors; *SITE* (site where the subject was recruited) as a random factor; and *distance* (photographic distance) as a covariate.

With the assumption that the determination of SC types was correlated with each site, all potential variability due to the site with two-way, three-way and four-way interaction terms was allowed. To verify all possible variance due to the site, the preliminary mixed model considering FW33 and FW43 (dependent variables, *DV*) was established with the following form:

$$DV = \mu + SC + GENDER + AGE + distance + SC * distance + GENDER * AGE + SITE + SC * SITE + GENDER * SITE + AGE * SITE + GENDER * AGE * SITE + SC * GENDER * AGE * SITE + \varepsilon \quad (4)$$

where the residual term (ε) was assumed to be independently and identically normally distributed with a mean of zero with a constant variance σ^2. The parameters of each term in the model were estimated using a restricted maximum likelihood algorithm,[24] and Wald's Z-test[25] was used to reveal the significance of each estimated covariance in the random effects.

From the result of the preliminary mixed model analysis shown in Supplementary table* S2, the reduced model was rebuilt as follows by excluding the nuisance terms whose variance components were estimated to be nearly zero:

$$DV = \mu + SC + GENDER + AGE + distance + GENDER * AGE + SITE + SC * SITE + AGE * SITE + \varepsilon \quad (5)$$

To verify the variability due to the photographic distance in each dependent variable, new dependent variables, denoted by $FW33_{adj}$ and $FW43_{adj}$, were created that adjusted FW33 and FW43 by using Equation (1), and three different models were established:

$$\text{Model } 1-1: \; FW33 = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + \varepsilon \quad (6a)$$

$$\text{Model } 2-1: \; FW43 = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + \varepsilon \quad (6b)$$

$$\text{Model } 1-2: \; FW33 = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + distance + \varepsilon \quad (7a)$$

$$\text{Model } 2-2: \; FW43 = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + distance + \varepsilon \quad (7b)$$

$$\text{Model } 1-3: \; FW33_{adj} = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + distance + \varepsilon \quad (8a)$$

Table 4 – Significant feature variables associated with the Sasang constitution types.

