A Proposal of 3-dimensional Assessment of Face with CBCT images: A Pilot Study of Facial Analysis with 'Anterior Facial Pyramid'

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A Proposal of 3-dimensional Assessment of Face with CBCT images: A Pilot Study of Facial Analysis with 'Anterior Facial Pyramid'

Directed by Professor: Kyung-Ho Kim

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저를 이 자리에 있게 해주신 부모님, 철없는 동생을 아껴주는 언니들과 형부들, 하나뿐인 제 동생, 부족한 며느리에게 아낌없는 사랑을 주

시는 시부모님께 진정으로 사랑과 고마움의 마음을 전하며, 이 작고 소중한 기쁨을 함께 나누고자 합니다. 마지막으로 항상 제 곁에서 든든한 힘이 되어주는 제 남편에게 큰 고마움을 표시합니다.

2015년 12월

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Abstract

A Proposal of 3-dimensional Assessment of Face with CBCT Images: A Pilot Study of Facial Analysis with 'Anterior Facial Pyramid'

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Objectives: The aim of this study was to suggest a new reference frame concerning the zygoma area for the soft tissue analysis of lower face. The average relationship between the new frame and the facial landmarks in skeletal Class I patients was studied by using the CBCT records of Korean young adults.

Materials and methods: Anterior facial pyramid (AFP) was designed for evaluating the anterior facial profile on total 48 CBCT images (23 male and 25 female) in this study. AFP was composed of 4 soft tissue landmarks, which were pronasale, right zygomatic point, left zygomatic point, and soft tissue pogonion. The samples were classified into two groups by gender. The linear and angular measurements of AFP, nose, and lip were performed. The relationship between AFP and the landmarks of nose and lip was assessed.

Results: The zygomatic point was posteriorly located to N'-perpendicular plane (N'-per.). as much as 14.4 ±2.56 mm in men and 12.1±2.26 mm in women ($p < 0.01$). The pronasale was protruded to N'-per. as much as 22.5±2.55 mm in men and 20.4±2.36 mm in women ($p < 0.05$). The midface angle transverse was 114.4±3.61 degree in men and 118.6±4.48 degree in women ($p < 0.01$). The ratio of the height of base of AFP to the midface width was 64.4±5.68 % in men and 62.3±5.07 % in women ($p > 0.05$). The cheilion right/ left was protruded to the base as much as 1.6±2.86 mm in men and 0.1±3.04 mm in women ($p > 0.05$). The labiale superius right/ left was located away from the side 2.5±2.15 mm in men and 2.1±1.95 mm in women ($p > 0.05$). The distance between the labiale inferius right/ left and the side of AFP was 3.4±3.70 mm in men and 3.2±3.43 mm in women ($p > 0.05$). The upper lip point of men was protruded from anterior vertical edge (E-line) as much as 0.4±2.54 mm, the upper lip point of women was posteriorly positioned to the anterior vertical edge as much as 1.2±1.98 mm ($p < 0.05$). The lower lip point of men was protruded from the anterior vertical edge as much as 1.7±2.82 mm in men and 1.0±2.21 mm in women ($p > 0.05$).

Conclusions: A new facial reference frame, anterior facial pyramid (AFP), was proposed for the 3-dimensional assessment of face. The average relationship between the new frame and its contents was studied. This study may be fundamental to the 3-dimensional assessment of the lip concerning zygoma when planning orthodontic treatment.

Key words: CBCT, anterior facial pyramid (AFP), soft tissue, zygoma.

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I. Introduction

As the esthetic demand on the 'well-looking' has been increasing, more patients visit the dental clinic for improving their facial profile. The orthodontic treatment, as for the approach to correct the facial profile, shows the results not just from well aligned teeth but more often from their relationship with the soft tissues (Masella and Meister, 2007; Peck and Peck, 1995). In this aspect, proper analysis on the soft tissue before the treatment is necessary.

For the diagnosis of facial profile, various 3-dimensional (3D) technologies such as 3D computed tomography (Arridge et al., 1985; Ayoub et al., 2003; Han et al., 2005;

Olszewski et al., 2007; Park et al., 2006; Vezzetti et al., 2010), laser scanning (Arridge et al., 1985; Baik et al., 2007; Baik and Kim, 2010; Baik et al., 2006; Bush and Antonyshyn, 1996; Kau et al., 2006; Kovacs et al., 2006; Kusnoto and Evans, 2002; Moss et al., 1987), 3D stereo photogrammetry (Ayoub et al., 2003; Ayoub et al., 1998; Ferrario et al., 1998; Weinberg et al., 2004) and cone-beam computed tomography (CBCT) images have been introduced. These techniques are less invasive when archiving images, eliminate surface pressure from an apparatus, and avoid measurement errors that occur in 2-dimensional (2D) representations of 3D surfaces.

However, the facial assessment on 3D images is still performed by conventional methods. For example, lip protrusion is evaluated by measuring relative antero-posterior position of the lip landmark to the reference line introduced by Arnett (Arnett and Bergman, 1993a, 1993b; Arnett et al., 1999), Burstone (Burstone, 1967; Legan and Burstone, 1980), Holaway (Holdaway, 1983, 1984), Ricketts (Ricketts, 1968), etc. These previous reference lines are set on 2D mid-sagittal plane considering nose and chin. However, one's own face that patients see in a mirror by themselves or recognized by nearby people may not be the facial profile of 90-degree lateral side or at mid-sagittal plane, but the face of 45-degree or below angled side. To obtain the maximal satisfactory outcome after treatment of correcting facial profile, the facial analysis on non-sagittal plane, or 3D profile analysis should be conducted.

The physical features of the Asian face are related to their specific skeletal and morphological genetics that differ from those of Caucasians (Liew et al., 2015). The Asians tend to have a wide and short face. In the aspects of facial profile, it typically

appears flat or, in some cases, even concave due to their flat nose and concave central midface. In the Asian population, clinicians frequently encounter problems of the lip such as an acute nasolabial angle, protrusive everted lips and nonconsonant lip line (Choi et al., 2012). Many orthodontists have been using Ricketts' esthetic line (E-line) to assess the lip position for a long time. Although E-line is easy to apply with a ruler or a dental mirror at the chair-side, this is not always an appropriate reference line for the Korean patients who have relatively less prominent nose tip or chin than westerners.

