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Vertical facial height and its correlation with facial width and depth

Three dimensional cone beam computed tomography evaluation based on dry skulls

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Abstract

Introduction The aim of the present study was to evaluate how vertical facial height correlates with mandibular plane angle, facial width and depth from a three dimensional (3D) viewing angle.

Methods In this study 3D cephalometric landmarks were identified and measurements from 43 randomly selected cone beam computed tomography (CBCT) images of dry skulls from the Weisbach collection of Vienna Natural History Museum were analyzed. Pearson correlation coefficients of facial height measurements and mandibular plane angle and the correlation coefficients of height-width and height-depth were calculated, respectively.

Results The mandibular plane angle (MP-SN) significantly correlated with ramus height (Co-Go) and posterior facial height (PFH) but not with anterior lower face height (ALFH) or anterior total face height (ATFH). The ALFH and ATFH showed significant correlation with anterior cranial base length (S-N), whereas PFH showed significant correlation with the mandible (S-B) and maxilla (S-A) anteroposterior position.

Conclusions High or low mandibular plane angle might not necessarily be accompanied by long or short anterior face height, respectively. The PFH rather than AFH is assumed to play a key role in the vertical facial type whereas AFH seems to undergo relatively intrinsic growth.

Keywords Vertical face height · Mandibular plane angle · Cone beam computed tomography · Cephalometry · Maxillofacial development

Introduction

The fact that vertical dimension control is one of the most difficult tasks in orthodontic treatment has been recognized for a long time [15]. To thoroughly understand the vertical facial height (VFH) is therefore crucially important in orthodontic treatment. Vertical dimension, generally speaking, includes anterior (AFH) and posterior facial height (PFH). According to Björk [5] forward mandibular rotation occurs when PFH overdevelops relative to AFH; however, in many literature sources more attention was focused on the AFH and lower AFH has been confirmed as having a strong influence on the formation of vertical facial disproportions [27, 28, 34]. On the other hand some accepted terminologies used in describing vertical morphology, such as long and short face [4] or dolichofacial and brachyfacial [33] are mainly based on AFH. In the extreme case the short or long face syndrome is believed to be always characterized by low or high mandibular plane angle, respectively [32, 25]. Nanda [24] gave a similar viewpoint in a longitudinal study by differentiating the sample using the presence of anterior open bite or deep bite. However, in extreme vertical cases,

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muscle or organ dysfunction, such as nasal obstruction as suggested by Vig [39] is always involved. Van Spronsen et al. [38] also proposed that musculoskeletal interactions might differ between populations with normal faces and a selected group of individuals with long faces. Therefore, the orthodontic strategy on vertical control could be different between normal and extreme vertical cases. Thus it is important to study the facial height by excluding the extreme case of anterior open bite and deep bite so that the effect played by the muscle or organ dysfunction could be considerably diminished. Under the circumstances of anterior relatively normal overbite, the role played by both AFH and PFH in the formation of vertical facial type could become clear. At the same time it was also planned to verify if it is always true that the steeper the mandibular plane anteriorly inclines, the greater the AFH becomes or vice versa.

There is no doubt that longitudinal studies enable facial growth development to be understood more thoroughly than cross-sectional studies. However, fit is also necessary to know how the adult facial height, including AFH and PFH, correlates with mandibular plane angle, facial depth and width as well through the cross-sectional method.

