

A three-dimensional photogrammetric analysis of the facial esthetics of the Miss Korea pageant contestants

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Objective: The aims of this study were to measure and compare the facial dimensions of the Miss Korea pageant contestants and a selected group of women from the general population by using three-dimensional (3D) image analysis, as well as to compare various facial ratios to the golden ratio within each group. **Methods:** Three-dimensional images of 52 Miss Korea pageant contestants (MK group) and 41 young female adults selected from the general population (GP group) were acquired. Fifty-four variables and ratios were measured and calculated. Intergroup comparisons were performed using multivariate analysis of variance. **Results:** Compared to the GP group, the MK group showed greater total facial height and eye width, lesser lower-facial height, and lesser facial, lower-facial, and nasal widths. Moreover, compared to the GP group, the MK group had more protruded noses with greater nasolabial angle, greater vertical curvature of the foreheads, lesser horizontal curvature of the cheek, and lesser lower-lip-and-chin volume. **Conclusions:** The MK group had longer faces but smaller lower lips and chins than did the GP group. The golden ratio was not matching the current facial esthetic standards. These data might be beneficial for treatment planning of patients undergoing orthognathic and plastic surgeries.

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Key words: 3D facial photogrammetric analysis, Preferred facial appearance, Golden ratio, Miss Korea

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INTRODUCTION

Facial esthetics plays an inherent role in social behavior and perception worldwide. The increased awareness of facial esthetics has also led to an increase in the number of adults seeking orthognathic and orthodontic treatment.¹⁻³

Different facial features, their roles in facial esthetics, and the overall composition of the face have been previously assessed. Evaluations of the positions of the lip and chin have been conventionally performed by using lateral view photographs or lateral cephalograms,⁴⁻⁷ but few studies have based their evaluations on frontal view photographs.^{8,9} Several studies have demonstrated that an attractive lip proportion is a key factor for an esthetically pleasing lower face.⁴⁻⁶ Other reports have shown that the eyes, nose, and mouth were the preferred targets during the visual perception of a face.¹⁰ Yet another study suggested that the central area of average faces was perceived visually more quickly than the central area of unusual faces.¹¹ A previous study also confirmed the importance of the eyes and mouth in emotional decoding.¹²

Currently, the parameters that determine whether a face is attractive are still controversial. Sharma et al.¹³ showed a lack of consensus and confidence regarding a reliable, validated, and reproducible scoring system for facial esthetics. Galantucci et al.¹⁴ assessed the facial features on three-dimensional (3D) images of subjects with a preferred facial appearance by using principal component analysis. However, they reported that their method was not a valid prediction tool for attractiveness. Moreover, no previous study has compared a group with a preferred facial appearance to a group from the general population.

Facial esthetics has been compared between fashion models and non-fashion models from the same ethnic group and between models from different ethnic groups.^{8,9} Kim et al.¹⁵ evaluated the facial dimensions of young adult women with a preferred facial appearance. However, these studies were based on two-dimensional (2D) measurements taken using unstandardized photographs. Row and Rhu¹⁶ assessed the facial esthetics of the finalists of the Miss Korea contest in the late 1980s by using lateral cephalograms. They found that the Korean beauty standards favored a less prominent nose, more prominent lip, and deeper sulcus depth than did the Caucasian beauty standards. Nevertheless, the study was based on lateral cephalometric variables and overlooked the importance of the measurements on facial photographs.

Three-dimensional photogrammetry has recently been introduced to the medical and dental fields, and its accuracy, precision, reproducibility, and reliability have

been reported.¹⁷⁻¹⁹ Kim et al.²⁰ reported no significant differences in the position of any landmark between 2 repeated digitizations. Several studies have developed 3D facial analyses based on 3D photogrammetric data.^{20,21} Nevertheless, volumetric or curve variables were not incorporated into these 3D facial analyses. Ancient Greeks believed that a specific proportion between the elements of a body contributes to its beauty. The Greek mathematician Euclid described the “golden ratio” or the “divine proportion” that was later found to be equivalent to 1:1.618 and was denoted by the symbol “Phi” (ϕ). Intriguingly, the golden ratio is seen in nature, for example in the spirals of seashells. Moreover, for a long time, this ratio was considered the ideal ratio for beauty. Several studies have demonstrated that the proportions between facial measurements of attractive faces were close to the golden ratio.^{22,23} However, other authors have reported minimal, if any, significant association between the golden ratio and facial attractiveness.²⁴⁻²⁶ This controversy encourages further studies on the relationship between the golden ratio and contemporary facial proportions in different ethnicities.

To our knowledge, no study to date has been conducted to evaluate the modern facial esthetic standards of the Korean population by using 3D analysis, including the assessment of curve lengths and volumetric variables. Moreover, no study has evaluated the association between the proportions of these variables and the golden ratio, or other neoclassical canons or indices even though they have been suggested for a different ethnic group at a different time.

Therefore, the aims of this study were to measure and compare the facial dimensions of a group comprising the Miss Korea pageant contestants and a selected group of women from the general population by using 3D image analysis, as well as to compare various facial ratios to the golden ratio within each group.