Moreover, many patients complain over the lip protrusion in regard to the overall facial balance including upper 1/2 of the face in addition to chin and nose tip. As the zygoma is located on the middle third of the face, its prominence, contour, and width would have large effects on the facial impression (Watanabe et al., 1984). Considering this importance, the zygoma region should be concerned in the facial analysis process.

Aesthetic units of the face can be divided into facial content (eyes, nose, lips, and mouth) and facial frame (Choi et al., 2012). Well-balanced and pleasing face means that each facial structure has a good relationship with the frame. In this study, 'Anterior facial pyramid (AFP)' was suggested as the new reference frame of the facial analysis. AFP was formed by 4 angular points (zygomatic point right, soft tissue pogonion, zygomatic point left, and pronasale) on the zygoma, the chin, and the nose tip, since facial appearance is mainly determined by the convexities and projection provided by the zygomatic bone and the mental protuberance of the mandible, respectively (Shiffman and Di Giuseppe, 2012).

Certain concepts of facial beauty may indeed be timeless. Those concepts include symmetry, averageness, youth, and sexual dimorphism (Weeks and Thomas, 2014). Bashour (Bashour, 2006) found that 'averageness' is one of the most important cues determining attractiveness. Although the meaning of 'averageness' is not equal to 'beautiful or ideal face', average data of facial measurements are fundamental to the objective analysis, the prediction of final results, and the evaluation of treatment outcome.

The aim of this study was to suggest a new reference frame concerning the zygoma area for the soft tissue analysis of lower face. The average relationship between the new frame and contents in skeletal Class I patients was studied by using the CBCT records of Korean young adults.

II. Materials and Methods

1. Subjects

The data were selected among the CBCT images taken from the patient who visited the department of Orthodontics, Gangnam severance dental hospital, Seoul, Korea, from March 1, 2011 to March 31, 2015. The inclusion criteria:

- age in twenties (from 20 to 29 years old)
- skeletal Class I relationship (0° < ANB < 4°)
- normodivergent facial profile (30° < SN-GoMe < 37°)
- no severe facial asymmetry, deviation of pogonion within range of 2mm in the right or left direction
- no lip protrusion (90° < Cm-Sn-Ls < 110°)
- anterior crowding less than 3 mm
- no history of surgery at maxillofacial region and previous orthodontic treatment

Total 48 patients (23 male and 25 female) were selected and the average age of sample was 23.6 years old. The samples were classified into two groups by gender. All measurements were performed on CBCT images, and the mean and the standard deviation of the variables are calculated in each group. Table 1 shows the skeletal and

dental characteristics of the subjects, and there was no statistically significant difference between male and female groups by independent *t*-test ($P > 0.05$).

Table 1. Characteristics of subjects

Variable	Male		Female	
	Mean	SD	Mean	SD
SNA (°)	82.6	4.42	82.0	2.71
SNB (°)	79.9	4.41	79.4	2.63
ANB difference (°)	2.8	1.19	2.7	1.10
SN-GoMe (°)	34.8	4.27	34.6	4.10
FH- GoMe (°)	25.7	3.33	25.8	3.61
U1 to SN line (°)	104.1	7.41	103.4	6.63
IMPA (°)	90.8	8.64	92.5	8.31
Cm-Sn-Ls (°)	102.2	8.12	105.3	7.90

SD, standard deviation; SN, line passing the sella and nasion; GoMe, plane passing menton, right gonion and left gonion; U1, Long axis of right upper central incisor; IMPA(incisor mandibular plane angle), angular measurement of the mandibular plane and long axis of right lower central incisor; Cm-Sn-Ls, angle formed by columella, subnasale, and labiale superius.

2. CBCT images

The CBCT images were taken by Pax-Zenith3D® (Vatech Company Limited, Hwaseong-si, Gyeonggi-do, Korea) with the following parameters: 240×190 mm field of view, 5 mA, 120 kV, 15 seconds scan time, 0.3×0.3 isometric voxel size. The CBCT images were displayed with 0.3 mm gap at OnDemand3D Application® (Cybermed Incorporated, Seoul, Korea) and re-oriented by the 3 reference planes. The method of re-orientating CBCT images was modified from Dr. Cho's analysis (Cho, 2009). Frankfort horizontal plane (R-FH plane), the frontal plane, and the mid-sagittal plane were used for re-orienting CBCT images as the reference in this study. R-FH plane was the reference of axial plane which passed right porion, left porion, and right orbitale. The frontal plane was the reference of coronal plane which passed the right and left frontozygomatic point (the most inner point of right frontozygomatic suture), and perpendicular to R-FH plane simultaneously. The mid-sagittal plane was the reference of sagittal plane which passed nasion and perpendicular to R-FH plane and frontal plane.

After re-orientation of the CBCT images, assuming nasion as zero point, the X-axis (right-left), the Y-axis (anterior-posterior), and the Z-axis (superior-inferior) were established (Figure 1). The 3D coordinate values of the landmarks (x, y, and z) were acquired by tracing the CBCT images. The soft tissue landmarks used in this study were described in Figure 2 and Table 2. Most landmarks traced in this study were proposed by Farkas (Farkas, 1994). For clinical interpretation and reproducibility, soft tissue nasion was established as the most concave point in the tissue overlying the area of the frontonasal suture (Rhee et al., 2004). Several methods for locating the malar eminence

have been developed; Hinderer's (Hinderer, 1975), Wilkinson's (Wilkinson, 1983), Powell's (Powell and Humphreys, 1984), and Prendergast's methods (Shiffman and Di Giuseppe, 2012). In addition, a previously described point called the maxillozygion derives the location of the malar eminence by palpation only (Nechala et al., 2000). But these methods are difficult to reproduce on the CBCT images. For improving reproducibility and ease of tracing, the landmark of zygoma, zygomatic point was defined as the most lateral point when rotating the re-oriented images to 45-degree to the right or left side, taking the Z-axis as the reference. This method was similar to that used in previous studies (Baik et al., 2006; Han et al., 2005).

