

The location of midfacial landmarks according to the method of establishing the midsagittal reference plane in three-dimensional computed tomography analysis of facial asymmetry

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ABSTRACT

Purpose: The purpose of this study was to evaluate the influence of methods of establishing the midsagittal reference plane (MRP) on the locations of midfacial landmarks in the three-dimensional computed tomography (CT) analysis of facial asymmetry.

Materials and Methods: A total of 24 patients (12 male and 12 female; mean age, 22.5 years; age range, 18.2-29.7 years) with facial asymmetry were included in this study. The MRP was established using two different methods on each patient's CT image. The x-coordinates of four midfacial landmarks (the menton, nasion, upper incisor, and lower incisor) were obtained by measuring the distance and direction of the landmarks from the MRP, and the two methods were compared statistically. The direction of deviation and the severity of asymmetry found using each method were also compared.

Results: The x-coordinates of the four anatomic landmarks all showed a statistically significant difference between the two methods of establishing the MRP. For the nasion and lower incisor, six patients (25.0%) showed a change in the direction of deviation. The severity of asymmetry also changed in 16 patients (66.7%).

Conclusion: The results of this study suggest that the locations of midfacial landmarks change significantly according to the method used to establish the MRP. (*Imaging Sci Dent 2015; 45: 227-32*)

KEY WORDS: Facial Asymmetry; Anatomic Landmarks; Tomography, X-Ray Computed

Introduction

Since symmetry is considered to be an essential element of an esthetic and attractive face, establishing a symmetric face is one of the main goals of orthodontic treatment. Orthognathic surgery is currently a popular method for improving facial symmetry. The accurate analysis of facial asymmetry is an essential step in orthognathic surgery planning and post-treatment evaluation. Facial asymmetry has traditionally been evaluated using posteroanterior

cephalometric radiography.¹⁻³ The location of the menton (Me) has been shown to have a significant association with the perception of asymmetry, and deviation of the Me from the facial midline has been considered the most important indicator of facial asymmetry.^{4,5} The deviation of the Me has usually been measured as the distance or angle of the Me from the midfacial line.^{1,6-10} Two-dimensional (2D) cephalometric radiography has been used for the analysis of facial asymmetry; however, it is limited in its utility for analyzing three-dimensional (3D) human structures.^{1,11}

Three-dimensional computed tomography (CT) has none of the inherent problems of 2D radiography, such as superimposition, magnification, and distortion. Measurements made with 3D CT images show high conformity to measurements made on dry bones, with high repeatability and

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accuracy.¹¹⁻¹³ Furthermore, 3D volumetric imaging allows human structures to be viewed at multiple angles.^{1,14} Previous studies have demonstrated that 3D CT is more effective than cephalometric radiography for analyzing facial asymmetry.^{15,16}

Various methods for analyzing facial asymmetry using 3D CT have been recently introduced.^{1,7-10,14} The first step in analyzing facial asymmetry is to establish reference planes. The midsagittal reference plane (MRP) is the most critical reference plane for the diagnosis of facial asymmetry, as the lateral deviation of facial landmarks is measured from the MRP. Therefore, establishing the MRP is the most fundamental step in making a correct diagnosis of facial asymmetry.

The method of establishing the MRP has varied among researchers; however, two main methods have been commonly applied. One method is to first establish the horizontal reference plane (HRP) using three facial landmarks and to then establish the MRP by using two midfacial landmarks so that it is perpendicular to the HRP. The other method is to establish the MRP by using three midfacial landmarks.^{1,7-10,14}

Although establishing the MRP is the first fundamental step in the accurate analysis of facial asymmetry, only a few studies have assessed the methods of establishing the MRP.^{17,18} Therefore, this study aimed to investigate the influence of the method of establishing the MRP on the location and measurement of facial landmarks through a comparison of two different methods of establishing the MRP.