To identify such correlations is crucial for fully understanding human craniofacial morphology and the functional interrelationship among the three dimensional (3D) structures so that orthodontic treatment strategies can be more effectively designed. Only a few studies, however, have focused on the assessment of the correlations of the 3D craniofacial structures measurements, especially on the linear measurements. Because of the well-known reason of the distortion and magnification of linear measurements in the conventional cephalometric measurements, angle measurements wherever feasible were suggested to be employed [3]. On the other hand Lundström et al. [18] evaluated facial depth and height changes by using ratio measurements. In addition to inaccuracy the traditional two-dimensional (2D) cephalometric analysis was actually based on a combination of lateral and posteroanterior films although it was referred to as a 3D method for several decades [6, 10, 16]. The same landmarks located in lateral and posteroanterior films were not always identical in these traditional studies [10]. The advent of 3D computed tomography (CT) technology allows direct visualization of the entire craniofacial structure instead of combining two projected films. Furthermore, advances in 3D software have led to actual 3D measurements becoming a reality. It is indubitable that the traditional cephalometry is still a valuable tool that can provide important information when used properly. During the past decade however, it has been verified many times in the literature that 3D CT, especially 3D cone-beam CT (CBCT) has shown to be greatly superior to the 2D approach both in the reliability of anatomical landmark identification [17, 7] and in measurement accuracy [1, 11, 23]. Therefore, in the present study in order to investigate the craniofacial structure three dimensionally accurately the 3D CBCT technique was used to preliminarily evaluate how the vertical facial height correlates with mandibular plane angle, facial width and depth in Caucasian dry skulls to deepen the understanding of vertical facial dimension and its functional interrelationships among 3D structures.

Material and methods

Subjects

The sample consisted of the CBCT data from 43 dry skulls which had been previously acquired in the Natural History Museum of Vienna by scanning the dry skulls of the Weisbach collection which includes the dry skulls of soldiers of the Austrian Imperial Army who died around 1870. Archival records show that the skulls mainly belonged to adult males who died between the ages of 19 and 50 years.

The following inclusion criteria were used in this study: no cranial deformities, complete skull bone structure, stable and reproducible mandibular position, no obvious skeletal asymmetry and normal anterior bite or mild deep bite (maximum deep bite is on the lingual cervical one third of upper incisors) or mild open bite (maximum of edge to edge bite).

Processing and image acquisition

A team of orthodontists checked the occlusion of each specimen to confirm stability and reproducibility before scanning. Silicone plaster was placed in the joint space between the mandibular fossa and the condylar head to improve stability. The dentition of each specimen was reconfirmed and placed in stable maximum intercuspation. A plastic holder was custom-designed to support skulls during CT scanning. For the details on image acquisition see Basili et al. [2].

Standardized head positioning and reference system acquisition

The orientation protocol and reference system were set up in Maxilim software as described by Swennen et al. [35]. Orienting the skulls in 3D space was carried out in a similar manner to that which radiologists use to position a patient's head in a cephalostat. However, the operators of 3D images have far more anatomical structures as objective references than radiologists. The lateral and frontal cephalograms (Fig. 1) were combined with frontal and caudocranial views (Fig. 2) to reconfirm head positioning. In the lateral film the bilateral structures should be perfectly superimposed, especially on the mandibular inferior border and the central axis of the skull should be parallel to the lateral film (Fig. 1). The median reference plane should pass through the central axis of the skull in the caudocranial view (Fig. 2). These maneuvers minimized the effects of the cant and yaw of the skulls.

Once the points of sella (S) and nasion (N) were defined the 3D cephalometric reference system was automatically generated by the computer.