		30–49				50–69			
Face Shape	**Male**	**TE (n = 109)**	**SE (n = 74)**	**SY (n = 80)**	**F**	**TE (n = 120)**	**SE (n = 43)**	**SY (n = 80)**	**F**
	FW33	77.190 ± 4.690[a]	74.580 ± 4.016[b]	75.550 ± 4.712[ab]	7.82‡	75.380 ± 4.896[a]	72.570 ± 5.951[b]	73.400 ± 4.874[ab]	6.40†
	FW43	69.290 ± 5.453[a]	65.050 ± 4.545[b]	66.450 ± 5.163[b]	16.50‡	68.000 ± 6.524[a]	64.120 ± 6.569[b]	65.000 ± 5.491[b]	8.92‡
	FD(47,51)	199.000 ± 10.830	198.300 ± 11.150	200.200 ± 11.770	0.60	201.600 ± 12.670[a]	196.000 ± 14.140[b]	200.500 ± 12.020[ab]	3.14*
	FW33/FD(47,51)	0.388 ± 0.024[a]	0.377 ± 0.026[b]	0.378 ± 0.022[b]	6.48†	0.375 ± 0.026	0.371 ± 0.025	0.367 ± 0.022	2.57
	FW33/FD(52,51)	0.628 ± 0.040[a]	0.610 ± 0.038[b]	0.615 ± 0.035[ab]	5.81†	0.612 ± 0.042	0.602 ± 0.036	0.602 ± 0.036	1.82
	FW43/FD(47,51)	0.349 ± 0.030[a]	0.329 ± 0.029[b]	0.333 ± 0.028[b]	12.4‡	0.338 ± 0.035	0.327 ± 0.029	0.325 ± 0.028	4.63*
	FW43/FD(52,51)	0.564 ± 0.048[a]	0.532 ± 0.043[b]	0.532 ± 0.045[b]	12.1‡	0.552 ± 0.057	0.532 ± 0.043	0.533 ± 0.045	4.38*
	FA(33,43,51)	131.700 ± 4.743[a]	134.600 ± 6.015[b]	134.600 ± 5.424[b]	8.86‡	131.600 ± 4.576[a]	133.400 ± 4.460[ab]	133.700 ± 5.211[b]	5.25†
	Female	**TE (n = 173)**	**SE (n = 162)**	**SY (n = 212)**	**F**	**TE (n = 173)**	**SE (n = 97)**	**SY (n = 141)**	**F**
	FW33	72.590 ± 3.796[a]	70.260 ± 3.779[b]	71.140 ± 3.611[b]	16.90‡	72.420 ± 4.773[a]	70.350 ± 4.498[b]	70.770 ± 3.964[b]	8.68‡
	FW43	63.520 ± 4.021[a]	60.120 ± 4.312[b]	61.070 ± 4.153[b]	30.40‡	64.250 ± 5.273[a]	61.280 ± 4.951[b]	62.530 ± 4.970[b]	11.40‡
	FD(52,51)	116.300 ± 5.524	115.200 ± 5.559	115.200 ± 5.473	2.37	117.800 ± 6.460	116.300 ± 6.110	116.000 ± 5.870	4.03*
	FW33/FD(47,51)	0.385 ± 0.021[a]	0.374 ± 0.023[b]	0.377 ± 0.020[b]	12.50‡	0.381 ± 0.024	0.372 ± 0.026	0.377 ± 0.026	4.06*
	FW33/FD(52,51)	0.625 ± 0.035[a]	0.610 ± 0.034[b]	0.618 ± 0.033[ab]	7.64‡	0.615 ± 0.038[a]	0.606 ± 0.043[b]	0.611 ± 0.038[ab]	1.81
	FW43/FD(47,51)	0.337 ± 0.023[a]	0.320 ± 0.026[b]	0.323 ± 0.024[b]	23.10‡	0.338 ± 0.028[a]	0.324 ± 0.029[b]	0.333 ± 0.031[ab]	7.03‡
	FW43/FD(52,51)	0.547 ± 0.039[a]	0.522 ± 0.040[b]	0.531 ± 0.038[b]	17.50‡	0.546 ± 0.046[a]	0.528 ± 0.046[b]	0.540 ± 0.045[ab]	5.02†
	FA(33,43,51)	133.100 ± 3.872[a]	135.300 ± 4.000[b]	134.700 ± 3.760[b]	14.70‡	132.000 ± 4.326	132.900 ± 4.058	133.000 ± 4.624	2.25
Forehead	**Male**	**TE (n = 109)**	**SE (n = 74)**	**SY (n = 80)**	**F**	**TE (n = 120)**	**SE (n = 43)**	**SY (n = 80)**	**F**
	PA(9, 6)	61.280 ± 6.366[ab]	62.690 ± 5.135[a]	60.230 ± 5.795[b]	3.39*	59.650 ± 6.068	61.150 ± 6.258	59.350 ± 6.228	1.82
Eye	**Male**	**TE (n = 109)**	**SE (n = 74)**	**SY (n = 80)**	**F**	**TE (n = 120)**	**SE (n = 43)**	**SY (n = 80)**	**F**
	FA(25,17)	19.290 ± 4.427	20.400 ± 5.075	19.520 ± 3.920	1.41	20.160 ± 4.469[a]	22.460 ± 3.606[b]	21.170 ± 4.861[ab]	4.42*
	FA(18,17,25)	135.300 ± 7.923	132.800 ± 7.520	133.800 ± 6.812	2.55	136.700 ± 7.470[a]	133.100 ± 7.457[b]	135.300 ± 7.610[ab]	3.71*
	Female	**TE (n = 173)**	**SE (n = 162)**	**SY (n = 212)**	**F**	**TE (n = 173)**	**SE (n = 97)**	**SY (n = 141)**	**F**
	FDH(18,25)	29.370 ± 2.604a	28.330 ± 2.098[b]	28.600 ± 2.468[b]	8.60‡	28.200 ± 2.766[a]	27.260 ± 2.742[b]	27.710 ± 2.673[ab]	3.89†
	FDV(17,26)	1.801 ± 1.340	1.983 ± 1.245	2.140 ± 1.348	3.17*	1.543 ± 1.133	1.576 ± 1.178	1.752 ± 1.323	1.25
	FDV(17,26)/FDH(18,25)	0.062 ± 0.047a	0.071 ± 0.046[ab]	0.077 ± 0.050[b]	4.17*	0.055 ± 0.041	0.058 ± 0.044	0.064 ± 0.050	1.60
	FA(25,18)	-3.029 ± 3.257a	-3.616 ± 3.186[ab]	-3.974 ± 3.362[b]	3.98*	-1.967 ± 3.409	-1.624 ± 3.837	-2.607 ± 3.847	2.28
	FA(25,17)	21.230 ± 4.491a	22.630 ± 4.107[b]	21.460 ± 4.009[a]	5.43†	21.710 ± 4.138[a]	23.460 ± 4.690[b]	21.480 ± 3.865[a]	7.36‡
	FA(25,26)	7.079 ± 5.609	8.287 ± 5.442	8.503 ± 5.719	3.40*	5.800 ± 6.211[ab]	4.112 ± 7.002[a]	6.220 ± 6.519[b]	3.24*
	FA(17,18)	30.740 ± 4.722[a]	31.910 ± 4.385[ab]	32.300 ± 4.488[b]	5.92†	26.800 ± 4.890	27.290 ± 4.853	27.050 ± 4.728	0.32
	FA(18,17,25)	128.000 ± 7.214[a]	125.500 ± 6.747[b]	126.200 ± 6.545[b]	6.38†	131.500 ± 7.328[a]	129.300 ± 7.096[b]	131.500 ± 6.542[a]	3.73†