MATERIALS AND METHODS

The Miss Korea (MK) group comprised 52 young female adult who had participated in the final round of the Miss Korea contest in 2012 (age, 21.8 ± 2.0 years). The selected group of women from the general population (GP) comprised 41 young adult female students of a nursing school at Wonkwang Health Science University, Korea (age, 20.2 ± 1.3 years).

The inclusion criteria for the GP group were a straight profile with a mesocephalic face type and balanced facial appearance (judged by the consensus of 2 orthodontists), no previous plastic or maxillofacial surgery or orthodontic treatment, and absence of mentalis hyperactivity with an interlabial gap less than 1 mm. The participants in both groups signed an informed

consent form to participate in this study, which was approved by the institutional review board of The Catholic University of Korea (KC140ISE0057).

A 3D scanner (Morpheus3D Co., Ltd., Seongnam, Korea) was used to acquire the 3D photographs of the participants in both groups. The camera resolution was 0.8 megapixels, and the data accuracy was less than 0.1 mm (declared by the manufacturer). The images were acquired in the natural head position at a distance of about 650 mm from the scanner, with no make-up and under normal room lighting. Each participant's face was scanned 3 times frontally and at 45° on the right and left sides for 0.8 seconds each time. Then, Morpheus3D Dental Solution 3.0.8 (Morpheus3D Co., Ltd.) was used to convert the images acquired using the 3D scanner into models by registering the 3 scans, i.e., converting their data into a single coordinate system by using iterative closest point algorithms to determine a pair of points closest to the predefined, overlapped area between the 2 data sets and calculate the 3D conversion



Figure 1. Reorientation of the head position and construction of the three-dimensional coordinate system.

Table 1. Definitions of linear variables

Linear variable	Definition
Inter-pupil width	Horizontal distance between right and left centers of the pupils
Inter-endocanthus width	Horizontal distance between right and left endocathi (En)
Inter-exocanthus width	Horizontal distance between right and left exocathi (Ex)
Eye width	Horizontal distance between ipsilateral En and Ex
Facial width	Horizontal distance between right to left zygion (Zy)
Nasal width	Horizontal distance between right and left ala of nose (Al)
Philtrum width	Horizontal distance between right and left chresta philtri (Chp)
Mouth width	Horizontal distance between right and left cheilion (Ch)
Lower-facial width	Horizontal distance between right and left gonions (Go)
Total facial height	Vertical distance between trichion (Tr) and soft tissue gnathion (Gn)
Facial height	Vertical distance between glabella (G) and Gn
Lower-facial height	Vertical distance between subnasale (Sn) and Gn
Forehead height	Vertical distance between Tr and G
Eye height	Vertical distance between ipsilateral palpebrale superius (Ps) and palpebrale inferius (Pi)
Nasal height	Vertical distance between N and Sn
Ear height	Vertical distance between ipsilateral supraurale (Sa) and subaurale (Sba)
Mouth height	Vertical distance between labrale superius (Ls) and labrale inferius (Li)
Upper lip height	Vertical distance between Sn and stomion (Stm)
Lower lip height	Vertical distance between Stm and soft tissue B point
Upper vermilion height	Vertical distance between Ls and Stm
Lower vermilion height	Vertical distance between Stm and Li
Cupid's bow height	Vertical distance between Chp and Stm
Lower-lip-&-chin height	Vertical distance between Stm and Gn
Nasal protrusion	Sagittal distance between Sn and pronasale (Prn)
Upper lip protrusion	Sagittal distance between Ls and frontal plane
Lower lip protrusion	Sagittal distance between Li and frontal plane

parameter that minimizes the distance between the points.²⁷ The same software was used for analyzing the 3D models.

Reorientation was performed as follows: a horizontal plane was constructed to contain the right and left pupils and the soft-tissue nasion (N); then the sagittal plane was set to be the perpendicular plane that contains the N-subnasale (Sn) line. Finally, the coronal plane was set as the one perpendicular to both the previously described planes (Figure 1).

Tables 1 and 2, and Figures 2–5 illustrate the linear, angular, curve length, areal, and volumetric variables. The following neoclassical canons were calculated²⁸:

Canon 1: Trichion (Tr)-N = N-Sn = Sn-gnathion (Gn). However, for easier comparisons, the canon was rewritten as follows: Tr-N/N-Sn = 1, Tr-N/Sn-Gn = 1, and N-Sn/Sn-Gn = 1.