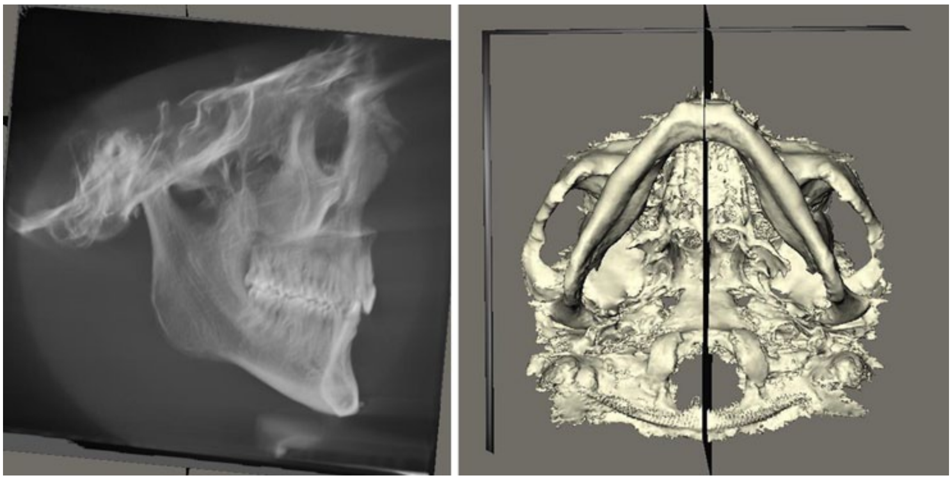

Fig. 1 In the lateral film the bilateral structures should be perfectly superimposed especially on the mandibular inferior border (*left*) and the central axis of the skull should be parallel to the lateral film (*right*)

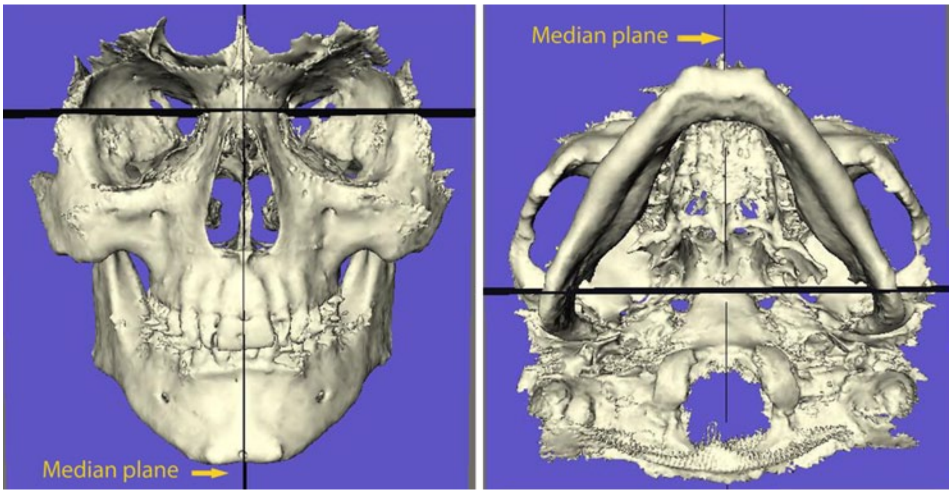

Fig. 2 The median reference plane is shown passing the central axis of the skull in the frontal (*left*) and caudocranial (*right*) views

Table 1 Description of the 3D cephalometric landmarks used in this study

Landmark	Definition
S (sella)	Midpoint of the pituitary fossa in the sagittal plane
N (nasion)	Middle point of the frontonasal suture in the frontal plane
Frz (frontozygomatic point)	Intersection of the frontozygomatic suture and the inner rim of the orbit in the frontal plane
Max (maxillary basal point)	Points in the lateral outline of the maxilla at which the lateral surfaces of the maxilla turn into the inferior surfaces of the maxillary zygometic processes in the frontal plane
ANS (anterior nasal spine)	Most anterior point of the premaxillary bone in the sagittal plane
PNS (posterior nasal spine)	Most posterior point of the palatine bone in the sagittal plane
A (point A)	Deepest point in the anterior outline of the maxilla between supradental and anterior nasal spine in the sagittal plane
B (point B)	Deepest point in the anterior outline of the mandible between infradental and pogonion in the sagittal plane
Pg (pogonion)	Most anterior point in the mandibular chin area in the sagittal plane
Gn (gnathion)	Middle point between Pg and Me at the surface of mandibular chin in the sagittal plane
Me (Menton)	Most inferior point in the mandibular chin area in the sagittal plan
Go (Gonion)	Point in the inferoposterior outline of the mandible at which the surface turns from the inferior border into the posterior border in the sagittal plane
Co (condyle)	Most posterosuperior point of mandibular condyle.
Zyg (zygomatic)	Most lateral aspect of the zygomatic arch
Ba (basion)	Anterior-inferior margin of the foramen magnum

