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Quantitative analysis of the morphology of the lips according to different anteroposterior and vertical skeletal patterns

Running title : Lip morphology according to different skeletal patterns

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ABSTRACT

Quantitative analysis of the morphology of the lips according to different anteroposterior and vertical skeletal patterns

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Objectives: The aim of this study was to compare the differences in the morphology of the lips according to anteroposterior dentoskeletal patterns and facial divergence.

Materials and Methods: The samples were composed of the frontal facial photographs of 117 adult patients who satisfied all the cephalometric measurements for six groups (Class I or II or III and normodivergent or hyperdivergent). The morphology of the lips was evaluated on the frontal facial photographs and the measurements were compared between the groups.

Results: In the normodivergent groups, the height-to-width ratio of the lip vermilion was significantly greater in the Class II group than in the Class I group, and the labrale superius angle and upper lip convexity of the Class II group was smaller than that of the Class I group. In the hyperdivergent groups, the stomion inferius angle of the Class III group was smaller than that of the Class II group. Lower facial height and the interlabial gap in the hyperdivergent groups tended to be larger than those in the normodivergent groups. The height-to-width ratio of the lip vermilion and the commissure height were larger in the hyperdivergent groups than in the normodivergent groups. However, the upper lip height and philtrum height did not differ between the hyperdivergent and normodivergent groups.

Conclusion: The morphological characteristics of the lip vermilions on the frontal view differed according to the sagittal dentoskeletal relationship and facial divergence.

Key words : Photography, Soft tissue, Classification, Lip

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Ⅰ. INTRODUCTION

The lip vermilion is defined as the keratinized intraoral mucosa of the lip that can be distinguishable by its red color and distinctive form in the lower facial area. The shape of the lip vermilion is known to be affected by various factors such as growth, aging[1], ethnic differences[2], thickness or tone of the soft tissue, and the dentoskeletal relationship[3~9]. The height of the lip vermilion is reported to increase during the pubertal growth period and decrease with aging[10]. Orthodontic treatment affects the esthetics of the lower face including the lips as well as the occlusion. Because the lips are the component most affected by orthodontic treatment[11], orthodontists have been interested in the ideal relationship of the lips among the facial components[12,13], and the shape of the lips from various views[4,6~9,14].

Many earlier studies reported the effect of the anteroposterior dentoskeletal patterns[3,4,8] and facial divergence[5,15] on the morphology or position of the lips. The anteroposterior position of the lips was closely related to the underlying incisors and anteroposterior skeletal discrepancies[3]. Compared to a short facial pattern, subjects with long faces showed thicker and longer lips and the lips were more protrusive and incompetent as the facial divergence increased[15]. However, most of these studies estimated the characteristics of the lips in the sagittal view, even though people are more familiar with their face from the frontal view than the lateral profile[16]. Lucker[12] and Proffit et al.[13] proposed the ideal facial proportions on the frontal view. Arnett et al.[17] and Ackerman et al.[18] also emphasized the importance of frontal aesthetics in orthodontics.

Quantitative and qualitative analyses of the overall facial proportion and shape of the lip vermilion have been performed[6~9,14]. Islam et al.[6,7] investigated the differences in the frontal shape of the lip vermilion among subjects with normal occlusion, Class II malocclusion, and Class III malocclusion. Trisnawaty et al.[9] also reported that the frontal shape of the lip vermilion in patients with bi-alveolar protrusion differed from that of subjects with normal occlusion or orthodontic treatment experiences. Some researchers analyzed the morphology of the lips and overall facial soft tissue using three-dimensional (3D) measurement tools[14,19]. However, these previous studies did not consider vertical facial divergence, which may be associated with the shape of the lips in the frontal view. Therefore, the purpose of this study was to compare the frontal shape of the lip vermilion in Korean adult female among three different anteroposterior dentoskeletal patterns considering facial divergence.

Ⅱ. MATERIALS AND METHODS

The sample in this retrospective study consisted of frontal facial photographs taken for the purpose of orthodontic diagnosis between January 2011 and December 2016 at the Department of Orthodontics, Gangneung-Wonju National University Dental Hospital. The inclusion criteria were (1) Korean adult female patients aged 16-40 years with (2) available

frontal facial photos and lateral cephalograms before treatment. The subjects who satisfied the following cephalometric and dentoalveolar criteria were enrolled into six groups based on their anteroposterior and vertical skeletal relationships. The anteroposterior patterns were classified as Class I (0° ≤ ANB ≤ 5°, 0 mm ≤ overjet ≤ 5 mm), Class II (ANB 〉 5°, overjet 〉 5 mm), or Class III (ANB 〈 0°, overjet 〈 0 mm) groups, and the vertical patterns were classified into normodivergent (27° ≤ SN-MP angle 〈 37°) or hyperdivergent (SN-MP angle ≥ 37°) groups. The exclusion criteria were bi-alveolar protrusion (U1 to A-Pog 〉 10 mm, L1 to A-Pog 〉 6 mm), previous orthodontic treatment, facial deformities, syndromes, trauma history, facial esthetic surgery, anterior missing teeth, facial asymmetry (menton deviation ≥ 2 mm), and thick make-up.