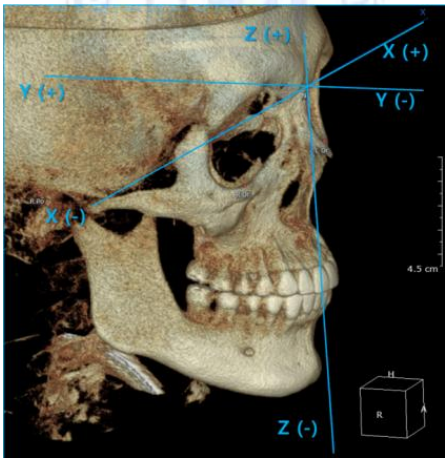

Figure 1. Re-orientation and coordination of CBCT images.

X, the X-axis (right-left); Y, the Y-axis (anterior-posterior); Z, the Z-axis (superior-inferior).

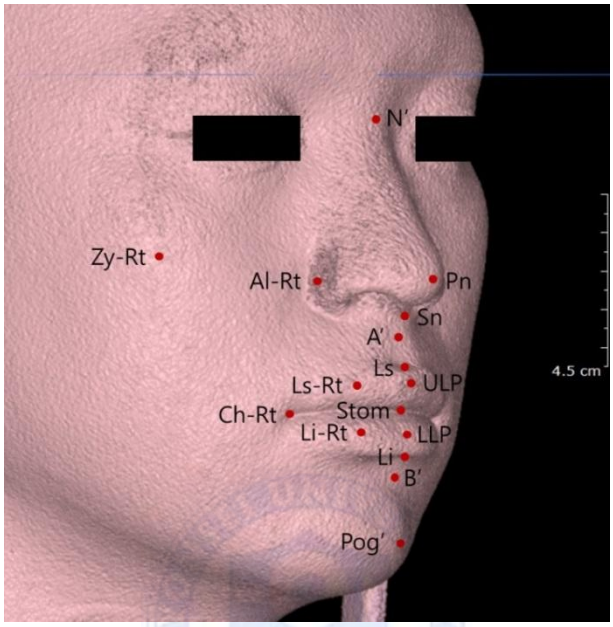

Figure 2. Soft tissue landmarks.

N', soft tissue nasion; Zy-Rt, zygomatic point right; Al-Rt, alare lateralis right; Pn, pronasale; Sn, subnasale; A', soft tissue A point; Ls, labiale superius; Ls-Rt, labiale superius right; ULP, upper lip point; Stom, stomion; Ch-Rt, cheilion right; LLP, lower lip point; Li-Rt, labiale inferius right; Li, labiale inferius; B', soft tissue B point; Pog', soft tissue pogonion.

Table 2. Soft tissue landmarks

Landmark	Location
Soft tissue nasion (N')	Most concave point in the tissue overlying the area of the frontonasal suture
Alare lateralis right/ left (Al-Rt/ Lt)	Most right/ left lateral point of alar contour
Zygomatic point right / left (Zy-Rt/ Lt)	Most protruding point to the right/ left when rotating the re-oriented images to 45-degree to right/ left side, taking Z-axis as the reference
Pronasale (Pn)	Most protruding point of the nasal tip
Subnasale (Sn)	The junction between the lower border of the nasal septum and upper lip in the midline
Soft tissue A point (A')	Deepest point between subnasale and labiale superius
Labiale superius (Ls)	Point of the upper lip where curvature changes from convex to concave in the midline
Labiale superius right/ left (Ls-Rt/ Lt)	Most anterior point on sagittal plane which was passing the midpoint of upper lip point and cheilion
Upper lip point (ULP)	Most anterior point of the upper lip
Stomion superius (Stoms)	Most inferior point of the upper lip vermilion
Stomion inferius (Stomi)	Most superior point of the lower lip vermilion
Cheilion right/left (Ch-Rt/ Lt)	Right/left inner corner of the mouth
Lower lip point (LLP)	Most anterior point of the lower lip
Labiale inferius right/ left (Li-Rt/ Lt)	Most anterior point on sagittal plane which was passing the midpoint of lower lip point and cheilion
Labiale inferius (Li)	Point of the lower lip where curvature changes in the midline
Soft tissue B point (B')	Deepest point between soft tissue pogonion and labiale inferius
Soft tissue pogonion (Pog')	Most anterior point of the chin

3. Measurements

(1) Frame: Anterior facial pyramid

Concerning convexity of the face and the attachment areas of muscle related to the lip (Shiffman and Di Giuseppe, 2012), 'anterior facial pyramid (AFP)' was designed as a new facial frame for evaluating the anterior facial profile. This pyramid was composed of 4 soft tissue landmarks, which were pronasale, right zygomatic point, left zygomatic point, and soft tissue pogonion (Figure 3-A), The pronasale was the most prominent point of the nose. The right/ left zygomatic point was the most prominent point to the right or left when rotating the re-oriented images to 45-degree to the right or left side, taking the Z-axis as the reference. The zygomatic point was on the curvature of malar region and located near the attachment area of zygomatic muscles and the condensation of connective tissue at the borders of the medial and middle fat compartments (Figure 3-B). The soft tissue pogonion was the most prominent point of the chin. The planes consisting AFP were also called base, top, right side, left side (Figure 3-A, B). The base was the posterior surface of AFP and the reverse triangle formed by zygomatic point right, soft tissue pogonion and zygomatic point left. The top was formed by zygomatic point right, pronasale and zygomatic point, and this was the superior surface of AFP. The right/ left side were formed by zygomatic point right/ left, soft tissue pogonion and pronasale. The anterior vertical edge was drawn from pronasale to soft tissue pogonion. This line was the anterior boundary of AFP and same with Ricketts' esthetic line (E-line).