Landmarks and measurements definitions

Table 1 and Figs. 3, 4, 5, 6 show the landmarks designed in this study. Although most of the 3D landmarks were easily visualized and identified in reconstructed 3D virtual space some landmarks, such as the condyle could not be directly visualized. Under these conditions the coronal and sagittal slice view was used to

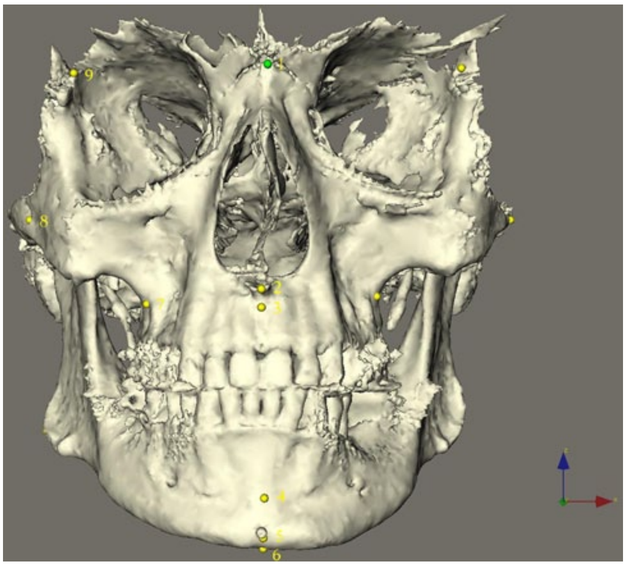

Fig. 3 The 3D landmarks in the frontal view: *1* N, *2* ANS, *3* A, *4* B, *5* Pg, *6* Me, *7* Max, *8* Zyg and *9* Frz

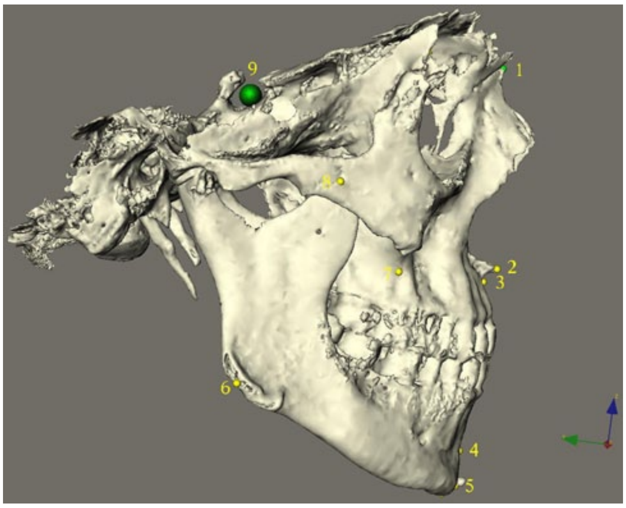

Fig. 4 The 3D landmarks in the lateral view: *1* N, *2* ANS, *3* A, *4* B, *5* Pg, *6* Go, *7* Max, *8* Zyg and *9* S

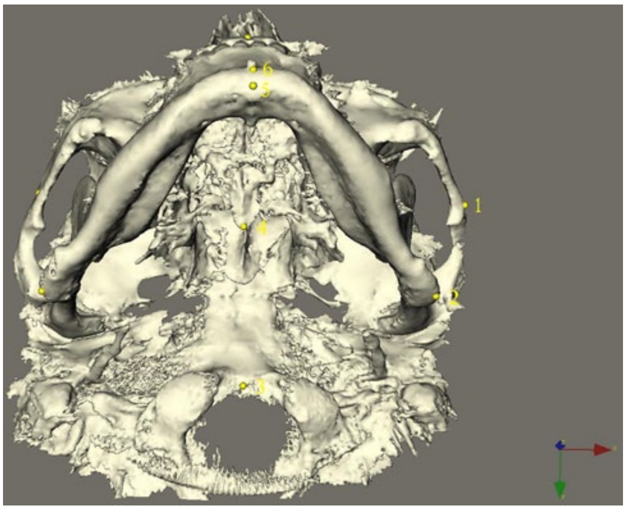

Fig. 5 The 3D landmarks in the caudocranial view: *1* Zyg, *2* Go, *3* Ba, *4* PNS, *5* Me and *6* Pg

help locate the landmarks (Fig. 6) and this coronal and sagittal slice view was also used to check if the landmarks had been correctly located in the reconstructed 3D virtual space.