Table 4 (Continued)

Nose	TE (n = 109)	SE (n = 74)	SY (n = 80)	F	TE (n = 120)	SE (n = 43)	SY (n = 80)	F
Male								
FW35	21.690 ± 1.332	21.180 ± 1.525	21.600 ± 1.641	2.78	22.160 ± 1.777^{a}	21.220 ± 1.921^{b}	21.440 ± 1.768^{ab}	$6.23^{\dagger}$
PDV(12,14)	37.670 ± 3.951	39.150 ± 4.230	38.690 ± 4.187	3.16^{*}	38.210 ± 4.389	38.570 ± 3.786	38.680 ± 4.341	0.32
FD(52,49)/FW35	2.285 ± 0.177	2.351 ± 0.240	2.339 ± 0.241	2.51	2.244 ± 0.237^{a}	2.322 ± 0.231^{ab}	2.354 ± 0.219^{b}	$5.94^{\dagger}$
PA(14,12)	56.760 ± 4.980	58.560 ± 4.892	57.920 ± 4.392	3.33^{*}	57.460 ± 4.917	57.270 ± 4.882	58.060 ± 4.751	0.51
PA(14,21)	43.900 ± 6.601^{a}	40.270 ± 7.445^{b}	42.330 ± 6.963^{ab}	$5.99^{\dagger}$	44.430 ± 8.359	43.240 ± 6.749	44.000 ± 7.067	0.39
Female	TE (n = 173)	SE (n = 162)	SY (n = 212)	F	TE (n = 173)	SE (n = 97)	SY (n = 141)	F
FW35	20.050 ± 1.436^{a}	19.370 ± 1.461^{b}	19.720 ± 1.479^{ab}	$9.11^{\ddagger}$	20.870 ± 1.799^{a}	20.220 ± 1.766^{b}	20.120 ± 1.596^{b}	$8.67^{\ddagger}$
FD(52,49)/FW35	2.378 ± 0.223^{a}	2.477 ± 0.244^{b}	2.420 ± 0.237^{ab}	$7.49^{\dagger}$	2.322 ± 0.223	2.326 ± 0.229	2.354 ± 0.219	0.85

Each value represents mean ± standard deviation. Asterisks on F statistics indicate the magnitude of the *p*-value: *($p < 0.05$), †($p < 0.01$), ‡($p < 0.001$). Alphabetic notations (a, b, ab) indicate homogeneous subgroups resulting from the *post hoc* test applying Sheffe's method.
SE, So-Eum; SY, So-Yang; TE, Tae-Eum.

$$\text{Model } 2-3: \ FW43_{adj} = \mu + SC + GENDER + AGE + GENDER * AGE + SITE + SC * SITE + AGE * SITE + distance + \varepsilon \qquad (8b)$$

The first model was built without the covariate of photographing distance (Model 1–1 and Model 2–1), and the second model was built by adding the photographic distance term (Model 1–2 and Model 2–2) to verify the effect of the photographing distance. Finally, the model for the new adjusted variables $FW33_{adj}$ and $FW43_{adj}$ was built (Model 1–3, Model 2–3) to verify that the compensation for the conversion error reduced the variability caused by the differences between the sites.

3. Results

The significant face shape feature variables selected from the results of the one-way ANOVA are listed in Table 4. The results for all facial features are given in Supplementary Tables S3 to S7.

3.1. *Significant face shape features*

The size-relative features for the cheekbone and jaw half-width, FW33 and FW43, and the shape-relative features, FW43/FD(47,51) and FW43/FD(52,51), which represent the ratio of facial horizontal width to vertical length, showed significant differences among the SC types in all subgroups; the TE type had a wider cheekbone and jaw than the SE type.