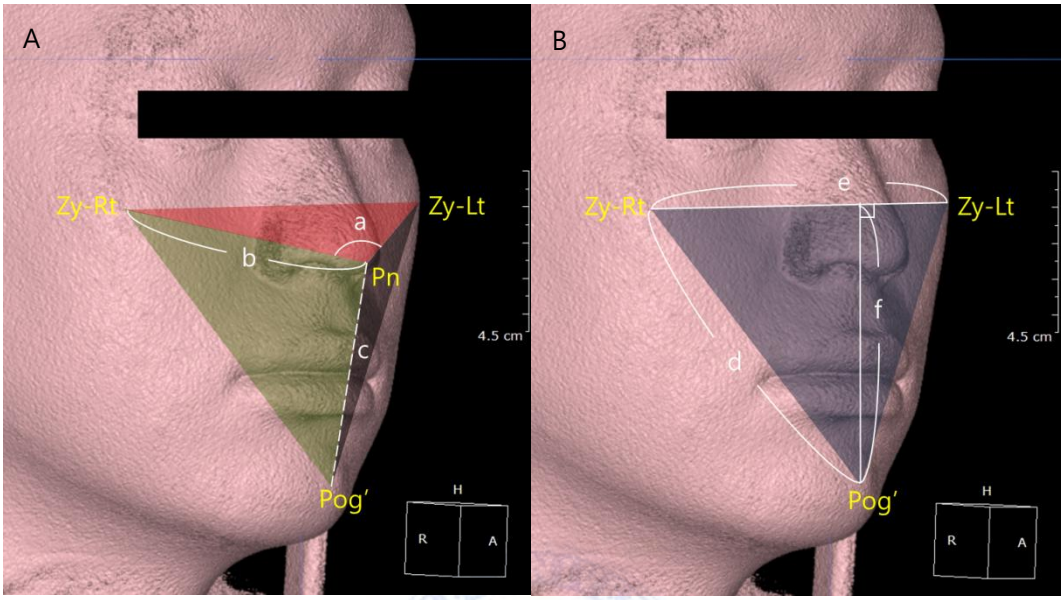

Figure 3. Anterior facial pyramid (AFP).

Zy-Rt, zygomatic point right; Zy-Lt, zygomatic point left; Pn, pronasale; Pog', soft tissue pogonion.

A. Red colored triangle, top of AFP; green colored triangle, right side of AFP; black colored triangle, left side of AFP; dashed line, anterior vertical edge of AFP; a, midface angle transverse; b, distance between Zy-Rt/Lt and Pn; c, distance between Pn and Pog'.

B. Blue colored triangle, base of AFP; d, distance between Zy-Rt/Lt and Pog'; e, upside length of the base (interzygoma width) ; f, height of the base.

To evaluate the chariacteristics of AFP, the linear and angular measurements were performed (Figure 3 and 4). The angle formed by zygomatic point right, pronasale, zygomatic point left was defined as midface angle transverse and measured (Figure 3-B, a). This measurement corresponded to the transverse nasal prominence examined by Baik et al. (Baik et al., 2007). The lengths of all edges of the AFP were measured (Figure 3, b-e). The upside length (width) of the base could represent the interzygoma width (Zy-Rt ~ Zy-Lt) (Figure 3-B, e). The height of base could represent the height of lower half face (Figure 3-B, f). The ratio of the height to the upside length of the base was also calculated (height of the base ÷ upside length of the base × 100).

N'-perpendicular plane (N'-per.) was named the plane perpendicular to the R-FH plane and passing through soft tissue nasion. As N'-per. passed the AFP and was easy to be set on the image, this plane was taken as the reference to evaluate the antero-posterior position of AFP landmarks. The antero-posterior position of the angular points consisting AFP relative to N'-per. was calculated by subtracting y value of the landmark from y value of soft tissue nasion (Figure 4). The mean y value of zygomatic point right and zygomatic point left was calculated, and the difference between this mean y value and the y value of pronasale was named midface depth.

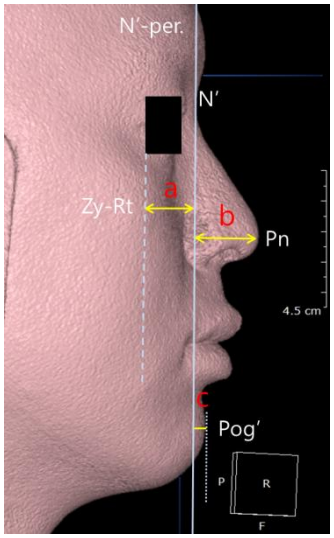

Figure 4. The anteroposterior position of the landmarks consisting AFP relative to N'-per.

AFP, anterior facial pyramid; N'-per., N'-perpendicular plane; N', soft tissue nasion; Zy-Rt, zygomatic point right; Pn, pronasale; Pog', soft tissue pogonion.

a, zygoma prominence; b, nose tip prominence; c, chin prominence.

(2) The assessment of facial soft tissue with AFP

The relationship of nose and lip to the AFP was evaluated by measuring the perpendicular distance from the landmarks of nose and lip to AFP. The landmarks using for evaluating the relationship with the base were pronasale, subnasale, labiale superius, labiale superius right, labiale superius left, upper lip point, stomion superius, cheilion right, cheilion left, stomion inferius, lower lip point, labiale inferius right, labiale inferius left, labiale inferius and soft tissue B point. The depth of AFP could be inferred from the

perpendicular distance between pronasale and base. The landmarks using for evaluating the relationship with the right side were labiale superius right, cheilion right and labiale inferius right. The landmarks using for evaluation the relationship with the left side were labiale superius left, cheilion left and labiale inferius left. The landmarks for evaluating the relationship with the anterior vertical edge (E-line) were labiale superius, upper lip point, lower lip point and labiale inferius. When the landmark was located in the space of AFP, the distance value between the landmarks and AFP was marked with negative sign (-), or else marked with positive sign (+).

