Int J Clin Exp Med 2018;11(8):8186-8195
www.ijcem.com /ISSN:1940-5901/IJCEM0069720

Original Article

Three-dimensional computed tomography analysis of female skeletal class III facial asymmetry with and without maxillary occlusal cant

Siyao An[1], Tao Wang[2], Yin Ding[1]

[1]State Key Laboratory of Military Stomatology & National Clinical Research Center for Oral Diseases & Shaanxi Clinical Research Center for Oral Diseases, Department of Orthodontics, School of Stomatology, The Fourth Military Medical University, Xi'an 710032, Shaanxi, China; [2]Department of Stomatology, Affiliated Hospital of Guangdong Medical University, Zhanjiang 524000, Guangdong, China

Received August 2, 2017; Accepted April 25, 2018; Epub August 15, 2018; Published August 30, 2018

Abstract: This study aimed to evaluate craniofacial morphology features of two types of skeletal Class III facial asymmetry, with and without maxillary occlusal cant, using three-dimensional computed tomography (CT), in order to help orthodontists and orthognathic surgeons perform different treatment plans for patients with different types of facial asymmetry. This was a retrospective study including patients that visited the Fourth Military Medical University (China) and accepted spiral CT examinations. CT data of 133 adult women were chosen and included in the study, according to inclusion and exclusion criteria. The data contained three groups: symmetry (chin deviation <2 mm; n=60), asymmetric non-canted (chin deviation >4 mm, maxillary occlusal cant <2°, n=44), and asymmetric canted (chin deviation >4 mm, maxillary occlusal cant >4°, n=29) groups. Craniofacial morphology measurements were compared between the groups. The glenoid fossa and condyle were located more anteriorly on the non-deviated side in the non-canted group while located more posteriorly in the canted group. Gonial angle increased on the non-deviated side in the non-canted group while there was no significant difference between both sides in canted group. The lower boundary of zygoma was more inferior on the non-deviated side in the canted group, while it was more superior on the deviated side in non-canted group. There were different features in the positions of glenoid fossa and condyle and morphology of the mandible and zygoma between canted and non-canted groups. Correlations between chin deviation and craniofacial morphology in canted and non-canted groups were also fundamentally different.

Keywords: Facial asymmetry, three-dimensional, maxillary occlusal cant

Introduction

Correct assessment of facial asymmetry is important for patients requiring orthodontics or orthognathic treatment. Facial asymmetry is not rare, affecting 25-34% of the population in the United States [1, 2] and about 25% of the population in China [3]. Skeletal Class III deformity leads to important dental problems and is more frequent in Asian populations compared with Caucasian populations [4, 5]. Because of the complexity of the deformity, correction of Class III skeletal deformity with asymmetry must be carefully planned [6].

Three-dimensional (3D) computed tomography (CT) has been widely used in diagnosis and research on patients with severe skeletal deformities seeking orthodontic or orthopedic treatments. Three-dimensional-CT has the advantages of being accurate, without distortion magnification, compared to two-dimensional cephalometric analysis [7, 8].

Previous studies of facial asymmetry have mainly been focused on mandibular symmetry between both sides [9-11]. Lee et al. [12] compared mandibular dimensions in subjects with asymmetric skeletal Class III malocclusion and those with normal occlusion. Marianetti et al. [13] showed the positional difference of glenoid fossa between symmetry and asymmetry groups. Nevertheless, there remains a lack of 3D analysis of craniofacial morphology among different types of facial asymmetry [14] as well as a lack of eventual correlations between ch-