Table 2 and Figs. 7, 8, 9 show the measurements designed in this 3D study. The dimensions of height were mostly measured along the vertical axis (Fig. 7) except for the mandibular ramus, which was measured directly from the Co to Go. In this way the 3D length of the mandibular ramus was obtained. To study the complete structure the true length was important rather than the projected length which was liable to be influenced by a poor head position. The only angle measurement applied in this study was MP-SN and the ratio measurement S-Go/N-Me. As for the measurements of bilateral sides the means of the values measured on the bilateral sides were considered as final values.

Depth was mostly measured along the anteroposterior-axis (Fig. 8) except the distances between S and N, between ANS and PNS and between Go and Gn. The reason as mentioned before was that the study focused on the actual length of cranial base, the maxilla and the mandibular corpus rather than the projected length.

Fig. 6 Coronal (*left*) and sagittal (*right*) slice view of the condyle (Co) landmark

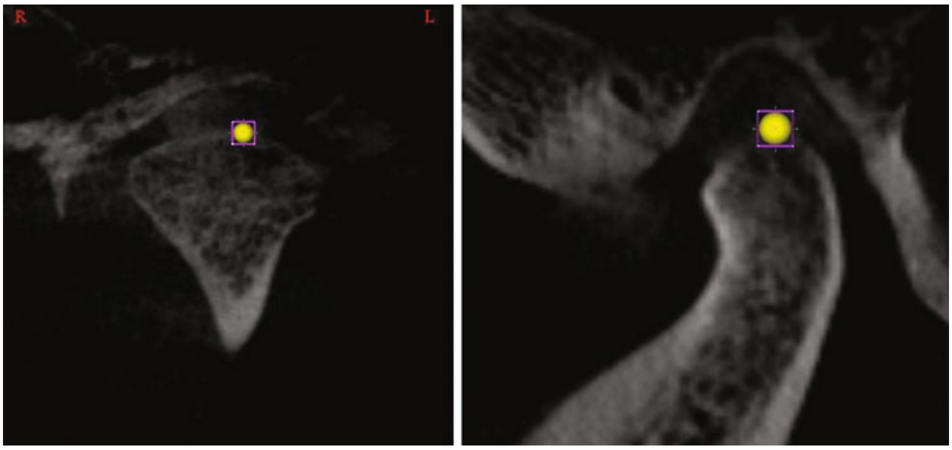

Table 2 Definition of the measurements used in this study

Measurement	Definition
Width	
Frz-Frz	Distance between the right and the left Frz along the transverse-axis
Zyg-Zyg	Distance between the right and the left Zyg along the transverse-axis
Max-Max	Distance between the right and the left Max along the transverse-axis
Co-Co	Distance between the right and the left Co along the transverse axis
Go-Go	Distance between the right and the left Go along the transverse axis
Height	
N-Me (total face height)	Distance between N and Me along the vertical axis
N-ANS (upper face height)	Distance between N and ANS along the vertical axis
ANS-Me (lower face height)	Distance between ANS and Me along the vertical axis
Co-Go (ramus length)	Distance between Co and Go
S-Go (posterior height)	Distance between S and Go along the vertical axis
S-Go/N-Me	Ratio of the linear measurement S-Go to N-Me
MP/SN	Angle between the projection of the lines of MP and SN on the median plane where MP plane is defined as connecting Go and Me
Depth	
S-N	Distance between S and N
S-Ba	Distance between S and Ba along the anteroposterior axis
Ba-N	Distance between Ba and N along the anteroposterior axis
ANS-PNS	Distance between the projection of ANS and PNS
Go-Gn	Distance between point Go and point Gn
S-A	Distance between S and A along the anteroposterior axis
S-B	Distance between S and B along the anteroposterior-axis