(3) Contents: Nose and lip

The linear and angular measurements were performed for form evaluation of nose and lip. Nose angle sagittal, nose length and nose tip prominence were evaluated at sagittal view of nose (Table 3 and Figure 5-A). Nose tip prominence was same value to the anteroposterior position of pronasale relative to N'-per. (Figure 4). Nose angle transverse and nose width were measured at transverse view of nose (Table 3 and Figure 5-B). The measurement items for evaluating the lip and its formula were described at Table 4 and Figure 6. The upper lip angle transverse was measured by same way as transverse upper lip prominenc examined by Baik et al. (2007), and was subdivided into upper lip angle axial and upper lip angle frontal by projecting the landmarks to R-FH plane or frontal plane.

Table 3. Morphological measurements of nose

	Name	Measurement
Sagittal view	Nose angle sagittal (°)	The angle between N'-per. and nasal line
	Nose length (mm)	The distance between N' and Pn
	Nose tip prominence (mm)	The perpendicular distance between Pn and N'-per.
Transverse view	Nose angle transverse (°)	The angle formed by Al-Rt, Pn, Al-Lt
	Nose width (mm)	The distance between Al-Rt and Al-Lt

N'-per., N'-perpendicular plane; Nasal line, the line passed soft tissue nasion and pronasale; N', soft tissue nasion; Pn, pronasale; Al-Rt, alare lateralis right; Al-Lt, alare lateralis left.

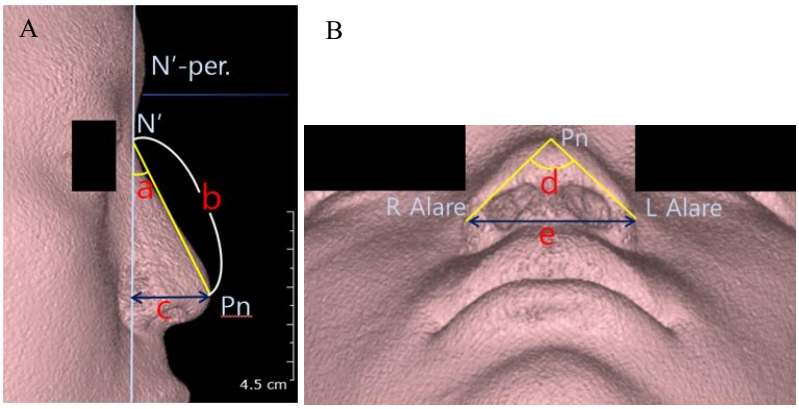

Figure 5. Morphological measurements of nose.

N'-per., N'-perpendicular plane; N', soft tissue nasion; Pn, pronasale; R Alare, alare lateralis right; L Alare, alare lateralis left.

A. Measurements at sagittal view. a, nose angle sagittal; b, nose length; c, nose tip prominence.

B. Measurements at transverse view. d, nose angle transverse; e, nose width.

Table 4. Morphological measurements of lip

	Name	Measurement
Length (mm)	Upper vermilion height	Difference between Z values of Ls and Stoms
	Lower vermilion height	Difference between Z values of Li and stomi
	Lip width	Difference between x values of Ch-Rt and Ch-Lt
Angle (°)	Upper lip angle sagittal	The angle between upper lip line and N'-per.
	Upper lip angle transverse	The angle formed by Ch-Rt, ULP, Ch-Lt
	Upper lip angle axial	The angle formed by Ch-Rt, ULP, Ch-Lt when these 3 dots were projected to R-FH plane
	Upper lip angle frontal	The angle formed by Ch-Rt, ULP, Ch-Lt when these 3 dots were projected to frontal plane

Ls, labiale superius; Stoms, stomion superius; Li, labiale inferius; Stomi, stomion inferius; Ch-Rt, cheilion right; Ch-Lt, cheilion left; upper lip line, line formed by subnasale and labial superius; N'-per., N'-perpendicualr plane; ULP, upper lip point; R-FH plane, Frankfort horizontal plane.

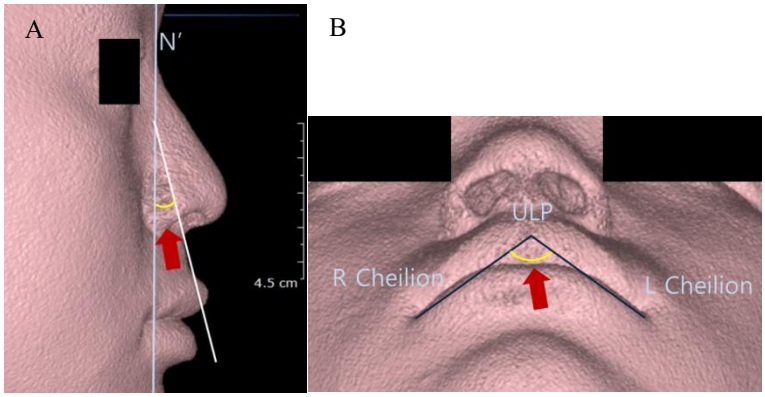

Figure 6 . Angular measurements of lip.

N', soft tissue nasion; R Cheilion, cheilion right; ULP, upper lip point; L Cheilion, cheilion left.

A. Upper lip angle sagittal.

B. Upper lip angle transverse.

4. Statistical analysis

The intra-class correlation coefficient (ICC) was used to test the intra-examiner reliability and the reproducibility of 22 soft tissue landmarks traced on randomly selected 20 CBCT images by repeating measurements. As this study showed high reliability with the range of ICC from 0.828 to 0.935 ($p = 0.000$), the mean and standard deviation of all variables were calculated in each group. Kolmogorov-Smirnov test and Shapiro-Wilk test were preceded in regard of every variable to test normality. Since all variables showed normal distribution in both groups ($p > 0.05$), parametric test was conducted. The difference between male and female group was compared by independent *t*-test at significance level of $p = 0.05$. Correlation and partial correlation among the midface angle transverse and its determinant factors, which were the interzygoma width (width of the base) and the midface depth, were assessed by Pearson's correlation coefficient analysis at significance level of $p = 0.05$. All statistical analysis was performed with IBM SPSS Statistics version 22.0 program® (IBM corporation, New York, United states).