Canon 2: nasal width/facial width = 1/4

Canon 3: nasal height/ear height = 1

Canon 4: endocanthal width/nasal width = 1

Table 2. Definitions of angular, curve length, and volumetric variables

Variable	Definition
Angular	
Nasal tip angle	Angle between right Al, Prn, and left Al
Nasolabial angle	Angle between columella, Sn and Ls
Cupid's bow angle	Angle between Ch, Chp and Ls
Central bow angle	Angle between right Chp, Ls, and left Chp
Upper vermilion angle	Angle between Chp, Ch, and Ch
Lower vermilion angle	Angle between Li, Ch, and Ch
Mentolabial fold	Angle between Li, soft tissue B point and pogonion (Pg)
Curve length	
Horizontal curvature of Forehead	From a constructed point on the vertical plane passing through the left Ex to the most prominent point on forehead, and a similar constructed point on the right side (All points were taken on the same horizontal plane)
Vertical curvature of forehead	From Tr to the most prominent point on forehead to N
Horizontal curvature of cheek	From a constructed point on the vertical plane passing midway between the 2 vertical planes at tragon (T) and Ex to the most prominent point on cheek to a point on the outline of the nose at the same horizontal plane
Vertical curvature of cheek	From soft tissue orbital to most prominent point on cheek to a constructed point on the horizontal plane passing through Ch.
Horizontal curvature of chin	From a constructed point on a vertical plane passing through the left Ch to soft tissue Pg to a similar constructed point on the right side
Vertical curvature of chin	From soft tissue B point to Pg to soft tissue menton (Me)
Mandibular curve	From left Go to a point on the outline of the mandible at intersection with the vertical plane passing through the left Ch, then to Me, then to a similar point on the border of the mandible at the right side, and finally to the right Go
Volume	
Upper facial volume	Defined through a coronal plane passing through left T, upper horizontal plane passing through left Ex, and lower horizontal plane passing through Sn
Cheek volume	Defined through the landmarks used for defining the horizontal and vertical curvature of cheek with a coronal plane passing through T
Nasal volume	Defined through a coronal and horizontal planes passing through Sn
Lower lip and chin volume	Defined through a coronal plane passing through left T, upper horizontal plane passing through Stm, lower plane passing through Me, and right and left Go
Chin volume	Defined through the 2 vertical planes used for defining the horizontal curvature of chin, a horizontal plane passing through the soft tissue B point, and a coronal plane passing through left T

Refer to Table 1 for the finitions of three-dimensional facial photogrammetric analysis.

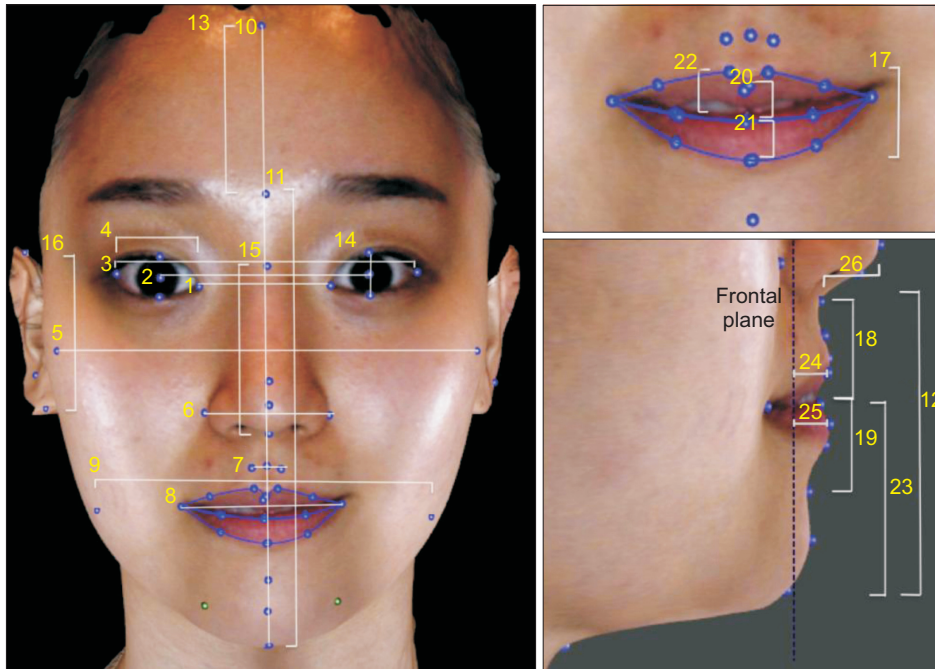


Figure 2. Linear variables. 1, Inter-endocanthal width; 2, inter-pupil width; 3, inter-exocanthal width; 4, eye width; 5, facial width; 6, nasal width; 7, philtrum width; 8, mouth width; 9, lower-facial width; 10, total facial height; 11, facial height; 12, lower-facial height; 13, forehead height; 14, eye height; 15, nasal height; 16, ear height; 17, mouth height; 18, upper lip height; 19, lower lip height; 20, upper vermilion height; 21, lower vermilion height; 22, Cupid's bow height; 23, lower-lip-and-chin height; 24, upper lip protrusion; 25, lower lip protrusion; 26, nasal protrusion.