Materials and Methods

The CT scans of twenty-four patients (12 male and 12 female; mean age, 22.5 years; age range, 18.2-29.7 years) who were treated with orthognathic surgery for facial asymmetry at Chonnam National University Dental Hospi-

tal from 2000 through 2007 were reviewed for this study.

The CT scans were obtained using a spiral CT scanner (Light Speed QX/I; GE Medical Systems, Milwaukee, WI, USA) with a 512 × 512 matrix. The imaging parameters were 120 kV, 200 mAs, and a gantry angle of 0°. The axial image slice thickness was 2.5 mm, the table speed was 3 mm/s, and the scanning time was 0.8 s. Digital Imaging and Communication in Medicine (DICOM) images were acquired with a slice thickness of 1.0 mm. The acquired DICOM data were transferred to a personal computer, and 3D images were constructed from the CT data with the software program Vworks + Vsurgery (Cybermed, Seoul, Korea).

The surface shaded display was obtained with a threshold value of 126. Facial landmarks were identified and their location was confirmed on the axial, sagittal, and coronal planes. On each CT scan, horizontal reference landmarks (the right porion [PoR], left porion [PoL], right orbitale [OrR], and left orbitale [OrL]), midsagittal reference landmarks (crista galli [Cg], the prechiasmatic groove [P], anterior nasal spine [ANS], and opisthion [Op]), and midfacial landmarks (Me, nasion [Na], upper incisor [U1], and lower incisor [L1]) were identified (Table 1). Two distinct methods (Methods 1 and 2) of establishing the MRP were applied for each CT scan (Fig. 1). In Method 1, the PoR, PoL, and OrL landmarks were used to establish the horizontal reference plane (HRP), the Cg and P were used to establish the MRP, and the Op was used for establishing the coronal reference plane (CRP), with the three planes perpendicular to one another on Vworks. All of the data for the landmarks and planes were transferred to Vsurgery. In Method 2, the Op, Cg, and ANS landmarks were used to establish the MRP on Vsurgery for each CT scan, using the same values of Op and Cg as Method 1 (Table 2).

The x-coordinate, severity of asymmetry, and direction

Table 1. Anatomic landmarks used in this study

Horizontal reference landmarks	PoR	The highest midpoint of the roof of the right external auditory meatus
	PoL	The highest midpoint of the roof of the left external auditory meatus
	OrR	The lowest point on the right infraorbital margin of the orbit
	OrL	The lowest point on the left infraorbital margin of the orbit
Midsagittal reference landmarks	Cg	The most superior point of the crista galli of the ethmoid bone
	P	The vertical and transverse midpoint of the prechiasmatic groove
	ANS	The most anterior point of the nasal floor
	Op	The most posterior point on the posterior margin of the foramen magnum
Midfacial landmarks	Me	The most inferior point on the symphysis of the mandible
	Na	The most posterior point on the curvature between the frontal bone and the nasal bone in the midsagittal plane
	U1	The point of the maxillary alveolar process between the left and right maxillary incisors
	L1	The point of the mandibular alveolar process between the left and right mandibular incisors