III. Results

1. Frame: Anterior facial pyramid

The results of the linear and the angular measurement of AFP were indicated in Table 5. Since there was no statistically significant difference in bilateral length between both sides, the average distance of both side was tabulated as one variable (the bilateral landmarks). The midface angle transverse was 114.4 degree in men and 118.6 degree in women (Table 5) ($p < 0.01$). The size of AFP was significantly larger in men than in women ($p < 0.01$), but the ratio of height to upside length of the base was similar between genders in average of 63.3 % ($p > 0.05$).

Table 5. Morphological features of AFP

	Variable	Male		Female		*p*-value
		Mean	SD	Mean	SD	
a	Midface angle transverse (°)	114.4	3.61	118.6	4.48	.003**
b	Zy ~ Pn (mm)	70.0	2.62	65.4	2.79	.000**
c	Pn ~ Pog' (mm)	67.5	4.54	62.4	3.63	.000**
d	Zy ~ Pog' (mm)	95.8	4.66	89.8	4.83	.000**
e	Upside length of base (mm)	117.6	4.79	112.4	5.25	.003**
f	Height of base (mm)	75.5	5.83	69.9	5.41	.004**
g	Ratio (%)	64.4	5.68	62.3	5.07	.240

Independent *t*-test was conducted to compare the values of male and female group at significance level of $p < 0.05$. AFP, anterior facial pyramid; SD, standard deviation; a-e, the variables corresponded to a-e of Figure 3.; **, $p < 0.01$; Zy~Pn, distance between zygomatic point right/ left and pronasale; Pn~Pog', distance between pronasale and soft tissue pogonion; Zy~Pog', distance between zygomatic point right/ left and soft tissue pogonion; Upside length of base (interzygoma width), distance between zygomatic point right and zygomatic point left; ratio, the percentage of height (f) to upside length of the base (e) (height of the base ÷ upside length of the base × 100).

The anteroposterior position of the angular points consisting AFP relative to N'-per. was tabulated in Table 6. The zygomatic point was located posteriorly to N'-per. as much as 14.4 mm in male and 12.1 mm in female ($p < 0.01$). The pronasale was protruded to N'-per. as much as 22.5 mm in male and 20.4 mm in female ($p < 0.05$). The soft tissue pogonion was positioned anteriorly to N'-per. as much as 5.1 mm in male and 6.1 mm female ($p > 0.05$). The midface depth was 36.9 mm in male and 32.5 mm in female ($p < 0.01$).

Table 6. The anteroposterior position of the landmark consisting AFP relative to N'-per.

Variable	Male		Female		*p*-value
(mm)	Mean	SD	Mean	SD	
Zygoma prominence	-14.4	2.56	-12.1	2.26	.006**
Nose tip prominence	22.5	2.55	20.4	2.36	.014*
Chin prominence	5.1	4.48	6.1	4.14	.457
Midface depth	36.9	2.64	32.5	2.40	.000**

Independent *t*-test was conducted to compare the values of male and female group at significance level of $p < 0.05$. The definition of variables was described in Figure 4. AFP, anterior facial pyramid; N'-per., N'-perpendicular plane; SD, standard deviation; *, $p < 0.05$; **, $p < 0.01$.

2. The assessment of facial soft tissue with AFP

The relationship between the landmark and AFP was indicated in Table 7. Some landmarks of the lip were positioned near to the boundaries of AFP. The perpendicular distance from cheilion right/ left to the base was 1.6 mm in male and 0.1 mm in female. Labiale superius right/ left was located away from the right/ left side 2.5 mm in male and 2.1 mm in female. Labiale inferius right/ left was located away from the right/ left side 3.4 mm in male and 3.2 mm in female. Cheilion right/ left was anteriorly positioned to the right/ left side in both groups as much as 0.8 mm. Lower lip point was anteriorly positioned away from anterior vertical edge 1.7 mm in male and 1.0 mm in female. There was no statistically significance between genders ($p > 0.05$). However, the position of the upper lip point from the anterior vertical edge (E-line) showed different tendency between genders, which was protruded in male about 0.4 mm and was posteriorly positioned in female about 1.2 mm ($p < 0.05$).

Table 7. The relationship between AFP and its contents

Variable (mm)		Male		Female		*p*-value
Reference	**Landmark**	**Mean**	**SD**	**Mean**	**SD**	
Base	Pn	33.7	3.07	29.3	2.72	.000**
	Sn	18.2	2.16	14.8	1.87	.000**
	Ls	18.2	2.18	15.1	1.91	.000**
	Ls-Rt/Lt	15.5	3.57	12.6	3.48	.001**
	ULP	19.0	2.22	15.9	1.82	.000**
	Stoms	10.1	3.83	8.0	3.59	.076
	Ch-Rt/Lt	1.6	2.86	0.1	3.04	.100
	Stomi	8.8	4.05	7.1	3.62	.170
	LLP	12.5	2.30	10.5	1.87	.004**
	Li-Rt/Lt	10.2	3.06	8.1	3.04	.026*
	Li	8.8	2.74	7.3	1.81	.049*
	B’	2.1	1.52	1.4	0.60	.089
Sides	Ls-Rt/Lt	2.5	2.15	2.1	1.95	.507
	Ch-Rt/Lt	0.8	2.74	0.8	1.89	.995
	Li-Rt/Lt	3.4	3.70	3.2	3.43	.883
Anterior vertical edge (E-line)	Ls	-3.0	3.21	-3.7	2.99	.492
	ULP	0.4	2.54	-1.2	1.98	.042*
	LLP	1.7	2.82	1.0	2.21	.363
	Li	0.1	3.74	-0.3	3.12	.680

Independent *t*-test was conducted to compare the values of male and female group at significance level of $p < 0.05$. The definition of landmarks was described in Figure 2 and Table 2. SD, standard deviation; *, $p < 0.05$; **, $p < 0.01$.

3. Contents: Nose and lip

The evaluation of the nasal shape was showed in Table 8. The nose angle sagittal and the nose angle transverse showed no significant difference between genders ($p > 0.05$). However, the male group showed significantly larger value than the female group in the nose length ($p < 0.01$), the nose tip prominence ($p < 0.05$), and the nose width ($p < 0.01$).