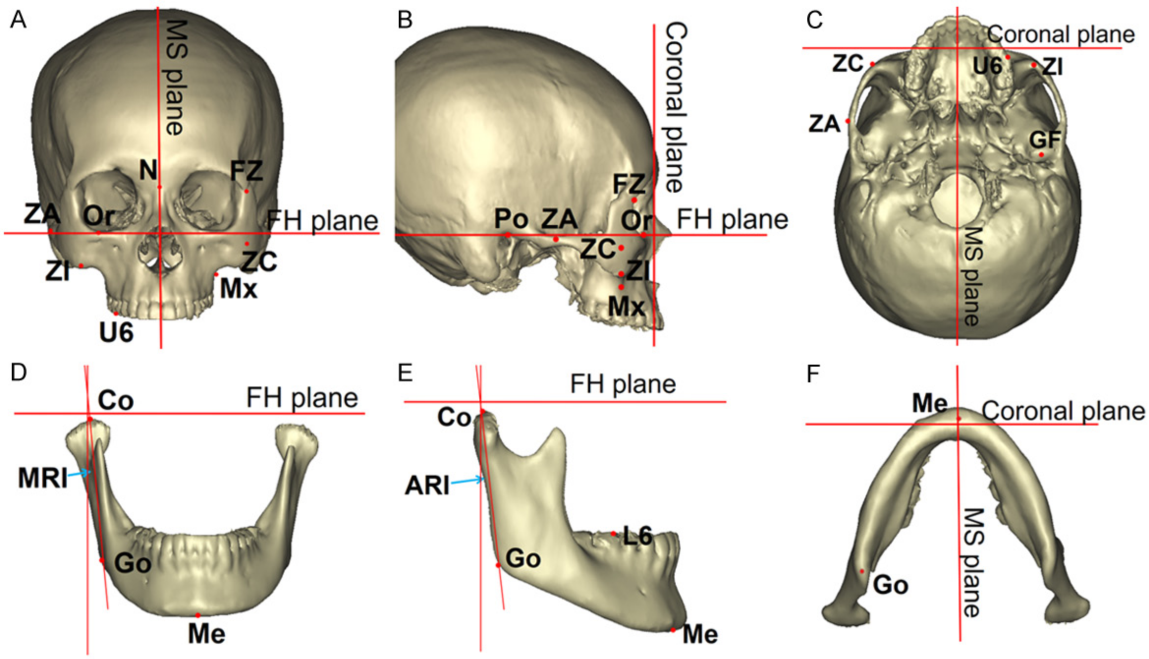

Figure 1. Landmarks and reference planes used in this study. A and D. Frontal view; B and E. Lateral view; C and F. View from below. D and E. Show the ramal inclination in the frontal and lateral directions to FH plane (ARI, anteroposterior ramal inclination; MRI, mediolateral ramal inclination). Please see **Table 1** for abbreviations of the landmarks.

in deviation and craniofacial morphology [15]. Patients with severe skeletal Class III deformity and facial asymmetry are usually treated with orthognathic surgery to retract the mandible and correct mandibular asymmetry, protracting the maxilla and correcting maxillary occlusal cant [16]. Nevertheless, except for positions of the mandible and maxilla, characteristic changes often represent with different forms or on the other parts of the craniofacial bones, affecting the appearance of patients.

Therefore, the aim of this study was to compare the dimensions and characteristics of craniofacial morphology in patients with skeletal Class III facial asymmetry, with and without maxillary occlusal cant, using spiral CT. This study also aimed to determine correlation between chin deviation and craniofacial characteristics. This study may help orthodontists and orthognathic surgeons make appropriate treatment plans for different types of deformities.

Materials and methods

Study design

This retrospective study was based on CT data of female patients that visited the School of Stomatology of the Fourth Military Medical University (Xi'an, Shaanxi, China), between October 2014 and October 2016. This study was approved by the Ethics Committee of the Fourth Military Medical University (approval # IRB-REV-2016043). Need for individual consent was waived by the committee due to the retrospective nature of the study.

Patients

Inclusion criteria included: 1) >18 years of age; 2) Female; 3) Skeletal Class III; 4) Symmetry group: chin deviation <2 mm; 4) Asymmetric non-canted group: chin deviation >4 mm and maxillary occlusal cant <2°; and 5) Asymmetric canted group: chin deviation >4 mm and maxillary occlusal cant >4°. Exclusion criteria were: 1) Craniofacial syndrome; 2) Maxillofacial tumors; 3) Facial trauma history; 4) Cleft lip and palate; or 5) Missing molars.

Grouping

For this study, facial asymmetry was defined as chin deviation from the midsagittal reference plane. Maxillary occlusal cant was defined as the angle between the line connecting bilateral

Table 1. Landmarks, reference planes, and measurements used in this study

Landmarks	Definitions
N (nasion)	"V" notch between the frontal and nasal bones
S (sella)	Midpoint of the pituitary fossa of the sphenoid bone
Po (porion)	Most superior point of the external auditory meatus
Or (orbitale)	Most inferior point of the lower margin of the bony orbit
ANS (anterior nasal spine)	Most anterior point of the nasal floor
GF (glenoid fossa)	Posterosuperior point of the glenoid fossa boundary
FZ (frontozygomatic suture)	Most anterior point of the frontozygomatic suture
ZC (convex of zygoma)	Point on the external surface of zygomatic arch where the arch turns medially and directly starts on a backward sweep
ZI (inferior of zygoma)	Most inferior point of the zygoma
ZA (zygomatic arch)	Most lateral point of the zygomatic arch
Mx (maxillare)	Zygomaticoalveolar crest, points showing maximum concavity on contour of the maxilla around molars and lower contour of the maxilla-zygomatic process
U6 (upper first molar)	The mesio-buccal cusp tip of upper first molar
Co (condylion)	The most superior point of the condylar head
Go (gonion)	Midpoint of posterior border of mandibular angle
Me (menton)	Most inferior point on symphysis of mandible
L6 (lower first molar)	The mesio-buccal cusp tip of lower first molar
Reference planes	
Frankfurt horizontal plane (FH)	The plane passing through the bilateral Po points and left or point
Midsagittal plane (MS)	The plane passing through S and N, and perpendicular to the FH plane
Coronal plane	The plane passing through N and perpendicular to the FH and MS planes
Measurements	
Maxillary occlusal cant	The angle between the line connected bilateral U6 and FH plane
Maxilla height	Distance from Mx to FH plane
Mandibular ramus length	Distance from Co to Go
Mandibular body length	Distance from Go to Me
Mandibular body height	Distance from center point of lower first molar to most inferior point of mandibular body
Chin deviation	Distance from Me to MS plane
Gonial angle	Angle of Co-Go-Me
Anteroposterior ramal inclination	Inclination of ramus in anteroposterior direction with FH plane
Mediolateral ramal inclination	Inclination of ramus in Mediolateral direction with FH plane

U6 (the mesio-buccal cusp tip of maxillary first molar) landmarks and the Frankfurt horizontal plane.