Two other facial features associated with the ratio of the half-width of cheekbone to vertical face-lengths, FW33/FD(47,51) and FW33/FD(52,51), were statistically significant in specific subgroups: all subgroups except the male aged 50–69 group for FW33/FD(47,51) and the aged 30–49 groups for FW33/FD(52,51). The result of the *post hoc* test indicated that the TE type had a larger ratio than the SE and SY types for FW33/FD(47,51); similarly, the TE type had a larger ratio than the SE type for FW33/FD(52,51).

Another facial feature relevant to the shape of the jaw line, FA(33,43,51), showed statistically significant differences in all subgroups except the female aged 50–69 group, where the TE type had a wider and more bulged jaw than the other SC types.

3.2. *Significant forehead features*

There were no significant forehead features that could be used to distinguish among the SC types except PA(9,6), which describes the slope of the forehead in the male aged 30–49 group. The SY type had a more slanted forehead, whereas the SE type had a less slanted forehead.

3.3. *Significant eye features*

The differences among the SC types in terms of characteristic eye features typically appeared in the female groups. The mean value of FDH(18,25), which was a measure of the

Table 5 – Estimates of the Parameters for Models 1–1 through 1–3.

		Model 1–1		Model 1–2		Model 1–3	
		Estimated parameter	SE	Estimated parameter	SE	Estimated parameter	SE
Fixed effects	*Intercept*	75.15‡	0.510	70.950‡	0.654	78.040‡	0.687
	[SC = SE] vs. TE	-2.156‡	0.347	-2.113‡	0.358	-2.297‡	0.382
	[SC = SY] vs. TE	-1.774‡	0.333	-1.733‡	0.345	-1.887‡	0.369
	[*GENDER* = 1] vs. 0§	-3.017‡	0.325	-3.006‡	0.318	-3.318‡	0.337
	[*AGE* = 0] vs. 1§	1.665‡	0.360	1.764†	0.377	1.971†	0.407
	[*GENDER* = 1]*[*AGE* = 0]§	-1.645‡	0.440	-1.641‡	0.430	-1.783‡	0.457
	Distance			0.003‡	0.000	0.001	0.000
Random effects	*SITE*	2.768*	1.094	1.611*	0.742	1.608*	0.761
	*SC * SITE*	0.286	0.237	0.365	0.250	0.423	0.290
	*AGE * SITE*			0.110	0.158	0.156	0.196
	Residuals	15.550‡	0.585	14.780‡	0.558	16.650‡	0.628

The t-test result for fixed effects and Wald's Z-test for random effects: *($p < 0.05$), †($p < 0.01$), ‡($p < 0.001$).
§Dummy variables: *GENDER* = 0: male, *GENDER* = 1: female, *AGE* = 0: 30–49, *AGE* = 1: 50–69.

eye width, was greater in the TE type and smaller in the SE type than in the other SC types. FA(18,17,25), representing the shape of the upper eyelid, showed statistical significance. The female aged 30–49 TE type had a flatter eye shape, and the female aged 50–69 SE group had a more rounded eye shape. The feature values measuring the rate of vertical eye height with respect to the horizontal width FDV(17,26)/FDH(18,25) and the slant of the eye (FA(25,18), FA(17,18)) only showed significant differences in the female aged 30–49 group, where the SY type had a larger value than the TE type. Another shape-related variable, FA(25,17), also showed significant differences: the SE type had a more downward slanting eye than the other SC types.

For the male groups, there was no evidence to demonstrate the differences among SC types. Only FA(25,17) and FA(18,17,25) showed significant differences, and these were in the male aged 50–69 group.

3.4. *Significant nose features*

The major nose characteristic distinguishable among the SC types was FW35, representing the half-nose width. FW35 was statistically significantly different between the TE and SE types in all subgroups except the male aged 30–49 group. The TE type had a larger half-nose width than the SE type. A nose shape-related feature, FD(52,49)/FW35, representing the ratio of the vertical length of the nose to the horizontal width, showed significant differences in the male aged 50–69 and female aged 30–49 groups. The *post hoc* tests revealed that the SY type had a larger value than the TE type in the male aged 50–69 group and a larger value than the SE type in the female aged 30–49 group. A feature related to nose height, PA(14,21), was significantly different only in the male aged 30–49 group, where the TE type had a more upturned nose than the SE type.

3.5. *Significant mouth features*

There was no evidence to verify the differences in mouth characteristics among the SC types.

3.6. *Mixed-effect model analysis*

The results of the mixed-effect model analysis for FW33 and $FW33_{adj}$ are shown in Table 5.