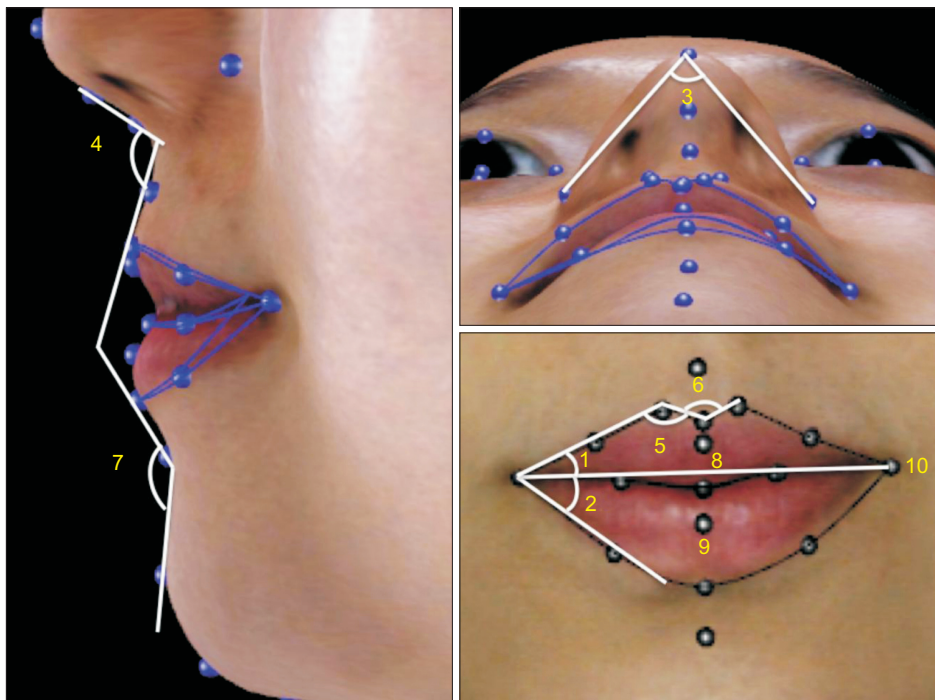


Figure 3. Angular and areal variables. 1, Upper vermilion angle; 2, lower vermilion angle; 3, nasal tip angle; 4, nasolabial angle; 5, Cupid's bow angle; 6, central bow angle; 7, labiomental fold; 8, upper vermilion area; 9, lower vermilion area; 10, total vermilion perimeter.

Canon 5: endocanthal width/eye width = 1
 Canon 6: mouth width/nasal width = 3/2

Moreover, several proportion indexes (PIs) were calculated (Table 3).²⁹ In addition, the ratios between the variables forming each PI were calculated.

The landmarks were digitized on each 3D image by a single operator. Ten models from each group were

redigitized 2 weeks later by the same operator. Intraclass correlation coefficient (ICC) was applied to evaluate the intraobserver reliability. The reliability of the digitization process showed an ICC > 0.8.

Statistical analysis

Statistical evaluation was performed using IBM SPSS

Table 3. Definitions of the proportion indexes (PIs)

PI	Definition	Equation
PI1	Facial height/width	$N-Gn \times 100/Zy-Zy$
PI2	LL-&-chin/lower-facial width	$Stm-Gn \times 100/Go-Go$
PI3	LL-&-chin/facial heights	$Stm-Gn \times 100/N-Gn$
PI4	Lower-facial/facial widths	$Go-Go \times 100/Zy-Zy$
PI5	Inter-endocanthus/Inter-exocanthus widths	$En-En \times 100/Ex-Ex$
PI6	Eye height/width	$Ps-Pi \times 100/Ex-En$
PI7	Nasal width/height	$Al-Al \times 100/N-Sn$
PI8	Nasal protrusion/width	$Sn-Prn \times 100/Al-Al$
PI9	UL height/mouth width	$Sn-Stm \times 100/Ch-Ch$
PI10	Nasal/facial heights	$N-Sn \times 100/N-Gn$
PI11	Nasal/facial widths	$Al-Al \times 100/Zy-Zy$
PI12	LL/UL Heights	$Stm-B \times 100/Sn-Stm$
PI13	Mouth/facial widths	$Ch-Ch \times 100/Zy-Zy$
PI14	Ear/facial heights	$Sa-Sba \times 100/N-Gn$
PI15	Lower-facial/facial heights	$Sn-Gn \times 100/N-Gn$
PI16	LL-&-chin/lower-facial height	$Stm-Gn \times 100/Sn-Gn$
PI17	Nasal/mouth widths	$Al-Al \times 100/Ch-Ch$
PI18	Upper vermilion/UL heights	$Ls-Stm \times 100/Sn-Stm$
PI19	Upper/Lower vermilion heights	$Ls-Stm \times 100/Stm-Li$
PI20	Philtrum/mouth widths	$Chp-Chp \times 100/Ch-Ch$
PI21	UL/nasal heights	$Sn-Stm \times 100/N-Sn$
PI22	LL height/LL-&-chin	$Stm-B \times 100/Stm-Gn$
PI23	Lower vermilion/LL heights	$Stm-Li \times 100/Stm-B$

UL, Upper lip; LL, lower lip.

Refer to Table 1 for the definitions of three-dimensional facial photogrammetric analysis.

The nose was also more protruded in the MK group than in the GP group. Moreover, the MK group had greater nasolabial angle and smaller nasal tip angle than did the GP group.

A proportional diagram of the average face of the MK group and another of the GP group were sketched to visually present the differences between the average faces of both groups (Figure 6).

Curves, surface areas, and volumetric measurements (Table 4)

Compared to the GP group, the MK group demonstrated a greater vertical curvature of the forehead, but smaller horizontal curvature of the cheek and vertical curvature of the chin. The MK group also showed lesser lower-lip-and-chin volume and chin volume than did the GP group. In addition, no significant intergroup differences were observed in the areal or perimeter variables.