The frontal facial photographs were taken in a relaxed seated posture and the camera lens was positioned vertically at the level of the subject's eyes. The subjects were instructed to stare at the camera lens with a slight contact of their teeth and relaxed lips without lip strain. Photographs in which the subject was suspected of having lip strain were also excluded from the study. A total of 117 frontal facial photographs were collected, and their characteristics are summarized in Table 1. This study was reviewed and approved by the Ethics Committee of Gangneung-Wonju National University Dental Hospital (IRB 2019-002).

The frontal facial images were reoriented with the interpupillary line as the X-axis and a line perpendicular to the X-axis through the subnasale as the Y-axis. The distance between the outermost borders of the irises was set to 100%. The images were analyzed using measuring software (AutoCad LT 2019, San Rafael, CA, USA). Right vertical line (RVL) and left vertical line (LVL) which is bisecting the median vertical line (MVL) and cheilion were drawn. Subnasale, soft tissue menton, and the points on the borderlines of the upper and lower lip vermilions passing through the MVL, RVL, and LVL were determined as landmarks (Table 2, Fig. 1). Thirteen linear and seven angular measurements were measured, and six ratio values were calculated (Table 3, Fig. 1). The mean of the bilateral measurements was used for statistical analysis.

1. Method errors

Twenty out of 117 frontal facial photographs were arbitrarily selected, and measurements were repeated by one examiner at a 2-week interval. The method error was calculated using Dahlberg's formula and ranged from 0.10 to 0.38% for the linear measurements, and 0.57 to 2.54° for the angular measurements.

2. Statistical analysis

The Shapiro-Wilk test showed that several measurements were not normally distributed. Therefore, nonparametric tests were performed. The Kruskal-Wallis test was performed to evaluate the differences in measurements among the Class I, Class II, and Class III groups. The Mann-Whitney U test with Bon-

Table 1. Mean and standard deviation of ages and cephalometric measurements in each group

Group	N	Age (yr)	ANB (°)	Overjet (mm)	SN-MP (°)
Class I normodivergent	26	24.8±7.1	2.4±1.6	3.5±1.0	32.0±2.8
Class II normodivergent	13	22.8±7.8	6.4±1.4	6.9±1.7	32.8±3.3
Class III normodivergent	13	21.2±6.2	−2.9±2.2	−1.7±1.3	34.2±1.6
Class I hyperdivergent	27	23.3±6.2	2.3±1.4	3.1±1.3	41.8±4.5
Class II hyperdivergent	26	22.1±5.2	7.9±2.0	7.7±3.1	45.0±5.8
Class III hyperdivergent	12	20.0±5.2	−1.8±1.1	−1.9±1.4	40.2±3.8

Mean ± SD

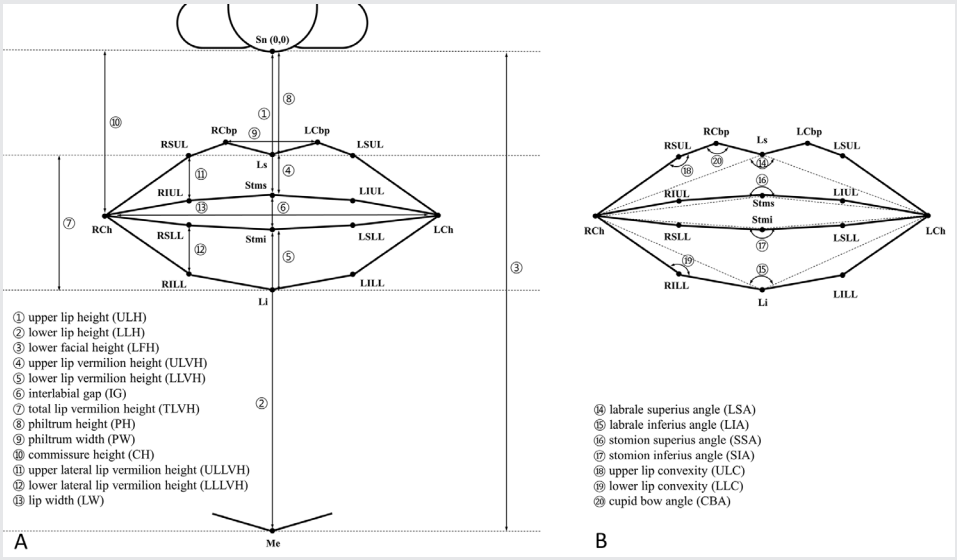

Figure 1. A, Thirteen linear measuring variables. B, Seven angular measuring variables. Sn, subnasale; Ls, labrale superius; Li, labrale inferius; Stms, stomion superius; Stmi, stomion inferius; Me, soft tissue menton; RCh, right cheilion; LCh, left cheilion; RCbp, right cupid bow point; LCbp, left cupid bow point; RSUL, right superior point upper lip; RIUL, right inferior upper lip point; RSLL, right superior lower lip point; RILL, right inferior lower lip point; LSUL, left superior point; LIUL, left inferior upper lip point; LSLL, left superior lower lip point; LILL, left inferior lower lip point.