Through retrospective analysis of CT data and clinic records, 133 female patients were chosen out and included into three groups: 1) Symmetry group: patients of skeletal Class III without obvious facial asymmetry and maxillary occlusal cant (chin deviation <2 mm, maxillary occlusal cant <2°, ANB <0°, n=60) [14]; 2) Non-canted group: patients of skeletal Class III deformity with facial asymmetry and without obvious maxillary occlusal cant (chin deviation >4 mm, maxillary occlusal cant <2°, ANB <0°, n=44) [17, 18]; and 3) Canted group: patients of skeletal Class III with facial asymmetry and maxillary occlusal cant (chin deviation >4 mm, maxillary occlusal cant >4°, ANB <0°, n=29) [19].

Computed tomography

The 3D craniofacial CT data were obtained using a LightSpeed 16 spiral scanner (GE Healthcare, Waukesha, WI, USA) with the following settings: 512×512 pixels, 120 kV, 497.03 mA, 0.625 mm slice increment, and field of view of 25 cm. CT data were saved as DICOM format and reconstructed and analyzed using Mimics 18.0 image-processing package software (Materialise, Leuven, Belgium).

Anatomical landmarks

Most landmarks were directly marked on 3D reconstruction images (**Figure 1**). Internal landmarks were marked and adjusted on sagittal, horizontal, and coronal views (**Figure 1**). The reference system was composed of three reference planes, established as follows: Frank-

Table 2. Basic information and clinical features of patients

	Symmetry group (n=60)	Non-canted group (n=44)	Canted group (n=29)	P[a]	P[b]	P[c]
Age (years)	25.2±4.7	25.1±4.3	24.4±4.2	NS	NS	NS
ANB (°)	-3.46±2.13	-3.36±2.08	-3.59±2.47	NS	NS	NS
Chin deviation (mm)	1.04±0.51	6.99±2.17	7.90±3.37	**	**	NS
Maxillary occlusal cant (°)	1.13±0.65	1.19±0.80	5.98±1.37	NS	**	**

[a]Comparison between the symmetry and non-canted groups; [b]Comparison between the symmetry and canted groups; [c]Comparison between the non-canted and canted groups; **P<0.01, NS: No statistical significance.

furt horizontal (FH) plane was defined as the plane passing through the bilateral porion (Po) landmark and left orbitale (Or) landmark. Midsagittal (MS) plane was defined as the plane passing through the sella (S) and nasion (N), perpendicular to the FH plane. Coronal plane was defined as the plane passing through the N landmark, perpendicular to the FH and MS planes.

The intersection of the above three planes was regarded as the origin (0, 0, 0) of the 3D coordinate system. Coordinates (x, y, z) of a selected landmark represented linear distances to midsagittal, horizontal, and coronal planes.

Landmarks were selected, according to Park et al. [20]. Landmarks and reference planes are presented in **Table 1** and **Figure 1**. Measurements included: 1) Coordinates of the FZ, ZC, ZI, ZA, GF, and Co landmarks; 2) Linear measurements of maxilla height, mandible ramal length, mandible body length, mandible body height, and chin deviation and 3) Angular measurements of anteroposterior ramal inclination, mediolateral ramal inclination, and gonial angle (**Figure 1**).

The precision of linear and angular measurements was 0.01 mm and 0.01°, respectively.

Quality control

Landmark locations and measurements were performed by one experienced investigator (T.W.) with experience in 3D computer technology. To test intra-observer reliability, 10 randomly selected CT scans were re-analyzed 2 weeks later by the same investigator. The intra-class correlation coefficient (ICC) ranged from 0.902 to 0.953, indicating high reliability of these measurements.

Statistical analysis

Distribution was tested using the Shapiro-Wilks test and all continuous data were normally distributed. Continuous data are presented as mean ± standard deviation. Differences between non-deviated and deviated sides of each group were tested by paired samples t-tests. Differences of measurements between the groups were tested by two sample t-tests. Pearson's correlation analysis was used to determine correlation between chin deviation and measurements. SPSS 17.0 (IBM, Armonk, NY, USA) was used for all statistical analyses. Two-sided *P*-values <0.05 were considered statistically significant.

Results

Basic information and clinic characteristics of the patients

A total of 133 female adults were included in the study, according to inclusion and exclusion criteria. The symmetry group included 60 patients with skeletal Class III symmetry without obvious maxillary occlusal cant (age, 25.2 ±4.7 years; ANB, -3.46±2.13°; chin deviation, 1.04±0.51 mm; maxillary occlusal cant, 1.13 ±0.65°). Non-canted group included 44 patients of skeletal Class III facial asymmetry without obvious maxillary occlusal cant (age, 25.1±4.3 years; ANB, -3.36±2.08°; chin deviation, 6.99±2.17 mm; maxillary occlusal cant, 1.19±0.80°). The canted group included 29 patients of skeletal Class III facial asymmetry with obvious maxillary occlusal cant (age, 24.4±4.2 years; ANB, -3.59±2.47°; chin deviation, 7.90±3.37 mm; maxillary occlusal cant, 5.98±1.37°). According to previous studies [18, 19, 21], maxillary occlusal cant is remarkable when larger than 4° and difficult to be detected when smaller than 2°. For this reason, patients with maxillary occlusal cant between 2° and 4° were excluded. Basic information and clinical features of the patients are shown in **Table 2**. There were no significant differences in age and ANB angle. Chin deviation in non-canted and canted groups were larger