Canons, PIs, and ratios (Table 5)

Canon 1 in both groups was significantly different from the traditional value. Moreover, it was significantly different between the two groups except for the $Tr-N/N-Sn$. For Canons 3 and 5, significant differences were observed between the two groups, and within each group, they were significantly different from the traditional values. Canon 6 showed no significant difference between the groups, but within each group, it was significantly different from the traditional value. For Canons 2 and 4, no significant difference was observed between the groups or from the traditional value of the canon except in the GP group, which showed a significantly greater value than the traditional one for Canon 2.

Regarding Farka proportion index (PI), the MK group showed greater nasal protrusion/width and nasal/facial height than did the GP group. However, the MK group exhibited lesser lower-lip-and-chin/facial height, lower-facial/facial width and height, endocanthal/exocanthal

Table 4. Comparison of facial dimensions between the Miss Korea (MK) and general population (GP) groups

Linear variable (mm)	No. on figures	MK group	GP group	p-value*
Linear variable (mm)				
Inter-endocanthus width	F2-1	36.2 ± 2.1	37.7 ± 2.9	0.087
Inter-pupil width	F2-2	61.3 ± 2.0	62.0 ± 2.9	1.000
Inter-exocanthus width	F2-3	95.7 ± 3.2	95.1 ± 4.4	1.000
Eye width	F2-4	31.1 ± 1.7	29.7 ± 2.0	0.007
Facial width	F2-5	144.3 ± 4.4	147.2 ± 3.8	0.032
Nasal width	F2-6	36.3 ± 2.0	37.7 ± 1.8	0.017
Philtrum width	F2-7	11.7 ± 2.0	10.8 ± 1.3	0.258
Mouth width	F2-8	45.5 ± 2.9	45.6 ± 3.0	1.000
Lower-facial width	F2-9	119.1 ± 4.4	126.7 ± 7.1	< 0.001
Total facial height	F2-10	186.0 ± 5.7	177.3 ± 6.7	< 0.001
Facial height	F2-11	126.0 ± 3.9	126.0 ± 4.9	1.000
Lower-facial height	F2-12	56.6 ± 3.1	59.8 ± 3.5	< 0.001
Forehead height	F2-13	60.0 ± 4.5	51.3 ± 6.0	< 0.001
Eye height	F2-14	11.6 ± 1.1	10.6 ± 1.3	0.007
Nasal height	F2-15	52.9 ± 3.1	49.5 ± 3.1	< 0.001
Ear height	F2-16	50.7 ± 4.1	52.5 ± 4.5	0.962
Mouth height	F2-17	17.5 ± 1.9	17.9 ± 2.9	1.000
Upper lip height	F2-18	20.4 ± 1.7	21.1 ± 2.3	1.000
Lower lip height	F2-19	17.7 ± 1.8	18.5 ± 1.8	1.000
Upper vermilion height	F2-20	7.1 ± 1.2	7.4 ± 1.7	1.000
Lower vermilion height	F2-21	10.3 ± 1.4	10.3 ± 1.9	1.000
Cupid's bow height	F2-22	8.7 ± 1.2	8.9 ± 1.7	1.000
Lower lip & chin height	F2-23	36.1 ± 2.6	38.6 ± 2.5	0.001
Upper lip protrusion	F2-24	10.3 ± 1.5	10.1 ± 2.0	1.000
Lower lip protrusion	F2-25	8.0 ± 1.8	8.9 ± 2.4	0.945
Nasal protrusion	F2-26	14.7 ± 1.9	12.8 ± 1.6	< 0.001
Angular variable (°)				
Upper vermilion angle	F3-1	26.5 ± 3.3	26.6 ± 3.7	1.000
Lower vermilion angle	F3-2	33.5 ± 4.5	32.3 ± 4.8	1.000
Nasal tip angle	F3-3	81.8 ± 4.0	87.0 ± 4.9	< 0.001
Nasolabial angle	F3-4	121.2 ± 6.7	111.3 ± 8.0	< 0.001
Cupid's bow angle	F3-5	133.5 ± 7.8	131.3 ± 5.1	1.000
Central bow angle	F3-6	145.2 ± 11.5	144.7 ± 9.2	1.000
Mentolabial fold	F3-7	148.4 ± 9.1	150.2 ± 10.6	1.000
Curved variable (mm)				
Horizontal forehead curve	F4-A	113.4 ± 7.2	115.9 ± 7.1	1.000
Vertical forehead curve	F4-B	64.3 ± 5.1	54.2 ± 7.2	< 0.001
Horizontal cheek curve	F4-C	72.0 ± 3.3	76.1 ± 3.8	< 0.001
Vertical cheek curve	F4-D	54.5 ± 2.5	55.4 ± 3.1	1.000
Horizontal chin curve	F4-E	48.4 ± 3.9	48.9 ± 4.3	1.000
Vertical chin curve	F4-F	19.6 ± 2.0	22.1 ± 3.3	0.001
Mandibular curve	F4-G	183.7 ± 11.0	185.5 ± 15.2	1.000
Surface variable				
Upper vermilion area (mm ²)		109.2 ± 6.4	111.0 ± 8.3	1.000
Lower vermilion area (mm ²)		106.6 ± 7.5	105.6 ± 8.0	1.000
Total vermilion perimeter (mm)		114.8 ± 6.7	116.0 ± 8.7	1.000
Volumetric variable (mm ³)				
Volume of upper facial portion		605.3 ± 56.5	581.7 ± 43.4	1.000
Nasal volume		27.2 ± 5.5	29.0 ± 7.9	1.000
Cheek volume		40.2 ± 9.5	48.4 ± 9.8	0.410
Volume of lower lip and chin		288.0 ± 48.9	356.6 ± 34.2	0.001
Chin volume		112.3 ± 22.8	142.8 ± 23.1	0.009

Values are presented as mean ± standard deviation.