Table 2. Landmark definitions

Landmark (abbreviation)	Definition
Subnasale (Sn)	The midpoint between the tip of the nose and the philtrum
Labrale superius (Ls)	The intersecting point between the median vertical line and the superior borderline of the upper lip vermilion
Labrale inferius (Li)	The intersecting point between the median vertical line and the inferior borderline of the lower lip vermilion
Stomion superius (Stms)	The intersecting point between the median vertical line and the inferior borderline of the upper lip vermilion
Stomion inferius (Stmi)	The intersecting point between the median vertical line and the superior borderline of the lower lip vermilion
Soft tissue menton (Me)	The intersecting point between the median vertical line and the inferior borderline of the soft tissue chin
Cheilion (Ch, bilateral)	The point located at each corner of the lip (RCh, LCh)
Cupid bow point (Cbp, bilateral)	The highest points of the philtrum on the superior borderline of the upper lip vermilion (RCbp, LCbp)
Right superior point upper lip (RSUL)	The intersecting point between the right vertical line and the superior borderline of the upper lip vermilion
Right inferior point upper lip (RIUL)	The intersecting point between the right vertical line and the inferior borderline of the upper lip vermilion
Right superior point lower lip (RSLL)	The Intersecting point between the right vertical line and the superior borderline of the lower lip vermilion
Right inferior point lower lip (RILL)	The Intersecting point between the right vertical line and the inferior borderline of the lower lip vermilion
Left superior point upper lip (LSUL)	The intersecting point between the left vertical line and the superior borderline of the upper lip vermilion
Left inferior point upper lip (LIUL)	The intersecting point between the left vertical line and the inferior borderline of the upper lip vermilion
Left superior point lower lip (LSLL)	The intersecting point between the left vertical line and the superior borderline of the lower lip vermilion
Left inferior point lower lip (LILL)	The intersecting point between the left vertical line and the inferior borderline of the lower lip vermilion

Table 3. Definitions of linear, angular measurements, and ratio values

Measurement (abbreviation)	Definition
Linear measurement	
Upper lip height (ULH)	Distance between Sn and Stms
Lower lip height (LLH)	Distance between Stmi and Me
Lower facial height (LFH)	Distance between Sn and Me
Upper lip vermilion height (ULVH)	Distance between Ls and Stms
Lower lip vermilion height (LLVH)	Distance between Stmi and Li
Interlabial gap (IG)	Distance between Stms and Stmi
Total lip vermilion height (TLVH)	Distance between Ls and Li
Philtrum height (PH)	Distance between Sn and Ls
Philtrum width (PW)	Distance between RCbp and LCbp
Commissure height (CH)	Difference in Y-coordinate between Sn and Ch (mean)
Upper lateral lip vermilion height (ULLVH)	(Distance between RSUL and RIUL + Distance between LSUL and LIUL)/2
Lower lateral lip vermilion height (LLLVH)	(Distance between RIUL and RILL + Distance between LIUL and LILL)/2
Lip width (LW)	Distance between RCh and LCh
Angular measurement	
Labrale superius angle (LSA)	Angle (Rch, Ls, LCh)
Labrale inferius angle (LIA)	Angle (RCh, Li, LCh)
Stomion superius angle (SSA)	Angle (RCh, Stms, LCh)
Stomion inferius angle (SIA)	Angle (RCh, Stmi, LCh)
Upper lip convexity (ULC)	{Angle (RCh, RSUL, RCbp) + Angle (LCh, LSUL, LCbp)}/2
Lower lip convexity (LLC)	{Angle (RCh, RILL, Ls) + Angle (LCh, LILL, Ls)}/2
Cupid bow angle (CBA)	{Angle (RSUL, RCbp, Sn) + Angle (LSUL, LCbp, Sn)}/2
Ratio value	
Lip height ratio (LHR)	Upper lip height (ULH) / Lower lip height (LLH)
Lip vermilion height ratio (LVHR)	Upper lip vermilion height (ULVH) / Lower lip vermilion height (LLVH)
Vermilion height to width ratio (VHWR)	Total lip vermilion height (TLVH) / Lip width (LW)
Upper lip fullness index (ULFI)	Upper lateral lip vermilion height (ULLVH) / Upper lip vermilion height (ULVH)
Lower lip fullness index (LLFI)	Lower lateral lip vermilion height (LLLVH) / Lower lip vermilion height (LLVH)
Degree of lip Incompetence (DLI)	Interlabial gap (IG) / Total lip vermilion height (TLVH)

ferroni's correction ($P < 0.016$) was used to evaluate any differences between two groups. The differences between the normodivergent and hyperdivergent groups were estimated by the Mann-Whitney U test. All statistical analyses were performed using SPSS software version 25.0 (PASW Statistics 25.0, IBM Co., Armonk, NY, USA).