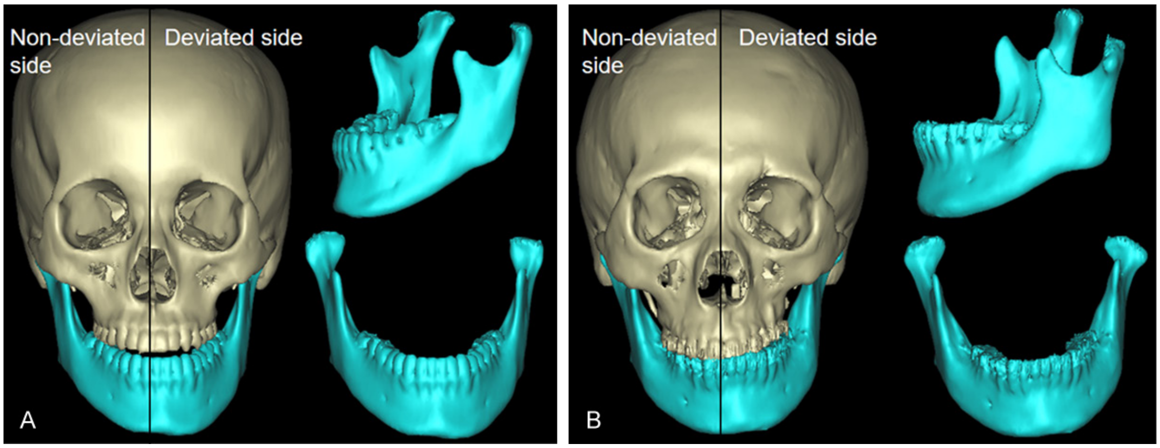

Figure 2. Differences between the non-canted and canted groups. A. Patients with facial asymmetry and without maxillary occlusal cant. Differences mainly exist in the gonial angle, anteroposterior ramal inclination, and mandible body height. B. Patients with facial asymmetry and maxillary occlusal cant. Differences mainly exist in maxilla height, mandible ramal length, mandible body length, and mediolateral ramal inclination.

than in symmetry group. Maxillary occlusal cant in canted group was larger than the other two groups.

Locations or morphology comparisons on glenoid fossa, zygoma, maxilla, and mandible among the three groups

The deviated and non-deviated sides were defined as shown in **Figure 2**. Paired t-tests showed differences between bilateral sides of the same group. In the non-canted group, mandible ramal length, mandible body length, gonial angle, anteroposterior ramal inclination, and mediolateral ramal inclination were significantly greater on the non-deviated side than on deviated side. Mandible body height was significantly smaller on the non-deviated side than on deviated side. Glenoid fossa and condyle were located more anteriorly and superiorly, respectively, on the non-deviated side than on the deviated side. Zygoma was located more anteriorly on the non-deviated side than on the deviated side. The average values of bilateral sides of the symmetry group were references for non-canted and canted groups. Two-sample t-test between one side of the non-canted group and the average value of symmetry group showed that mandible ramal length and gonial angle on the deviated side in non-canted group was smaller than reference value. The glenoid fossa and condyle on the non-deviated side were located more anteriorly than that of the symmetry group. Mandible body height and anteroposterior ramal inclination on the non-deviated side were larger than reference values. Mediolateral ramal inclination was larger on the non-deviated side while smaller on the deviated side when compared with reference values. Differences are shown in **Table 3** and **Figure 2**.

In the canted group, paired t-test showed that maxilla height, mandible ramal height, and mandible body length were significantly greater on the non-deviated side than on the deviated side. Mediolateral ramal inclination was significantly smaller on the non-deviated side than on the deviated side. There were no significant differences in mandible body height, gonial angle, and anteroposterior ramal inclination. The glenoid fossa and condyle were located more posteriorly and superiorly, respectively, on the non-deviated side than on the deviated side. The position of the zygoma was located more anteriorly and inferiorly on the non-deviated side than on the deviated side. Two-sample t-test showed that maxilla height, mandible ramal length, and body length on the deviated side in canted group was smaller than reference values. There was no significant anteroposterior ramal inclination, differing from non-canted group. Mediolateral ramal inclination was larger on the non-deviated side while smaller on the deviated side, compared to reference values. The glenoid fossa and condyle on the deviated side were located more anteriorly and superiorly. Position of the zygoma was moved anteriorly and superiorly when compared with symmetry group. Differences are shown in **Table 4** and **Figure 3**.