In Model 1–2, the covariate (*distance*) was significant, whereas the variance component of *SITE* decreased compared to the variance component in Model 1–1. It was revealed that the site-to-site variability was attributable to the variability in photographic distance, which affected the value of FW33. For Model 1–3, which was established after compensating for the conversion error, it was observed that the significance of *distance* was reduced, while the variance component of *SITE* was similar to Model 1–2. These results showed that the variability due to the site difference was reduced by compensating for the conversion error with the proposed method for FW33, even though the variance of *SITE* was still significant.

Similar results were obtained for FW43 and $FW43_{adj}$ from Models 2–1 through 2–3, as shown in Table 6.

4. Discussion

The goal of this study was to identify the significant facial features of the SC types using an objective and quantitative method inspired by the description of the facial characteristics of SC types in the classical SCM literature.

To analyze the features without the subjective bias introduced by the patient's response or the SCM doctor's opinions and experience, a large amount of data from various sites was required. At the same time, it was necessary to compensate for the systematic errors caused by processing data collected from various sites with heterogeneous experimental environments.

In this paper, therefore, frontal and profile face images from 1464 patients, acquired from 19 sites, were analyzed to minimize diagnostic bias. The patients were divided into subgroups of 30–49-year-olds and 50–69-year-olds for both male and female subjects. At this point, a compensation technique was employed to reduce the conversion error and site-to-site variability caused by the location of the ruler and the difference in photographic distance at each site.

Table 6 – Estimates of the parameters for models 2–1 through 2–3.

		Model 2–1		Model 2–2		Model 2–3	
		Estimated parameter	SE	Estimated parameter	SE	Estimated parameter	SE
Fixed Effects	*Intercept*	67.900‡	0.517	63.002‡	0.718	69.330‡	0.765
	[SC = SE] vs. TE	-3.445‡	0.435	-3.370‡	0.440	-3.613‡	0.467
	[SC = SY] vs. TE	-2.546‡	0.419	-2.484‡	0.425	-2.678‡	0.451
	[*GENDER* = 1] vs. 0†	-3.332‡	0.389	-3.311‡	0.381	-3.626‡	0.403
	[*AGE* = 1] vs.0†	1.075*	0.430	1.190*	0.446	1.358†	0.476
	[*GENDER* = 0]*[*AGE* = 1]†	-2.289‡	0.527	-2.288‡	0.516	-2.457‡	0.546
	Distance			0.004‡	0.000	0.001†	0.000
Random Effects	*SITE*	1.852*	0.844	0.730	0.543	0.897	0.644
	SC* SITE	0.526	0.368	0.597	0.373	0.679	0.422
	AGE* SITE			0.124	0.204	0.161	0.242
	Residuals	22.320‡	0.839	21.320‡	0.804	23.850‡	0.900

The t-test result for fixed effects and Wald's Z-test for random effects: *($p < 0.05$), †($p < 0.01$), ‡($p < 0.001$).
§Dummy variables: *GENDER* = 0: male, *GENDER* = 1: female, *AGE* = 0: 30–49, *AGE* = 1: 50–69.

The results of the statistical analysis showed the following:

(i) the TE type generally had a wider cheekbone and jaw than the SE type, and the TE type had a squarer face than the other SC types, except in the female aged 50–69 group;
(ii) in the male aged 30–49 group, the SY type tended to have a more slanted forehead than the SE type;
(iii) the female TE type had wider and flatter eyes, and the female SE type had rounder upper eyelids;
(iv) the TE type had a wider nose than the SE type, except in the male aged 30–49 group, and the TE type in the same group had a more upturned nose than the SE type; and
(v) no significant features were observed regarding the mouth shapes.

Many of these features were consistent with the facial characteristics described in the SCM literature, although some characteristics could not be represented exactly by the corresponding variables.

Through a variance component analysis using a mixed-effect model, it was confirmed that the site-to-site variability could be attributed to the difference in photographic distance, and this was reduced by compensating for the conversion error using the proposed technique. The significant facial features and characteristics were thus acquired from the results with a reduction in both diagnostic bias and site-to-site variability. It is noted that the features represent the common characteristics of each SC type in the sense that we collected extensive opinions from many SCM doctors with various points of view. We expect that these findings and the related compensation technique will contribute to establishing a scientific basis for the precise diagnosis of SC types in clinical practice. In recent studies, the association of SC types with metabolic disease was explored,[26–28] and they found that the prevalence of metabolic disease varied across different SC types. Therefore, the significant facial features representing the SC types may also be helpful in predicting metabolic disease susceptibility.

Conflict of interest

There is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.imr.2012.09.003.

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