III. RESULTS

1. Comparison among Class I, Class II, and Class III normodivergent groups (Table 4, Fig. 2)

Upper lip height (ULH) did not significantly differ between three groups. However, lower lip height (LLH) was greater in the Class III group (62.9) than in Class I (59.1) and II group (57.0). Therefore, the lip height ratio (LHR) was smaller in the Class III group (0.464) than in the Class II group (0.528).

With regard to lip vermilion, upper lip vermilion height (ULVH), lower lip vermilion height (LLVH), and interlabial gap (IG) was not different between three groups. However, total lip vermilion height (TLVH) was the greatest in the Class II group (28.3), and vermilion height-to-width ratio (VHWR) also showed greater value in the Class II group (0.460), because lip width (LW) was not different between groups. Philtrum height (PH), philtrum width (PW), and commissure height (CH) was not different between three groups.

In the shape of lip vermilion, lower lateral lip vermilion height (LLLVH) was greater in the Class II group, however lower lip fullness index (LLFI) was greater in the Class III group. The labrale superius angle (LSA) and upper lip convexity (ULC) were smaller in the Class II group (129.3° and 162.8°) than in the Class I group (139.4° and 168.7°, respectively).

2. Comparison among Class I, Class II, and Class III hyperdivergent groups (Table 5)

As in the nomodivergent groups, ULH showed no significant difference between three hyperdivergent groups, but LLH was greater in the Class III group (66.8) than in the Class II group (58.8). Therefore, LHR was smaller in the Class III group (0.457) than in the Class II group (0.523).

With regard to lip vermilion, ULVH was not different between three groups. However, LLVH, TLVH, and VHWR were greater in the Class II group (16.6, 32.8, and 0.538) than in the Class I group (14.5, 28.0, and 0.490, respectively). The IG and degree of lip incompetence (DLI) were greater in the Class II group than in Class I and Class III groups.

In the shape of lip vermilion, lower lateral lip vermilion height (LLLVH) was greater in the Class II group, however upper and lower lip fullness index was not different between groups. Unlike nomodivergent groups, LSA was not different between groups, whereas labrale inferius angle (LIA) was smaller in the Class II group (123.8°) than in the Class I group (132.9°).

Table 4. Comparison of measurements between Class I, Class II, and Class III normodivergent groups

Measurement	Class I		Class II		Class III									
	Mean	SD	Mean	SD	Mean	SD	I vs II vs III		I vs II		I vs III		II vs III	
Linear measurement[a]														
ULH (%)	29.6	2.6	30.0	2.1	29.0	2.7	.722		.612		.721		.397	
LLH (%)	59.1	3.4	57.0	3.4	62.9	3.6	.001	**	.136		.003	†	.001	†
LFH (%)	88.9	4.6	87.9	4.4	92.6	3.3	.013	*	.592		.011	†	.008	†
ULVH (%)	10.5	1.6	12.0	2.1	10.4	1.6	.066		.032		.823		.051	
LLVH (%)	14.2	2.2	15.4	1.3	12.7	3.0	.036	*	.065		.118		.031	
IG (%)	0.3	1.3	1.0	2.0	0.6	1.6	.160		.079		.079		.917	
TLVH (%)	24.9	3.2	28.3	3.2	23.7	4.4	.006	**	.005	†	.239		.010	†
PH (%)	19.1	2.6	18.0	4.7	18.7	3.2	.398		.170		.644		.473	
PW (%)	16.4	1.3	16.0	1.3	15.5	1.1	.108		.318		.037		.369	
CH (%)	30.8	2.6	32.7	2.8	31.6	2.3	.098		.032		.379		.281	
ULLVH (%)	9.4	1.7	10.7	1.3	8.9	2.0	.043	*	.033		.602		.022	
LLLVH (%)	11.6	2.0	13.3	1.4	11.2	2.5	.019	*	.010	†	.387		.027	
LW (%)	62.9	4.3	61.8	4.2	60.3	3.3	.267		.484		.118		.356	
Angular measurement														
LSA (°)	139.4	11.3	129.3	10.0	133.7	9.1	.014	*	.006	†	.129		.144	
LIA (°)	134.3	5.7	132.6	6.5	140.9	11.0	.104		.396		.065		.086	
SSA (°)	184.4	8.6	191.1	8.3	190.4	9.5	.029	*	.030		.033		.555	
SIA (°)	176.6	6.6	172.3	7.8	172.7	4.4	.130		.157		.065		.878	
ULC (°)	168.7	6.7	162.8	4.4	169.3	7.0	.005	**	.002	†	.582		.017	
LLC (°)	155.0	5.4	152.2	4.4	151.8	6.8	.175		.129		.132		.719	
CBA (°)	146.4	6.6	147.1	6.3	143.6	4.3	.380		.732		.264		.182	
Ratio value														
LHR	0.502	0.045	0.528	0.043	0.464	0.058	.010	*	.089		.049		.004	†
LVHR	0.752	0.151	0.776	0.100	0.844	0.159	.355		.688		.166		.317	
VHWR	0.398	0.066	0.460	0.060	0.395	0.085	.014	*	.004	†	.777		.029	
ULFI	0.902	0.116	0.914	0.122	0.853	0.121	.328		.929		.153		.249	
LLFI	0.817	0.071	0.867	0.082	0.889	0.093	.021	*	.057		.013	†	.343	
DLI	0.008	0.040	0.032	0.065	0.023	0.057	.161		.079		.079		.972	