Table 8. Morphological features of nose

Variable	Male		Female		*p*-value
	Mean	SD	Mean	SD	
Nose angle sagittal (°)	28.9	2.00	28.7	2.31	.751
Nose length (mm)	48.3	3.71	43.5	2.85	.000**
Nose tip prominence (mm)	22.5	2.55	20.4	2.36	.014*
Nose angle transverse (°)	91.5	7.69	89.9	5.53	.432
Nose width (mm)	39.1	1.91	36.0	2.33	.000**

Independent *t*-test was conducted to compare the values of male and female group at significance level of $p < 0.05$. The definition of variables was described in Table 3 and Figure 5. SD, standard deviation; Sig., significance (*p*-value); *, $p < 0.05$; **, $p < 0.01$.

The evaluation of the lip shape was enumerated in Table 9. The mean value of the upper vermilion height was measure to 11.1 mm in men, 10.7 mm in women ($p > 0.05$) and the lower vermilion height was 12.4 mm in men and 11.3 in women ($p < 0.05$). There were no significant differences between genders in the upper lip angle sagittal and the upper lip angle transverse ($p > 0.05$). Other variables showed significant differences that the upper lip angle axial of the men was larger than that of the women ($p < 0.01$), but the upper lip angle frontal of the men was smaller than that of women ($p < 0.05$).

Table 9. Morphological features of lip

Variable	Male		Female		*p*-value
	Mean	SD	Mean	SD	
Upper vermilion height (mm)	11.1	1.23	10.7	1.41	.366
Lower vermilion height (mm)	12.4	1.45	11.3	1.25	.018*
Lip width (mm)	45.6	3.88	43.5	2.65	.047*
Upper lip angle sagittal (°)	18.1	6.90	16.4	6.01	.441
Upper lip angle transverse (°)	103.4	4.79	102.2	3.83	.632
Upper lip angle axial (°)	115.5	5.19	110.6	4.25	.003**
Upper lip angle frontal (°)	129.9	5.02	133.9	6.39	.036*

Independent *t*-test was conducted to compare the values of male and female group at significance level of $p < 0.05$. The definition of variables was described in Table 4. SD, standard deviation; Sig., significance (*p*-value); *, $p < 0.05$; **, $p < 0.01$.

IV. Discussion

Anterior facial pyramid (AFP) was introduced as a facial reference frame and was consisted of only soft tissue landmarks including zygomatic point. AFP was composed of top, base, right side, and left side. Since the position of the lip can be changed dramatically when teeth are repositioned to antero-posterior direction (Talass et al., 1987), to achieve a satisfactory result of orthodontic treatment, it is important to evaluate the lip with regard to the facial frame during planning orthodontic treatment. For this reason, the relationship of lip landmarks to components of AFP was evaluated. The distance from side or base of AFP to labiale superius right/ left or labiale inferius right/ left could be the reference to assess change on the side of lip after orthodontic treatment. During orthodontic treatment, the orthodontists have to concern not only center of lip but also lateral area of lip.

Upper lip point, labiale superius right/ left, cheilion right/ left, lower lip point, and labiale inferius was positioned near to the components of AFP. Especially cheilion right/ left were traced near to right/ left edge of the base in frontal view. The triangle formed by cheilion right, soft tissue pogonion and cheilion left was similar figure to the base of AFP. Moreover there was proportional relation among interzygoma width (upside length of the base), nasal width and lip width. The interzygoma width was about 3 times wider than nasal width (the distance between alare lateralis right and alare lateralis left). The lip

width (the distance between cheilion right and cheilion left) was about 1.2 times wider than nasal width. The relative size of each structure is more important than the absolute size of that.

A difference in size between genders did not always suggest a difference in shape. The size of AFP was larger in men than women, but the ratio of the height of the base to upside length (interzygoma width) of the base was similar between two groups. The size of male nose was larger than women, but the shape of nose was similar between genders. There was no statistically significant difference in nose angle sagittal and nose angle transverse between genders.

Some measurements of this study were similar to the previous studies. The transverse nasal prominence examined by Baik et al. was corresponded to the midface angle transverse of this study, and was significantly smaller in men than in women (men, 112 °; women, 116 °) ($p < 0.05$) (Baik et al., 2007). The midface angle transverse of men was also smaller than women in this study (men, 114.4 °; women, 118.6 °) ($p < 0.01$), even though interzygoma width (upside length of base) of the men was wider than women (men, 117.6 mm; women, 112.4 mm) ($p < 0.01$). To find out the most influential factor for the midface angle transverse, additionally, Pearson's partial correlation analysis was conducted to compare the partial correlation coefficient among midface angle transverse and its determinants at significance level of $p = 0.05$. The determinants of midface angle transverse were the interzygoma width and the midface depth. The interzygoma width of male was wider than that of female as much as 5.2 mm (Table 5), and showed positive correlation with the midface angle transverse. The partial correlation coefficient of the

interzygoma width with the midface angle transverse was 0.858 when taking midface depth as the control variable ($p < 0.01$). The midface depth of male was deeper than that of female as much as 4.4 mm (Table 6), and showed negative correlation with the midface angle transverse. The partial correlation coefficient of the midface depth with the midface angle transverse was -0.958 when taking interzygoma width as the control variable ($p < 0.01$). According to absolute value of partial correlation coefficient, the midface angle transverse might be more affected by the midface depth than the interzygoma width, although the amount of the difference in the interzygoma width between genders was larger than that of the midface depth. In spite of wider interzygoma width of male ($p < 0.01$), the midface angle transverse of the men was smaller than that of women as much as 4.2 degree ($p < 0.01$) because of prominent nose and relatively retrusive zygoma to N'-per. of the men. The difference of facial depth between genders might affect sexual dimorphism and esthetics of facial profile. This is one of the reasons why zygoma prominence and shape should be concerned while orthodontists evaluate facial profile of patients.