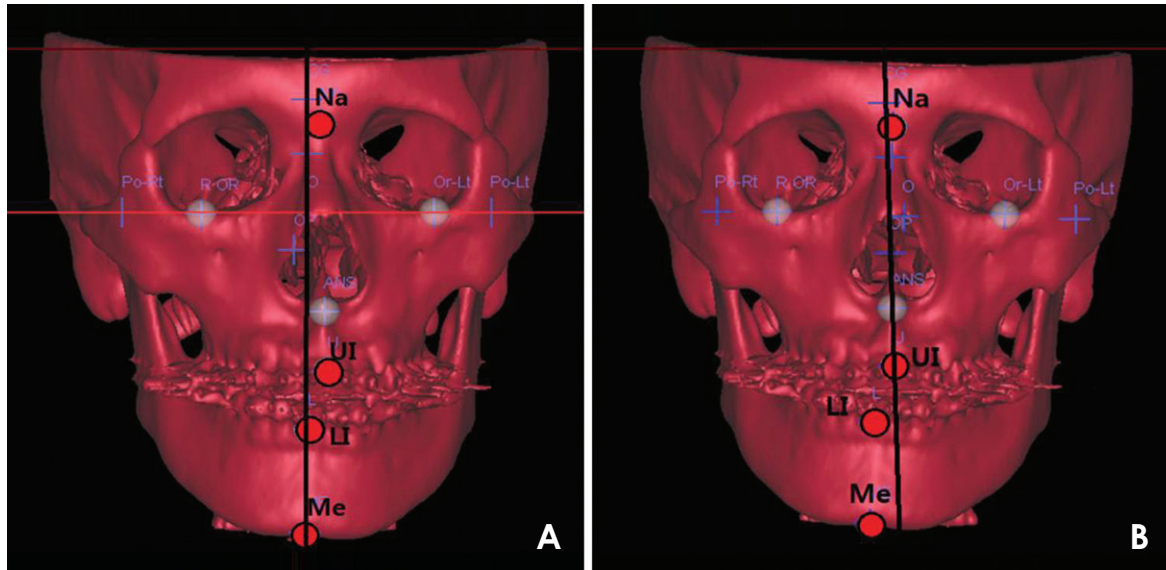


Fig. 1. The establishment of the midsagittal reference plane by two methods. A. In Method 1, the horizontal reference plane is established using the PoR, PoL, and OrL landmarks, the midsagittal reference plane (MRP) by using the Cg and P, and the coronal reference plane by using the Op. The planes are perpendicular to one another. B. In Method 2, the Op, Cg, and ANS landmarks identified in Method 1 are used to establish the MRP. Midfacial landmarks are indicated as circles, and the MRP is shown as a black vertical line. PoR: right porion, PoL: left porion, OrL: left orbitale, Cg: crista galli, P: prechiasmatic groove, Op: opisthion, ANS: anterior nasal spine.

Table 2. Reference planes used in Methods 1 and 2

Method 1	Horizontal reference plane (HRP)	Intersecting the PoR, PoL, and OrL
	Midsagittal reference plane (MRP)	Perpendicular to the HRP and intersecting the Cg and P
	Coronal reference plane	Perpendicular to the HRP and MRP, and intersecting the Op
Method 2	Midsagittal reference plane	Intersecting the Op, Cg, and ANS

PoR: right porion, PoL: left porion, OrL: left orbitale, Cg: crista galli, P: prechiasmatic groove, Op: opisthion, ANS: anterior nasal spine.

of deviation of the Me were compared between the two methods as follows. First, the x-coordinate of the Me was considered to be (+) when the landmark was located on the left side of the face and (-) when on the right. Then, Δx was defined as the difference between the x-coordinates calculated with Method 1 (x_1) and Method 2 (x_2). The severity of asymmetry was considered to be normal when the distance of the Me from the MRP ($|x|$) was less than 2 mm ($0 \text{ mm} \leq |x| < 2 \text{ mm}$), mild when less than 4 mm ($2 \text{ mm} \leq |x| < 4 \text{ mm}$), moderate when less than 8 mm ($4 \text{ mm} \leq |x| < 8 \text{ mm}$), and severe at values of 8 mm or higher ($8 \text{ mm} \leq |x|$).⁴ The direction (left or right) of the deviation of the Me was compared between the two methods.

The x-coordinates and directions of deviation for the Na, U1, and L1 were compared between the two methods in the same way as described above for the Me.

The one-sample t-test was performed using SPSS (IBM Corp., Armonk, New York, USA) to evaluate whether the Δx of the Me, Na, U1, and L1 landmarks varied to a sta-

tistically significant extent between the two methods.