SD indicates standard deviation.

[a]Linear unit is a proportional value when the distance between the bilateral outermost borders of the iris is set to 100%.

*P<0.05; **P<0.01, using the Kruskal–Wallis test.

†P<0.016, using the Mann–Whitney U–test with Bonferroni's correction.

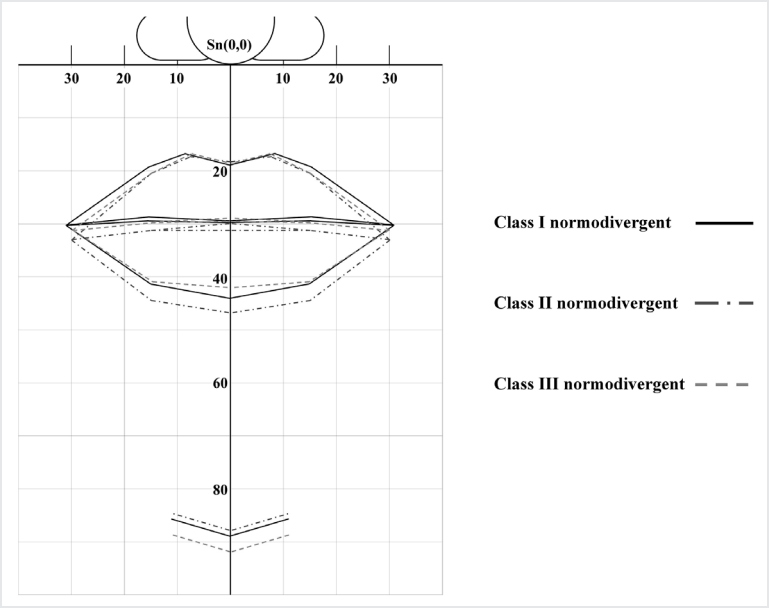

Figure 2. Comparison of lip morphology between the Class I, Class II, and Class III normodivergent groups.

Table 5. Comparison of measurements between Class I, Class II, and Class III hyperdivergent groups

Measurement	Class I		Class II		Class III									
	Mean	SD	Mean	SD	Mean	SD	I vs II vs III		I vs II		I vs III		II vs III	
Linear measurement[a]														
ULH (%)	30.3	3.1	30.6	2.9	30.5	2.5	.987		.887		.915		.925	
LLH (%)	62.0	5.5	58.8	5.1	66.8	5.0	.001	**	.065		.021		.000	†
LFH (%)	94.5	7.7	93.9	6.6	98.6	7.1	.148		.817		.110		.052	
ULVH (%)	11.3	1.8	11.8	2.1	13.0	2.2	.082		.332		.031		.124	
LLVH (%)	14.5	1.7	16.6	2.1	15.1	2.4	.000	**	.000	†	.377		.113	
IG (%)	2.2	3.6	4.5	3.8	1.3	3.2	.003	**	.009	†	.319		.005	†
TLVH (%)	28.0	4.3	32.8	5.0	29.3	6.3	.001	**	.000	†	.670		.043	
PH (%)	17.7	3.4	18.9	2.8	17.5	2.8	.266		.943		.161		.116	
PW (%)	15.3	1.8	15.5	1.2	15.5	1.5	.744		.476		.594		.887	
CH (%)	33.8	2.9	35.3	3.1	34.1	2.7	.262		.115		.808		.307	
ULLVH (%)	10.7	2.0	11.1	2.1	11.3	2.3	.541		.286		.484		.962	