*Analyzed using MANOVA; adjusted p-values using the Holm-Bonferroni method for multiple comparisons.

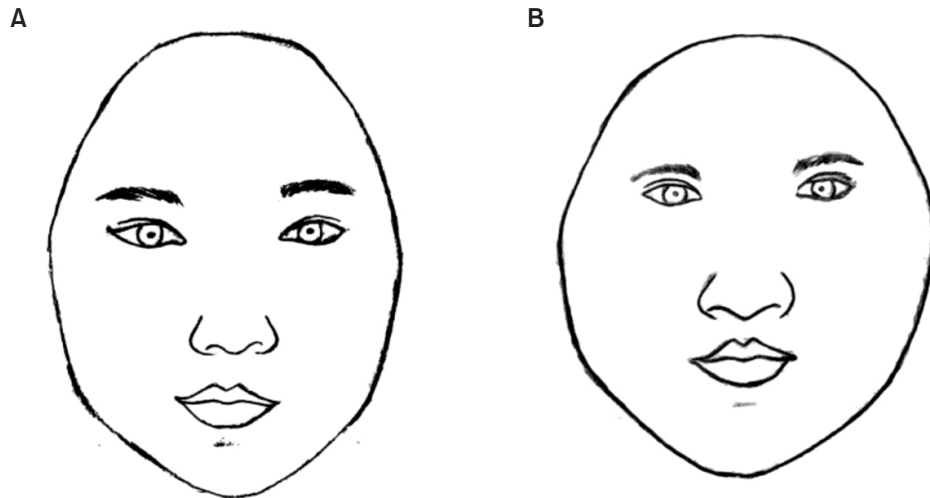


Figure 6. A proportional diagram of the average face from the Miss Korea group (A) and another from the general population group (B).

Table 5. Comparison of the canons and proportion index (PI) between the groups

Canons and PI variable	MK group	GP group	p-value		
			Between-group*	MK vs. standard†	GP vs. standard†
Tr.N-N.Sn	1.45 ± 0.12	1.38 ± 0.13	0.121	< 0.001	< 0.001
Tr.N-Sn.Gn	1.36 ± 0.12	1.14 ± 0.11	< 0.001	< 0.001	< 0.001
N.Sn-Sn.Gn	0.94 ± 0.09	0.83 ± 0.08	< 0.001	< 0.001	< 0.001
Nasal/facial widths	0.25 ± 0.01	0.26 ± 0.01	1.000	0.713	0.003
Nasal/ear heights	1.05 ± 0.10	0.95 ± 0.09	< 0.001	0.001	0.003
en.en/nasal width	1.00 ± 0.08	1.00 ± 0.08	1.000	0.997	0.880
en.en/eye width	1.17 ± 0.10	1.28 ± 0.14	< 0.001	< 0.001	< 0.001
Mouth/nasal widths	1.25 ± 0.09	1.21 ± 0.08	0.259	< 0.001	< 0.001
PI1 Facial height/width	75.94 ± 2.90	74.26 ± 3.06	0.129	< 0.001	< 0.001
PI2 LL-&-chin/lower-facial width	30.32 ± 2.50	30.48 ± 2.15	1.000	< 0.001	< 0.001
PI3 LL-&-chin/facial heights	32.94 ± 1.94	35.28 ± 1.74	< 0.001	< 0.001	< 0.001
PI4 Lower-facial/facial widths	82.62 ± 2.92	86.10 ± 4.34	< 0.001	< 0.001	< 0.001
PI5 en.en/ex.ex	37.84 ± 1.99	39.70 ± 2.56	0.003	< 0.001	< 0.001
PI6 Eye height/width	37.37 ± 3.48	35.90 ± 4.11	0.812	< 0.001	< 0.001
PI7 Nasal width/height	68.77 ± 5.11	76.51 ± 5.67	< 0.001	< 0.001	< 0.001
PI8 Nasal protrusion/width	40.71 ± 5.15	33.93 ± 4.07	< 0.001	< 0.001	< 0.001
PI9 UL height/mouth width	44.96 ± 5.06	46.44 ± 6.26	1.000	< 0.001	< 0.001
PI10 Nasal/facial height	48.35 ± 2.30	45.28 ± 2.26	< 0.001	< 0.001	< 0.001
PI11 Nasal/facial widths	25.18 ± 1.37	25.63 ± 1.17	1.000	< 0.001	< 0.001
PI12 LL/UL Heights	87.58 ± 10.55	88.76 ± 14.18	1.000	< 0.001	< 0.001
PI13 Mouth/facial widths	31.52 ± 1.96	31.00 ± 2.18	1.000	< 0.001	< 0.001
PI14 Ear/facial heights	40.10 ± 3.25	41.74 ± 3.83	0.377	< 0.001	< 0.001
PI15 Lower-facial/facial heights	51.65 ± 2.30	54.72 ± 2.26	< 0.001	< 0.001	< 0.001
PI16 LL-&-chin/lower-facial height	63.78 ± 2.42	64.51 ± 2.76	1.000	< 0.001	< 0.001
PI17 Nasal/mouth widths	80.12 ± 5.76	82.97 ± 5.50	0.259	< 0.001	< 0.001
PI18 Upper vermilion/UL heights	34.93 ± 5.99	35.12 ± 6.71	1.000	< 0.001	< 0.001
PI19 Upper/lower vermilion heights	69.91 ± 15.66	73.28 ± 17.64	1.000	0.023	0.003
PI20 Philtrum/mouth widths	25.67 ± 4.08	23.63 ± 2.82	0.096	< 0.001	< 0.001
PI21 UL/nasal heights	38.60 ± 4.49	42.87 ± 6.30	0.004	< 0.001	< 0.001
PI22 LL height/LL-&-chin	49.12 ± 3.94	47.97 ± 4.37	1.000	< 0.001	< 0.001
PI23 Lower vermilion/LL heights	58.56 ± 8.44	56.35 ± 10.53	1.000	0.007	0.005