Results

CT scans were obtained from 24 orthodontic patients with facial asymmetry, and 3D reconstructions of the CT scans were performed. Two methods of establishing the MRP were applied for each CT scan. The midfacial landmarks (the Me, Na, U1, and L1) were identified, and the x-coordinates and the direction of deviation of each landmark relative to the MRP were compared between the two methods (Fig. 1, Tables 3-5).

The direction of deviation for the Me was the same in both methods for all patients. The severity of asymmetry was the same in both methods in eight patients (33.3%). Differences were found in the severity of asymmetry in 16 patients (66.7%), with a difference of two or more stages in three patients (12.5%). The mean Δx was 2.77 ± 0.49 mm, and a statistically significant difference was

Table 3. Comparisons between Method 1 and Method 2 of the measurements of the Me, Na, U1, and L1 and the direction of deviation for midfacial landmarks

Landmarks	Measurements of landmarks			Direction of deviation between Method 1 and Method 2	
	x ₁	x ₂	x ₁ - x ₂	Same	Different
Me	2.56 ± 1.09*	2.88 ± 1.20*	2.77 ± 0.49	24 (100%)	0 (0%)
Na	1.40 ± 0.27*	0.60 ± 0.20*	0.92 ± 0.17	18 (75%)	6 (25%)
U1	1.55 ± 0.54*	0.55 ± 0.20*	1.88 ± 0.39	24 (100%)	0 (0%)
L1	3.36 ± 0.56*	2.06 ± 0.90*	3.60 ± 0.61	18 (75%)	6 (25%)

x₁: the x-coordinate as calculated by Method 1, x₂: the x-coordinate as calculated by Method 2, Me: menton, Na: nasion, U1: upper incisor, L1: lower incisor; *p < 0.05.

Table 4. The difference (Δx) of the measurements of the Me between Method 1 (x₁) and Method 2 (x₂)

Δx (mm)	0-2	2-4	4-8	8 or over	Total
Me	10 (41.7%)	9 (37.5%)	3 (12.5%)	2 (8.3%)	24 (100%)
Na	22 (91.7%)	2 (8.3%)	—	—	24 (100%)
U1	16 (66.7%)	5 (20.3%)	3 (12.5%)	—	24 (100%)
L1	11 (45.8%)	3 (12.5%)	8 (33.3%)	2 (8.3%)	24 (100%)

x₁: the x-coordinate as calculated by Method 1, x₂: the x-coordinate as calculated by Method 2, Me: menton.

Table 5. Comparison of the severity of the Me deviation between Method 1 and Method 2

Method 1	Method 2				Total
	Normal	Mild	Moderate	Severe	
Normal	1	1	—	2	4 (16.7%)
Mild	2	2	1	—	5 (20.8%)
Moderate	1	4	3	2	10 (41.7%)
Severe	—	—	3	2	5 (20.8%)
Total	4 (16.7%)	7 (29.2%)	7 (29.2%)	6 (25.0%)	24 (100%)

Me: menton.

found between the methods (p < 0.05). The value of Δx was between 2 mm and 4 mm in nine patients (37.5%), between 4 mm and 8 mm in three patients (12.5%), and 8 mm or more in two patients (8.3%) (Tables 3-5).

The direction of deviation for the Na was the same in both methods in 18 patients (75.0%), and different between the two methods in six patients (25.0%). The mean Δx was 0.92 ± 0.17 mm, and a statistically significant difference was found between the methods (p < 0.05). The value of Δx was between 2 mm and 4 mm in two patients (8.3%) (Tables 3 and 4).

The direction of deviation for the U1 was the same in both methods for all patients. The mean Δx was 1.88 ± 0.39 mm, and a statistically significant difference between the methods was observed (p < 0.05). The value of Δx was between 2 mm and 4 mm in five patients (20.3%) and bet-

ween 4 mm and 8 mm in three patients (12.5%) (Tables 3 and 4).