Measurement	Class I		Class II		Class III								
	Mean	SD	Mean	SD	Mean	SD	I vs II vs III		I vs II		I vs III	II vs III	
LLLVH (%)	12.5	1.8	14.4	1.8	12.9	2.5	.005	**	.001	†	.772	.109	
LW (%)	60.4	4.4	61.1	3.7	62.4	3.9	.395		.817		.161	.300	
Angular measurement													
LSA (°)	127.7	12.3	123.9	10.3	123.8	9.7	.403		.206		.361	.912	
LIA (°)	132.9	9.5	123.8	8.2	135.6	10.3	.000	**	.001	†	.456	.002	†
SSA (°)	193.8	12.1	196.6	11.2	193.3	7.2	.415		.240		.964	.300	
SIA (°)	174.7	8.8	178.8	8.5	171.0	6.9	.024	*	.104		.176	.008	†
ULC (°)	163.8	7.1	162.6	6.5	165.0	7.1	.603		.355		.915	.470	
LLC (°)	149.9	7.3	148.1	6.1	151.2	8.7	.435		.310		.819	.245	
CBA (°)	144.7	10.2	144.5	6.2	140.6	9.4	.484		.810		.394	.198	
Ratio value													
LHR	0.490	0.048	0.523	0.051	0.457	0.028	.001	**	.010	†	.048	.001	†
LVHR	0.782	0.119	0.715	0.121	0.871	0.127	.006	**	.057		.068	.003	†
VHWR	0.466	0.084	0.538	0.080	0.469	0.089	.005	**	.002	†	.927	.026	
ULFI	0.949	0.139	0.948	0.144	0.871	0.113	.192		.545		.191	.069	
LLFI	0.862	0.060	0.872	0.080	0.859	0.095	.897		.873		.626	.765	
DLI	0.066	0.107	0.128	0.103	0.031	0.076	.003	**	.013	†	.283	.002	†

SD indicates standard deviation.
[a]Linear unit is a proportional value when the distance between the bilateral outermost borders of the iris is set to 100%.
*P<0.05; **P<0.01, using the Kruskal–Wallis test.
†P<0.016, using the Mann–Whitney U–test with Bonferroni's correction.

3. Comparison between normodivergent and hyperdivergent groups (Table 6)

ULH did not differ between the normodivergent and hyperdivergent groups, while LLH was greater in Class I and Class III hyperdivergent groups than nomodivergent groups. Lower facial height (LFH) was greater in all hyperdivergent groups than the normodivergent groups.

In the lip vermilion, no significant difference was found in ULVH between the normodivergent and hyperdivergent groups. However, Class I and Class II hyperdivergent groups showed greater IG than the nomodivergent groups, and all hyperdivergent groups showed greater TLVH than the nomodivergent groups. CH was significantly larger in all hyperdivergent groups than nomodivergent groups.

In the angular measurements of the lip vermilion, Class I groups showed differences in both upper (LSA, SSA, and ULC) and lower lip vermilion variables (LLC) between the normodivergent and hyperdivergent groups. Class II groups showed differences

Table 6. Comparison of measurements between the normodivergent and hyperdivergent groups

Measurement	Class I			Class II			Class III		
	U value	P-value		U value	P-value		U value	P-value	
Linear measurement[a]									
ULH (%)	295.0	.319		156.5	.709		56.0	.231	
LLH (%)	235.5	.040	*	134.0	.297		38.0	.030	*
LFH (%)	199.5	.007	**	75.5	.005	**	26.0	.005	**
ULVH (%)	260.0	.105		153.5	.644		27.5	.006	**
LLVH (%)	297.5	.341		86.5	.014	*	42.5	.053	
IG (%)	247.0	.007	**	70.0	.002	**	75.0	.815	
TLVH (%)	190.5	.004	**	66.5	.002	**	34.0	.017	*
PH (%)	320.0	.581		131.5	.264		58.5	.288	
PW (%)	204.5	.009	**	136.5	.332		75.0	.870	
CH (%)	145.5	.000	**	95.0	.027	*	39.0	.034	*
ULLVH (%)	226.5	.027	*	134.5	.304		35.0	.019	*
LLLVH (%)	261.5	.111		105.0	.057		46.0	.082	
LW (%)	254.5	.086		143.0	.438		56.5	.242	
Angular measurement									
LSA (°)	154.0	.000	**	122.0	.161		35.5	.021	**
LIA (°)	314.0	.510		68.0	.003	**	55.5	.221	
SSA (°)	178.5	.002	**	117.5	.125		50.0	.128	
SIA (°)	301.5	.378		104.5	.055		54.0	.192	
ULC (°)	227.0	.027	*	160.0	.789		51.0	.142	
LLC (°)	214.0	.015	*	96.0	.030	*	75.0	.870	
CBA (°)	317.0	.545		138.5	.363		60.5	.341	
Ratio value									
LHR	292.0	.294		164.0	.882		74.0	.828	
LVHR	311.0	.477		118.0	.129		69.0	.624	
VHWR	170.0	.001	**	71.0	.004	**	42.0	.050	
ULFI	285.0	.240		139.0	.371		71.0	.703	
LLFI	217.0	.017	*	157.0	.721		69.0	.624	
DLI	247.0	.007	**	75.0	.004	**	75.0	.815	