Values are presented as mean ± standard deviation.

Within each group, values of the canons were compared the neoclassical standards, and values of PIs were compared to the golden ratio.

UL, Upper lip; LL, lower lip, MK, miss Korea; GP, general population.

*Independent t-test, †one-sample t-test; adjusted p-values using the Holm-Bonferroni method for multiple comparisons.

width, nasal width/height, and upper lip/nasal height than did the GP group. All ratios in each of the groups were significantly different from the golden ratio.

DISCUSSION

Assessment of facial appearance is a multifaceted process in modern globalized societies. Several interacting factors have been suggested to assess facial attractiveness; however, no consensus has currently been reached.³⁰⁻³² A few 3D parameters have been reported for the evaluation of facial attractiveness,³³ including the volume of facial structures,³⁴ but no study to our knowledge has yet evaluated the implications of curve length on attractiveness by using 3D facial imaging.

Therefore, in our study, several curve lengths and volumetric variables were evaluated. The MK group showed greater vertical curvature of the forehead than did the GP group, and this was consistent with the forehead height measurement. This finding was also in agreement with the finding of a previous study, which reported that, among Asian women, the most attractive group had greater forehead height than did the least attractive group.³⁵ Moreover, the MK group in our study had smaller horizontal cheek and vertical chin curvatures, as well as lesser lower-lip-and-chin and chin volumes, than did the GP group.

The MK group had longer faces but smaller lower-facial portions than did the GP group. The MK group also had narrower facial and lower-facial widths. This was contradictory to the results of Sforza et al.,³³ who reported that attractive adolescents have wider and shorter faces. This might be attributed to the cultural and social differences when evaluating attractive face samples. The difference in the age of the subjects in the studies (adolescents in Sforza et al.³³ vs. adults in our study) may also have caused the difference in esthetic facial preferences. Nevertheless, the results of other studies on the facial attractiveness of Caucasian groups have shown some similarities to our results, suggesting that attractiveness was associated with a larger eye and forehead and smaller chin.^{36,37}

In agreement with the findings of a study by Kim et al.,¹⁵ the total facial height of the MK group was greater than that of the GP group. However, the GP group in our study had a greater facial width than did the MK group, which was opposite to the results of Kim et al.¹⁵ In addition, the facial height as well as the intercanthal and interpupillary widths, which showed significant intergroup differences in the study of Kim et al.,¹⁵ showed no significant intergroup differences in our study. This might be attributed to the differences between the 2D and 3D nature of the studies and the associated difficulty in the identification of projected

landmarks on 2D images.

Farkas²⁸ proposed that the PIs might give a more accurate description of attractiveness than do measurements of facial features. Galantucci et al.,¹⁴ who evaluated the faces of the Miss Italy 2010 contestants, confirmed that attractiveness could be related to proportion, which could be a key factor in the perception of beauty. Therefore, in our study, 23 Farkas PIs were evaluated, and 8 of the 23 demonstrated significant differences on intergroup comparisons.

Our study showed that the MK group had longer and narrower faces with lesser lower-facial/facial widths and lower-lip-and-chin/facial heights than did the GP group. This suggests an inverted pear-shaped average face for the MK group and a more rounded average face for the GP group. However, these PIs were not significantly different between the attractive and non-attractive groups in a study on North American Caucasians, despite their agreement with our findings that the attractive group had a lesser facial width.²⁸

Attractive Caucasian women had eyes of larger width and height, and a larger PI between the height and width, than did a group of women with below-average attractiveness.²⁸ In our study, the MK group had larger eye width and height than did the GP group; however, no significant difference was observed in the PI between eye height and width. This may suggest that the geometrical shape of the eye has an effect on attractiveness in the Caucasian population, whereas the eye size alone affects attractiveness in the Korean population.