The direction of deviation for the L1 was the same in both methods in 18 patients (75.0%), and different between the two methods in six patients (25.0%). The mean Δx was 3.60 ± 0.61 mm, and a statistically significant difference was observed between the methods (p < 0.05). The value of Δx was between 2 mm and 4 mm in three patients (12.5%), between 4 mm and 8 mm in eight patients (33.3%), and 8 mm or more in two patients (8.3%) (Tables 3 and 4).

Discussion

As a result of the recent increase in the general societal interest in esthetic appearance, the number of patients whose primary complaint is facial asymmetry is rising. The usage of CT has been extended to the 3D analysis of facial asymmetry,^{19,20} which is performed by first establishing the appropriate reference planes, of which the MRP is the most fundamental. Several methods for establishing reference planes have been introduced for the 3D analysis of facial asymmetry.^{1,7-10,14,21} The results of facial asymmetry analysis using CT can be influenced by the method chosen for establishing the reference planes, similarly to the influence of reference lines on facial asymmetry analysis when using 2D radiographs.^{17,18} However, very few studies have evaluated the different methods used to determine the reference planes.^{17,18,21}

Therefore, this study compared the two most common methods (Method 1 and Method 2) of establishing the MRP and evaluated changes in the location of facial landmarks relative to the MRP according to the method of establishing the MRP. This evaluation was conducted by obtaining the x-coordinates of the midfacial landmarks Me, Na, U1, and L1, which can be used as reference points for analyzing facial asymmetry. The direction of deviation

and the severity of asymmetry of each landmark was also evaluated according to each of the methods.

In the comparison of these two methods of identifying midfacial landmarks in the radiographs of 24 patients, the x-coordinates of the four midfacial landmarks showed statistically significant differences between the methods ($p < 0.05$), which suggests that the method of establishing the MRP and the location of the Me, Na, U1, and L1 are significantly correlated (Table 3).

Although any facial structure can be asymmetric, structures in the lower third of the face have a higher prevalence of asymmetry than those in the upper and middle thirds. The deviation of the Me has been a point of particular interest.²² The Me has been identified as the most influential landmark in the perception of facial asymmetry, and has been used as the standard landmark for determining facial asymmetry on cephalometric radiography and 3D CT.^{23,24}

This study demonstrated that the x-coordinate of the Me significantly different depending on the method of establishing the MRP, which may have an impact on research into facial asymmetry.

The difference in the x-coordinates of the Me between the two methods of establishing the MRP was between 2 mm and 4 mm in nine patients (37.5%), between 4 mm and 8 mm in three patients (12.5%), and 8 mm or more in two patients (8.3%). A difference in the severity of asymmetry was observed in 16 patients (66.7%), with a difference greater than two stages in three patients (12.5%). Six patients (25.0%) were evaluated as being in the normal group of facial asymmetry by one of the methods, but in the asymmetric group by the other method. These results suggest that the diagnosis of asymmetry may differ according to the method used for establishing the MRP. It is uncertain which of these two methods is more reliable for determining the MRP (Tables 4 and 5).

The remaining three midfacial landmarks also showed significant differences in location according to the method used ($p < 0.05$). The location of the Na showed a difference of 2-4 mm in two patients (8.3%). The location of the U1 showed a difference of 2-4 mm in five patients (20.3%) and 4-8 mm in three patients (12.5%). The location of the L1 showed a difference of 2-4 mm in three patients (12.5%), 4-8 mm in eight patients (33.3%), and 8 mm or more in two patients (8.3%). The direction of deviation for the Na and L1 was different in six patients (25.0%). These results indicate that the method of establishing the MRP has a significant impact on the diagnosis of facial asymmetry (Tables 3 and 4).

In conclusion, this study showed that the x-coordinates of the midfacial landmarks may differ according to the method of establishing the MRP. The distance and direction of deviation, as well as the severity of asymmetry, may also be influenced by the method used. Depending on the method of establishing the MRP, the treatment plan could change and a different treatment outcome could result. Clinicians should be aware of this issue when assessing facial asymmetry and the location of landmarks.

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