[a]Linear unit is a proportional value when the distance between the bilateral outermost borders of the iris is set to 100%.
*P<0.05; **P<0.01, using the Mann-Whitney U-test.

only in the lower lip vermilion variables (LIA and LLC), while Class III groups showed in the upper lip vermilion variables (LSA).

Figure 3 shows the shapes of the lip vermilions between the Class I normodivergent group and the hyperdivergent group.

Ⅳ. DISCUSSION

Many researchers have studied the frontal aesthetics of lip vermilions[20,21]. The lip vermilion in the frontal view can be analyzed efficiently using high-quality digital photographs, and these can provide an intuitive understanding of the frontal shape of the lips[6,7,9]. Also, the photometric analysis is non-invasive, and its measurement errors were shown to be sufficiently reliable. To reduce confounding factors, only adult female Korean subjects were included in the present study. Trinaswaty et al.[9] reported significant differences in the height of the lip vermilions between normal occlusion subjects and bi-alveolar protrusion patients. Therefore, the present study excluded bi-alveolar protrusions in the Class I group, which served as the control group.

1. Differences in the morphology of lip vermilions according to sagittal dentoskeletal patterns

In the comparison of the normodivergent Class I, Class II, and Class III groups (Table 4), LLH and LFH were significantly greater in the Class III group than in Class I and Class II groups. These findings seem to be because the most prominent feature of skeletal Class III malocclusion is mandibular prognathism[22]. There were also significant differences in the lip vermilion morphology among the three groups. The lip vermilions in the Class II group were thick in the middle and had more triangular shapes than those in the Class I group (Fig. 4A). This result is consistent with several reports that the upper lips of Class II patients were shorter and more hypotonic than those of Class I patients because of maxillary incisor protrusion[23]. In contrast, the lower lip vermilions of the Class III subjects were thick in the bilateral area with greater LLFIs than those of the Class I group (Fig. 4B). These differences in lower lip morphology may be related to the anterior crossbite or great intercanine width of Class III malocclusion[24]. Islam et al.[6] reported that the area of the lower vermilion was larger in Class II than in Class I. In the present study, the LLVH in the Class II hyperdivergent group was larger than that of the Class I hyperdivergent group, although it was not statistically significant between the nomodivergent groups.

In the comparison between the Class I, Class II, and Class III hyperdivergent groups, LLH was greater in the Class III group than in Class I and II groups, which was also seen in the results of the normodivergent groups. Morphological characteristics of the lip vermilion also differed between the three hyperdivergent groups. The SIA was statistically smaller in the Class III group, indicating a higher stomion inferius and reverse shape of the lower lip in Class III hyperdivergent subjects (Fig. 4C). Tanikawa et al.[8] suggested that when both lips are in contact and the

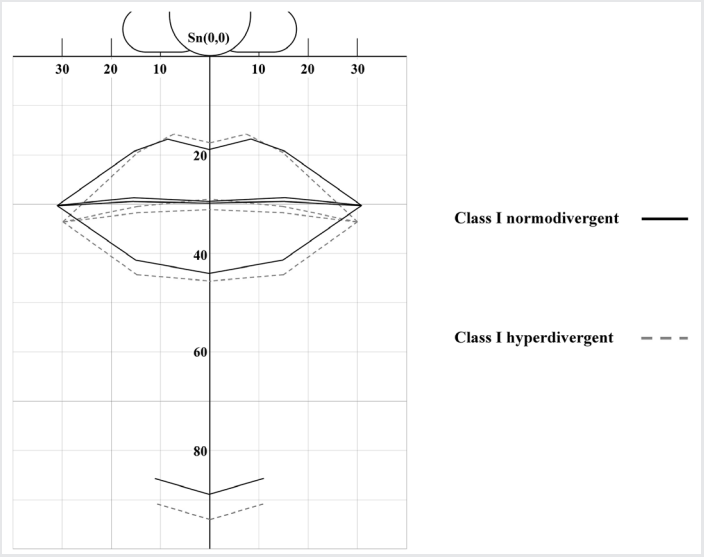

Figure 3. Comparison of lip morphology between the Class I normodivergent and hyperdivergent groups.