Table 3. Differences between the two sides in the non-canted group and comparison between non-canted group and average values in the symmetry group

Variables	Non-canted group (n=44)			Symmetry group (n=60)	P[b]	P[c]
	Deviated side	Non-deviated side	P[a]			
Maxilla height	31.62±3.35	31.86±3.04	NS	31.90±3.12	NS	NS
Mandible ramal length	62.82±4.73	65.26±5.48	**	63.54±4.28	*	**
Mandible body length	86.62±5.81	88.79±5.88	**	87.71±5.47	NS	NS
Mandible body height	33.22±2.15	31.52±1.88	*	31.37±1.67	NS	**
Gonial angle	114.19±5.39	116.64±5.71	**	116.42±5.91	**	NS
ARI	3.91±2.65	7.48±4.51	**	3.70±2.89	NS	**
MRI	8.84±5.42	10.28±4.70	*	9.26±5.46	**	*
GF|x|	49.26±3.36	49.92±3.53	NS	49.59±3.45	NS	NS
GF|y|	0.24±*3.37*	1.00±*3.49*	**	0.25±1.22	NS	**
GF|z|	72.15±5.39	69.47±4.99	**	70.31±5.89	**	NS
Co|x|	49.29±2.92	49.83±2.85	NS	49.56±3.78	NS	NS
Co|y|	1.26±0.65	0.96±0.56	**	1.42±0.57	NS	**
Co|z|	73.22±4.65	71.62±5.05	**	69.42±4.75	**	NS
FZ|x|	49.73±4.14	49.58±4.15	NS	49.66±4.13	NS	NS
FZ|y|	21.13±2.61	21.24±2.70	NS	21.19±2.44	NS	NS
FZ|z|	13.13±1.59	12.99±1.62	NS	13.06±1.48	NS	NS
ZC|x|	51.66±4.81	51.84±4.71	NS	51.75±4.58	NS	NS
ZC|y|	12.80±3.80	12.29±3.92	NS	12.55±3.46	NS	NS
ZC|z|	20.87±3.24	19.55±3.22	*	19.71±3.41	*	NS
ZA|x|	66.32±4.79	66.87±4.45	NS	66.60±4.32	NS	NS
ZA|y|	2.90±3.17	2.32±3.11	NS	2.61±3.11	NS	NS
ZA|z|	53.08±5.78	51.94±4.72	**	52.01±4.78	*	NS
ZI|x|	48.61±4.74	48.25±4.75	NS	48.43±4.28	NS	NS
ZI|y|	29.22±4.39	29.58±4.18	*	29.60±4.12	NS	NS
ZI|z|	21.44±3.83	22.89±3.72	*	21.67±3.17	NS	*

[a]Comparison between the non-deviated and deviated sides in non-canted group; [b]Comparison between average value in the symmetry group and the deviated side in the non-canted group; [c]Comparison between the average value in the symmetry group and the non-deviated side of the non-canted group; ARI: anteroposterior ramal inclination; MRI: mediolateral ramal inclination; The average value in the symmetry group = (Left + Right)/2. *P<0.05, **P<0.01, NS: No statistical significance.

Correlation between chin deviation and the bilateral differences was studied by Pearson's correlation analysis (**Table 5**). In the non-canted group, chin deviation was significantly correlated with differences in bilateral GF|z|, Co|z|, gonial angle, and anteroposterior ramal inclination. In the canted group, chin deviation was significantly correlated with differences in bilateral GF|z|, Co|z|, mandible ramal length, mandible body length, and mediolateral ramal inclination.

Discussion

The number of patients complaining of facial asymmetry has been increasing due to the pursuit of a beautiful or normal appearance. Accurate diagnosis is the basis for correct treatment plans for these facial asymmetry deformities. There are several methods of classifying facial asymmetry but no agreement among them [22-26]. Previous studies of facial asymmetry have mainly been focused on mandibular symmetry between both sides [9, 10, 27]. Study of craniofacial morphology, in different types of facial asymmetry, is rare. Therefore, this present study divided patients with facial asymmetry into non-canted and canted groups, according to maxillary occlusal cant, and evaluated the morphology of the zygoma, maxilla, mandible, and glenoid fossa in three dimensions.

Previous studies regarding the symmetry of zygoma in patients with facial asymmetry have been rare. Gong et al. [28] studied symmetry of

Table 4. Differences between the two sides in the canted group and comparison between the canted group and average values in the symmetry group