A previous study on the 3D images of the Miss Italy 2010 contestants showed that their facial width was 83.5 mm at the inter-exocanthus and 73.7 mm at the inter-gonion.³⁸ However, in the MK group of our study, the corresponding facial widths were 95.7 mm and 119.1 mm, respectively. In addition, the total facial height in their study was 168.2 mm, while in our MK group, it was 186.0 mm. The nasal width in their study was 30.2 mm, whereas in our MK group, it was 36.3 mm. Nevertheless, their Miss Italy group had a similar mouth width to our MK group (45.5 mm). These differences could be partly attributed to the racial differences between the study groups.

Ferrario et al.,³⁹ who compared the facial dimensions between Caucasian beauties and normal groups, found that the former group had greater forehead height than did the normal group, which was in agreement with our results. However, unlike our groups, their groups had lesser nasal height and greater lower-facial width. In addition, their groups had lesser facial height, greater inter-exocanthal width, and lesser nasal volume, but these variables were not significantly different between the groups in our study. Moreover, the authors

demonstrated no significant differences between their groups in lower-facial height and lower-lip-and-chin volume, which were significantly lesser in our MK group. Their normal group showed more convex and narrower faces with greater upper and total facial heights, and hence, they had lesser facial-width-to-height ratios and lesser volume of the facial upper third than did the beauties group. However, in our study, the GP group showed wider faces and lesser total facial height than did the MK group, but without significant intergroup differences regarding the volume of the upper facial portion or the ratio between the facial width and height.

The MK group had a longer, narrower, and more protruded nose with lesser nasal width/height and upper lip/nasal heights than did the GP group. This was not consistent with the findings in the Caucasian population, which showed no significant differences in these variables between the attractive and unattractive groups.²⁸

Moreover, compared to the unattractive group, the attractive Caucasian group had greater mouth/facial widths and lesser philtrum/mouth widths.²⁸ In contrast, our study showed that the mouth/facial widths and philtrum/mouth widths were not significantly different between groups.

Several authors have studied the mathematical relationships, especially the golden ratio, between different parts of the human body and face.⁴⁰ However, no consensus has been reached regarding relationship between this ratio and modern facial esthetics. A recent study proposed the utilization of this ratio in facial esthetics.²³ However, Rossetti et al.,²⁵ who evaluated 10 facial ratios obtained via 3D stereophotogrammetry from 60 attractive subjects, reported that 7 of these ratios were significantly different from the golden ratio.

Similarly, our results demonstrated that all ratios were significantly different from the golden ratio. In addition, when several classical canons were tested within each group independently, only the inter-endocanthus to nasal widths (in each group) and nasal to facial widths (in the MK group) showed no significant differences from the proposed values. This might be expected because these canons were proposed in a different era and for a different ethnic group. It also suggests the evolving nature of esthetic standards. Therefore, revisiting the application of such canons on contemporary facial esthetics might be important.

Asymmetries are commonly found between the right and left sides of the face.⁴¹ Faure et al.⁴² reported that symmetry has a negative effect on facial esthetics, while other studies have emphasized the importance of symmetry in the perception of faces.^{11,43} Sforza et al.⁴⁴ reported that the effect of symmetry on attractiveness changes as a function of age; the attractive children

in their study were more symmetric than the control children, unlike young adults. Our results showed no significant asymmetry in either group. Therefore, drawing strong conclusions related to the effect of facial asymmetry on the esthetic standards is difficult. In our study, the limited number of paired variables might have impaired our ability to evaluate facial symmetry. Therefore, an additional evaluation of the general and local facial asymmetry in these groups might be recommended.

Previous studies have applied the palpation and marking method for identifying some facial landmarks.^{34,39} However, in our study, the landmarks were placed directly on the 3D images without palpation. Considering the palpation method might be more accurate, a validation of our method compared to a gold standard might be warranted.

In addition, this analysis focused on the frontal and horizontal aspects, and the sagittal relationship was not included in order to decrease the complexity of this study. Therefore, further studies are necessary to investigate the anteroposterior relationships between the facial structures of the esthetically pleasing group and to compare them to the general population.

The MK group in our study also refused radiographic examination and would not answer whether they had undergone prior surgeries. This information was not relevant because the MK group represents the standards that the current society considers beautiful. A future study evaluating the skeletal dimensions and their relationship to the soft-tissue measurements of a sample of individuals with a preferred facial appearance by using cone beam computed tomography might be recommended. Despite these limitations, our results provide important information that may help in treatment planning and setting treatment goals for patients undergoing orthodontic treatment or orthognathic surgery for malocclusion or dentofacial deformity.

CONCLUSION

The MK group had longer faces, but lesser lower lip-and-chin height and lesser cheek and chin volumes, than did the general Korean population with mesocephalic faces.

The ratios between the facial dimensions in this study were not matching the golden ratio in either group. Therefore, the golden ratio and the neoclassical canons might not be of significant value for treatment planning in the Korean population according to the current esthetic preferences.

This 3D facial photogrammetric analysis provided useful information on facial dimensions that might be

beneficial for treatment planning of orthognathic and plastic surgery as well as orthodontic treatment. The measurements obtained in the MK group might be used as indicators of the current esthetic standards for Korean patients. Moreover, the measurements of the general population with mesocephalic faces could also be applied in treatment planning if achieving the values of the MK group is difficult.

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