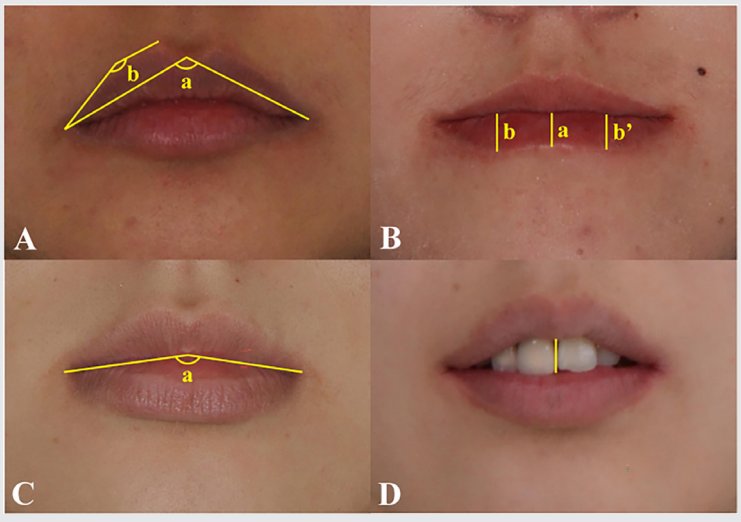

Figure 4. A, Triangular shape of the upper lip vermilion in the Class II normodivergent group with lower labrale superius angle (a) and upper lip convexity (b) than the Class I normodivergent group. B, Lower lip vermilion was thick in the lateral 1/4 area in Class III normodivergent group. C, Reverse lower lip in the Class III hyperdivergent group; a: stomion inferius angle. D, Severe lip incompetence in the Class II hyperdivergent group.

upper lip is more forward than the lower lip, the height of the lower lip appears shorter because the pressure of the upper lip is applied vertically and vice versa. It could be conjectured that the lower lip vermilion, which has a forward position in the Class III hyperdivergent group is less influenced by vertical pressure from the upper lip. Lip incompetence was more severe in Class II with greater IG and DLI than the Class I and Class III hyperdivergent groups (Fig. 4D). Our results are consistent with the suggestion of Van der Linden[25] that the lips of Class II patients were more incompetent than those of patients with other malocclusions. Satimary et al.[26] also reported that the lip incompetence group showed a more Class II skeletal relationship and a more posteriorly positioned pogonion. The LIA was significantly smaller in the Class II group, indicating that the Class II subjects may have a more triangular-shaped lower lip vermilion. This characteristic shape of the lower lip may relate to the direct contact of the lower lip with the upper incisors, which was found in Class II patients with a large anterior overjet[25].

2. Differences in lip vermilion morphology according to facial divergence

In the comparison between the normodivergent and hyperdivergent groups, the hyperdivergent groups showed larger LFH and more severe lip incompetence than the normodivergent group, as expected. The hyperdivergent group tended to show larger TLVH and VHWR, indicating a vertically thick and horizontally narrow lip vermilion than the normodivergent group. This may be related to the greater facial height and interlabial gap in hyperdivergent patients. Interestingly, the commissure was positioned lower in the hyperdivergent than the normodivergent groups, but philtrum height was not different between the groups. These results indicate that if the facial patterns of the patients are more hyperdivergent, the upper lip may appear to be relatively shorter and show a more reverse lip line at rest than the normodivergent subjects. The tension of the soft tissue including muscles near the commissures of the lower lip attached to the mandible is thought to be related to the reverse shape of the lips at rest[27].

Our results showed that both anteroposterior dentoskeletal patterns and facial divergence significantly affected the morphology of the lip vermilion in the frontal view. When orthodontic treatment is performed to change significant dentoskeletal features, our results could be helpful in predicting the frontal shape of the lip vermilion after treatment. Changes in the anterior occlusion and anteroposterior skeletal relationship can affect lip height and the interlabial gap because the lips are in direct contact with the labial part of the anterior teeth. Several researchers have suggested that the philtrum height should be roughly equal to the height of the commissure, and a short upper lip relative to the commissure height should be considered carefully[10]. If the lower facial height is increased by orthodontic treatment, the interlabial gap and reverse lip line can be worsened and vice versa. Therefore, facial divergence should also be taken into account in the

analysis of the patient's frontal face. And the goal of orthodontic treatment should be established to harmonize hard tissues and soft tissues as well.

V. CONCLUSIONS

- This study compared the differences in the shape of the lip vermilion by dividing the Korean female subjects into anteroposterior skeletal pattern and vertical pattern groups.
- Class III group showed greater lower lip height than those of Class I and Class II groups. However, Class II group showed larger lip vermilion height and more triangular shape than other groups.
- Compared to the normodivergent groups, the hyperdivergent groups showed greater lower facial height and commissure height. Greater interlabial gap and/or thicker lip vermilion increased lip vermilion height in the hyperdivergent groups.
- The lip morphology differed according to the sagittal dentoskeletal relationship and facial divergence.

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