Variables	Canted group (n=29)			Symmetry group (n=60)	P[b]	P[c]
	Deviated side	Non-deviated side	P[a]			
Maxilla height	28.45±2.74	31.38±3.04	**	31.90±3.12	**	NS
Mandible ramal length	57.15±4.66	63.12±5.16	**	63.54±4.28	**	NS
Mandible body length	83.11±4.38	87.78±4.91	**	87.71±5.47	**	NS
Mandible body height	31.97±2.06	31.55±1.83	NS	31.37±1.67	NS	NS
Gonial angle	114.93±5.22	115.32±5.12	NS	116.42±5.91	**	**
ARI	4.00±3.98	3.75±3.30	NS	3.70±2.89	NS	NS
MRI	6.78±5.19	12.35±5.87	**	9.26±5.46	**	**
GF|x|	49.21±*2.54*	49.72±2.49	*	49.59±3.45	NS	NS
GF|y|	1.19±2.42	0.21±2.30	**	0.25±1.22	**	NS
GF|z|	68.96±4.37	70.09±4.63	**	70.31±5.89	*	NS
Co|x|	49.75±2.25	50.81±2.22	*	49.56±3.78	NS	NS
Co|y|	1.85±0.42	1.52±0.77	*	1.42±0.57	*	NS
Co|z|	67.33±6.57	69.02±5.18	**	69.42±4.75	**	NS
FZ|x|	49.04±2.92	49.34±2.47	NS	49.66±4.13	NS	NS
FZ|y|	20.13±1.83	19.98±1.78	NS	21.19±2.44	NS	NS
FZ|z|	13.36±1.57	13.14±1.63	NS	13.06±1.48	NS	NS
ZC|x|	52.71±3.96	52.41±4.12	NS	51.75±4.58	NS	NS
ZC|y|	11.75±5.17	13.07±5.08	*	12.55±3.46	*	NS
ZC|z|	19.22±3.68	18.35±3.84	*	19.71±3.41	NS	*
ZA|x|	67.61±4.04	68.34±3.71	NS	66.60±4.32	NS	NS
ZA|y|	2.75±3.22	2.37±3.31	NS	2.61±3.11	NS	NS
ZA|z|	51.43±4.73	52.85±4.82	**	52.01±4.78	NS	*
ZI|x|	48.17±4.03	47.74±3.88	NS	48.43±4.28	NS	NS
ZI|y|	27.89±4.37	29.42±4.87	**	29.60±4.12	*	NS
ZI|z|	21.78±3.87	22.51±3.73	**	21.67±3.17	NS	*

[a]Comparison between the non-deviated and deviated sides in the canted group; [b]Comparison between the average value in symmetry group and the deviated side in the canted group; [c]Comparison between the average value of the symmetry group and the non-deviated side in the canted group; ARI: anteroposterior ramal inclination; MRI: mediolateral ramal inclination; The average value in the symmetry group = (Left + Right)/2. *P<0.05, **P<0.01, NS: No statistical significance.

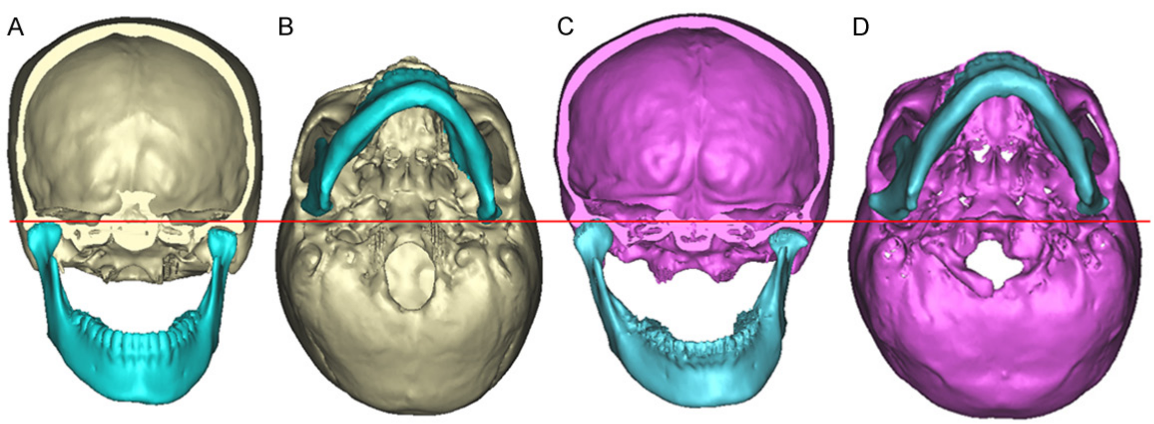

Figure 3. Differences in location of glenoid fossa and condyle. A. The glenoid fossa and condyle were displaced superiorly on the non-deviated side in the non-canted group. B. The glenoid fossa and condyle were displaced anteriorly on the non-deviated side in the non-canted group. C. The glenoid fossa and condyle were displaced superiorly on the non-deviated side in the canted group. D. The glenoid fossa and condyle were displaced posteriorly on the non-deviated side in the canted group.

Table 5. Correlations between chin deviation and the bilateral differences in each group (Pearson's correlation analysis)

Variables	Non-canted group	Correlation with chin deviation	Canted group	Correlation with chin deviation
Maxilla height	0.24±0.80	0.070	2.93±0.91	0.409*
Mandible ramal length	2.44±2.57	0.291	5.97±4.35	0.544**
Mandible body length	2.17±2.24	0.223	4.67±3.73	0.419*
Mandible body height	-1.70±1.02	-0.262	-0.43±2.23	-0.145
Gonial angle	1.44±2.09	0.339*	0.39±1.95	0.141
ARI	3.57±2.56	0.352*	0.25±2.62	0.134
MRI	1.44±1.77	0.253	3.57±5.79	0.371*
GF|x|	0.66±1.35	0.266	0.51±1.35	0.230
GF|y|	-0.76±1.59	0.142	-0.98±1.48	-0.346
GF|z|	2.68±2.27	0.365*	-1.14±1.87	0.390*
Co|x|	0.54±2.60	0.279	0.46±2.72	0.185
Co|y|	0.30±0.66	-0.077	0.33±0.71	0.230
Co|z|	1.61±2.61	0.313*	-1.69±3.10	0.395*
FZ|x|	-0.15±0.87	0.053	-0.30±0.95	-0.209
FZ|y|	-0.11±0.66	0.133	-0.14±0.47	-0.116
FZ|z|	-0.15±0.69	0.266	-0.22±0.77	-0.348
ZC|x|	-0.18±1.72	0.058	-0.29±1.36	0.299
ZC|y|	0.51±2.04	0.128	1.32±2.03	0.318
ZC|z|	1.32±1.10	0.280	0.87±1.79	0.363
ZA|x|	-0.55±1.92	-0.130	-0.73±3.30	0.127
ZA|y|	0.58±2.10	0.030	-0.62±1.86	0.286
ZA|z|	1.14±2.40	0.132	-1.42±1.36	0.343
ZI|x|	0.36±2.52	0.266	0.44±2.09	0.098
ZI|y|	0.36±1.95	-0.257	-1.54±2.74	0.299
ZI|z|	1.45±1.23	0.240	0.74±1.34	0.258