The transverse upper lip prominence examined by Baik et al. (2007) was defined as the angular measurement of cheilion right, upper lip point and cheilion left. There was no statistically significant difference between both genders (men, 107 °; women, 106 °) ($p > 0.05$) (Baik et al., 2007). In our study, upper lip angle transverse was measured by same way as the transverse upper lip prominence, and was subdivided into upper lip angle axial and upper lip angle frontal by projecting the landmarks to R-FH plane or frontal plane. Different from the previous study, upper lip angle axial of the men was larger than the

women (men, 115.5 °; women, 110.6 °) ($p < 0.01$) and upper lip angle frontal of the men was smaller than the women (men, 129.9 °; women, 133.9 °) ($p < 0.05$).

McNamara et al. (2008) showed that the vertical height of the upper and lower lips is an esthetic determinant for laypersons (McNamara et al., 2008). Ioi et al. (2014) defined the vermilion height as the distance between the superior and the inferior vermilion border. They surveyed that vermilion height have an effect on the lip esthetics. They set the average vermilion height as 20.0 mm and proposed that the range of -1 to +1 mm to be the most attractive lip range for Japanese and Korean people (Ioi et al., 2014). However the average of the vermilion height was 23.5 mm in male group and 22.0 mm in female group when the vermilion height was calculated by sum of upper and lower vermilion height in this study.

The limitation of this study was that the prominence or width of zygoma was not assessed when samples were selected. Additional studies whether the prominence or width of zygoma affects the patients' perception of lip protrusion and ideal incisor inclination or not would be required. Since the AFP was composed of soft tissue landmarks, the AFP could be changed by aging and smiling. Therefore the change of the relationship of lip landmarks to AFP by aging and smiling should be studied.

V. Conclusion

3D assessment of the facial soft tissue, especially the lip position, is important to plan appropriate orthodontic treatment. A new reference frame, anterior facial pyramid (AFP), was proposed for 3D assessment of the face concerning zygoma. The average relationship between the new frame and its contents was studied. The AFP could be used for not only facial analysis during planning of orthodontic treatment, but also assessment of the change on the side of lip after orthodontic treatment. Furthermore the cheilion right/ left was traced near to boundary of the base, and there was proportional relation among interzygoma width, nasal width and lip width (3: 1: 1.2). The average of the vermilion height was 23.5 mm in male group and 22.0 mm in female group. Lip width and height as well as protrusion should be concerned by orthodontists. The difference of anterior facial depth between genders was existed and seemed to be affected by morphological features of not only nose but also zygoma. This study may be fundamental to the 3D assessment of the lip concerning zygoma when planning orthodontic treatment.

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국문요약

CBCT를 이용한 3차원적 안모 분석 방법의 제안

: ‘Anterior Facial Pyramid’를 이용한 안모 분석

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김 난 희

서론: Zygoma는 중안모에서 차지하는 면적과 돌출도 때문에 안모의 심미성에 영향을 미칠 수 있다. 본 연구는 zygoma를 포함하는 새로운 기준 평면으로 연조직을 평가하는 방법을 제시하고, 골격성 I급 환자에서 제시된 기준 평면과 연조직 계측점 사이 위치적 관계의 평균치를 알아보고자 시행하였다.

연구재료 및 방법: 48명(남성 23명, 여성 25명)의 CBCT 영상에서 zygomatic point right, zygomatic point left, pronasale, soft tissue pogonion으로 이루어진 anterior facial pyramid(AFP)를 설정하고, 이의 형태를 계측하였다. AFP를 이루는 평면들을 base, right side, left side, top, 그리고 AFP의 전방 경계선을 anterior vertical edge라고 명명하고, base, right side, left side, anterior vertical edge와 연조직 계측점 사이의 수직 거리를 측정하였다. 추가적으로 코와 입술의 형태도 계측하였다. 모든 계측치는 남성과 여성의 두 군으로 나누어 평가하였고, 부가적으로 남성과 여성의 두 군 사이의 차이도 비교하였다.

연구결과: Zygomatic point right/ left는 N’ −perpendicular plane(N’ −per.)에 대해 남성은 14.4±2.56mm, 여성은 12.1±2.26mm만큼 후방에 위치했다 (p < 0.01). Pronasale는 N’−per.에 대해 남성이 22.5±2.55mm, 여성은 20.4±2.36mm 만큼 전방 위치했고 (p < 0.05), soft tissue pogonion은 남성은 5.1±4.48mm, 여성은 6.1±4.14mm 만큼 전방 위치했다 (p > 0.05). Midface angle transverse는 남성은 114.4±3.61도, 여성은 118.6±4.48도로 여성이 더 큰 각을 보였으며 (p < 0.05), AFP base의 윗변 길이 (midface width)와 base 높이와의 비율은 남성 64.4±5.68%, 여성 62.3±5.07%로 통계학적으로 유의한 차이가 없었다 (p > 0.05). Cheilion right/ left는 base에 대해 남성은 1.6±2.86mm, 여성은 0.1±3.04mm 전방 위치했다 (p > 0.05). Labiale superius right/ left는 side에 대해서 남성은 2.5±2.15mm, 여성은 2.1±1.95mm만큼, labiale inferius right/ left는 남성은 3.4±3.70mm, 여성은 3.2±3.43mm만큼 외측에 위치했다 (p > 0.05). Upper lip point는 anterior vertical edge에 대해 남성은 0.4±2.54mm만큼 전방에, 여성은 1.2±1.98mm만큼 후방에 위치하여 남성이 여성보다 더 돌출되어 있었다 (p < 0.05). Lower lip point는 anterior vertical edge보다 남성은 1.7±2.82mm, 여성은 1.0±2.21mm 돌출되어 있었다 (p > 0.05).

결론: 안모에서 zygoma까지 고려한 anterior facial pyramid (AFP)라는 새로운 reference frame을 제시하고 이에 대한 안모 연조직 계측점들의 3차원적 위치를 분석하였으며, 이를 근거로 안모의 3차원적 연조직 분석을 시행함으로써 교정치료 계획의 수립 시 도움을 줄 수 있을 것으로 기대된다.

핵심되는 말 : CBCT, anterior facial pyramid, 연조직, zygoma