Difference = non-deviated side-deviated side. Maxillary deviation was positive value if the deviation direction accorded with chin deviation, otherwise it was negative value. *P<0.05, **P<0.01.

the zygoma but their study group did not include patients with facial symmetry. In the non-canted group of the present study, there was no significant difference in the location of the zygoma between both sides of the face. Nevertheless, in the canted group, the zygoma moved posteriorly and superiorly on the deviated side compared to the non-deviated side, but the position of bilateral FZ had no significant difference. These results indicate that size (ZI-FZ) of the zygoma on the deviated side is smaller than the non-deviated side in canted group.

Marianetti et al. [13] divided patients with facial symmetry into vertical plane asymmetries and transversal plane asymmetries, studying the location of glenoid fossa. Their results showed that the glenoid fossa was moved, anteriorly and superiorly, on the non-deviated side compared to the deviated side. These results are similar to the non-canted group in the present study. Nevertheless, unlike the non-canted group, the glenoid fossa and condyle were moved, anteriorly and inferiorly, on the deviated side compared to non-deviated side. This was different from the study by Marianetti et al. [13]. A possible reason could be the use of different reference systems.

Lee et al. [12] studied mandibular dimensions of subjects with asymmetric skeletal Class III malocclusion and normal occlusion using cone-beam computed tomography (CBCT). They found that the asymmetric skeletal Class III group showed significant differences in condylar height, ramus height, and posterior part of the mandibular body compared to subjects with normal occlusion. These results were partially similar to those of the present study. In their study, however, patients with facial asymmetry deformity were not divided into sub-groups according to maxillary occlusal cant. In the present study, results between the canted and non-cant groups showed several differences. Correlations between chin deviation and the other variables indicated different possible etiology mechanisms in the two groups. In the non-canted group, gonial angle, anteroposterior ramal inclination, and location of glenoid fossa and condyle were correlated with chin deviation. Deformities mainly occurred in mandibular angular measurements and the maxilla was often not affected. In the canted group, mandible ramal length, mandible body length, mediolateral ramal inclination, and maxillary occlusal cant were correlated with chin deviation. Deformities mainly occurred in mandibular linear measurements and the maxilla was also affected. The results of the present study show the possible presence of a relationship between chin deviation and deformities in craniofacial structures. It is not possible, however, to determine the cause-effect relationship.

The present study had several limitations. The sample size was small and from a single geographical area. It is, thus, possible that this study examined population-specific changes in facial symmetry. This study divided facial asymmetry patients into two groups, only. Future studies should compare differences among more detailed types of facial asymmetry.

In conclusion, different types of facial asymmetry show different characteristics, between canted and non-canted groups, in the position of glenoid fossa and condyle and in the morphology of mandible and zygoma.

These findings could serve as a reference for orthodontists and orthognathic surgeons in performing different treatment plans for patients with different types of skeletal Class III facial asymmetry.

Disclosure of conflict of interest

None.

Address correspondence to: Yin Ding, State Key Laboratory of Military Stomatology & National Clinical Research Center for Oral Diseases & Shaanxi Clinical Research Center for Oral Diseases, Department of Orthodontics, School of Stomatology, The Fourth Military Medical University, Xi'an 710032, Shaanxi, China. Tel: +86- 15622094068; Fax: +86-21-64085875; E-mail: dingyin@fmmu.edu.cn

References

[1] Proffit WR, Phillips C and Dann C 4th. Who seeks surgical-orthodontic treatment? Int J Adult Orthodon Orthognath Surg 1990; 5: 153-160.

[2] Severt TR and Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population at the university of North Carolina. Int J Adult Orthodon Orthognath Surg 1997; 12: 171-176.

[3] Samman N, Tong AC, Cheung DL and Tideman H. Analysis of 300 dentofacial deformities in Hong Kong. Int J Adult Orthodon Orthognath Surg 1992; 7: 181-185.

[4] Lew KK and Foong WC. Horizontal skeletal typing in an ethnic Chinese population with true Class III malocclusions. Br J Orthod 1993; 20: 19-23.

[5] Ishii N, Deguchi T and Hunt NP. Craniofacial differences between Japanese and British caucasian females with a skeletal class III malocclusion. Eur J Orthod 2002; 24: 493-499.

[6] Vig KD and Ellis E 3rd. Diagnosis and treatment planning for the surgical-orthodontic patient. Dent Clin North Am 1990; 34: 361-384.

[7] Kragskov J, Bosch C, Gyldensted C and Sindet-Pedersen S. Comparison of the reliability of craniofacial anatomic landmarks based on cephalometric radiographs and three-dimensional CT scans. Cleft Palate Craniofac J 1997; 34: 111-116.

[8] Girod S, Keeve E and Girod B. Advances in interactive craniofacial surgery planning by 3D simulation and visualization. Int J Oral Maxillofac Surg 1995; 24: 120-125.

[9] Kwon TG, Park HS, Ryoo HM and Lee SH. A comparison of craniofacial morphology in patients with and without facial asymmetry--a three-dimensional analysis with computed tomography. Int J Oral Maxillofac Surg 2006; 35: 43-48.

[10] Baek SH, Cho IS, Chang YI and Kim MJ. Skeletodental factors affecting chin point deviation in female patients with class III malocclusion and facial asymmetry: a three-dimensional analysis using computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 104: 628-639.

[11] Lee JK, Jung PK and Moon CH. Three-dimensional cone beam computed tomographic image reorientation using soft tissues as reference for facial asymmetry diagnosis. Angle Orthod 2014; 84: 38-47.

[12] Lee H, Bayome M, Kim SH, Kim KB, Behrents RG and Kook YA. Mandibular dimensions of subjects with asymmetric skeletal class III malocclusion and normal occlusion compared with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2012; 142: 179-185.
[13] Marianetti TM, Marianetti S, Gasparini G and Pelo S. Correlation between cranial base morphology and the position of the glenoid fossa in patients with facial asymmetry. J Craniofac Surg 2014; 25: 1190-1194.
[14] Tyan S, Park HS, Janchivdorj M, Han SH, Kim SJ and Ahn HW. Three-dimensional analysis of molar compensation in patients with facial asymmetry and mandibular prognathism. Angle Orthod 2016; 86: 421-430.
[15] Kim SJ, Lee KJ, Lee SH and Baik HS. Morphologic relationship between the cranial base and the mandible in patients with facial asymmetry and mandibular prognathism. Am J Orthod Dentofacial Orthop 2013; 144: 330-340.
[16] Eslamipour F, Borzabadi-Farahani A, Le BT and Shahmoradi M. A retrospective analysis of dentofacial deformities and orthognathic surgeries. Ann Maxillofac Surg 2017; 7: 73-77.
[17] Ahn J, Kim SJ, Lee JY, Chung CJ and Kim KH. Transverse dental compensation in relation to sagittal and transverse skeletal discrepancies in skeletal class III patients. Am J Orthod Dentofacial Orthop 2017; 151: 148-156.
[18] Olivares A, Vicente A, Jacobo C, Molina SM, Rodriguez A and Bravo LA. Canting of the occlusal plane: perceptions of dental professionals and laypersons. Med Oral Patol Oral Cir Bucal 2013; 18: e516-520.
[19] Padwa BL, Kaiser MO and Kaban LB. Occlusal cant in the frontal plane as a reflection of facial asymmetry. J Oral Maxillofac Surg 1997; 55: 811-816; discussion 817.
[20] Park SH, Yu HS, Kim KD, Lee KJ and Baik HS. A proposal for a new analysis of craniofacial morphology by 3-dimensional computed tomography. Am J Orthod Dentofacial Orthop 2006; 129: 600, e623-634.
[21] Zheng X, Hu XX, Ma N and Chen XH. [A new method to orthodontically correct dental occlusal plane canting: wave-shaped arch]. Beijing Da Xue Xue Bao 2017; 49: 176-180.
[22] Obwegeser HL and Makek MS. Hemimandibular hyperplasia--hemimandibular elongation. J Maxillofac Surg 1986; 14: 183-208.
[23] Nitzan DW, Katsnelson A, Bermanis I, Brin I and Casap N. The clinical characteristics of condylar hyperplasia: experience with 61 patients. J Oral Maxillofac Surg 2008; 66: 312-318.
[24] Baek C, Paeng JY, Lee JS and Hong J. Morphologic evaluation and classification of facial asymmetry using 3-dimensional computed tomography. J Oral Maxillofac Surg 2012; 70: 1161-1169.
[25] Chen YJ, Yao CC, Chang ZC, Lai HH, Lu SC and Kok SH. A new classification of mandibular asymmetry and evaluation of surgical-orthodontic treatment outcomes in Class III malocclusion. J Craniomaxillofac Surg 2016; 44: 676-683.
[26] Gateno J, Alfi D, Xia JJ and Teichgraeber JF. A geometric classification of jaw deformities. J Oral Maxillofac Surg 2015; 73: S26-31.
[27] You KH, Lee KJ, Lee SH and Baik HS. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular prognathism. Am J Orthod Dentofacial Orthop 2010; 138: 540, e541-548; discussion 540-541.
[28] Gong X, He Y, He Y, An JG, Yang Y and Zhang Y. Quantitation of zygomatic complex symmetry using 3-dimensional computed tomography. J Oral Maxillofac Surg 2014; 72: 2053, e2051-2058.