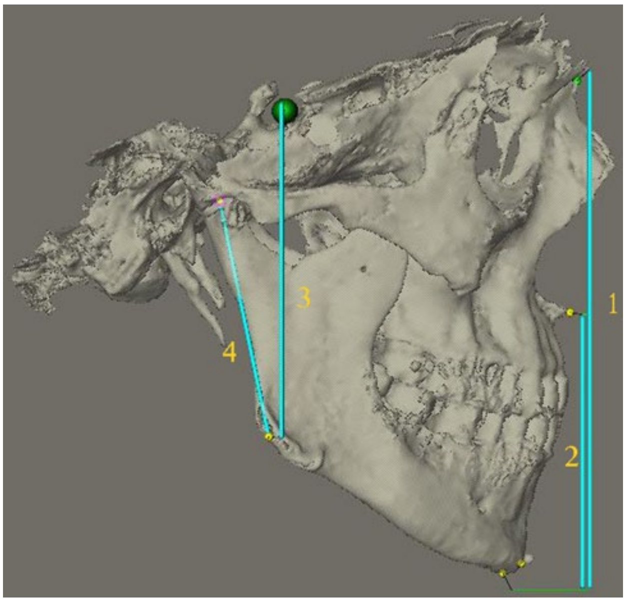

Fig. 7 Lateral view of height measurements: *1* N-Me, *2* ANS-Me, *3* S-Go, *4* Co-Go

Because direct measurements between identical anatomic structures of bilateral sides indicate not only width but also the vertical and anteroposterior difference between them,values measured along the transverse axis were defined as width (Fig. 9).

Statistical analysis

Data were statistically analyzed using SPSS 16.0 software for Windows. Pearson correlation coefficients among facial height measurements and mandibular plane angle and the correlation coefficients of height-width and height-depth were calculated, respectively and were considered significant when $p < 0.01$ and probably significant when p ranged between 0.01 and < 0.05. The absolute value of r was used to arbitrarily classify the correlation as low, moderate or high when it was < 0.40, 0.40–0.80 or > 0.80, respectively [9] and when r was between zero and 1 the correlation was positive and when between -1 and zero it was negative.

Before the Pearson correlation analysis, the normal distribution of all measurements had been tested and all the data were normally distributed. The same investigator located the same landmarks and measured the same

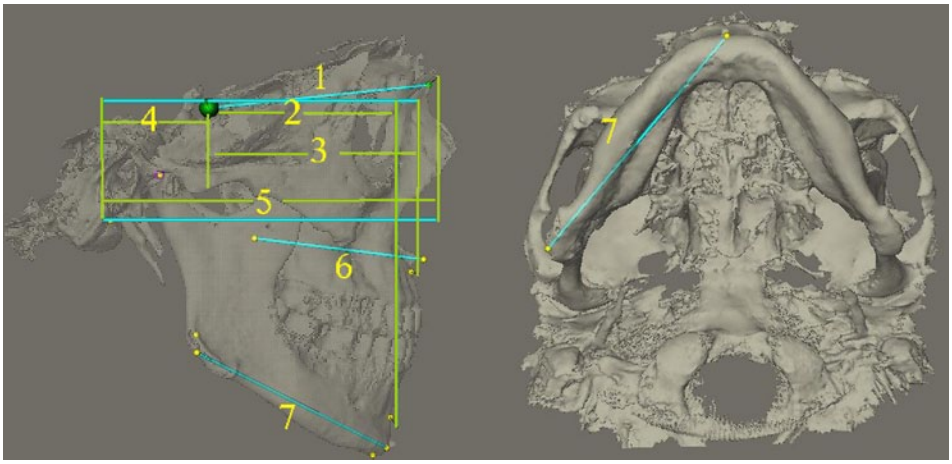

Fig. 8 Lateral (*left*) and caudiocranial (*right*) views of depth measurements: *1* S-N, *2* S-B, *3* S-A, *4* S-Ba, *5* Ba-N, *6* ANS-PNS, *7* Go-Gn

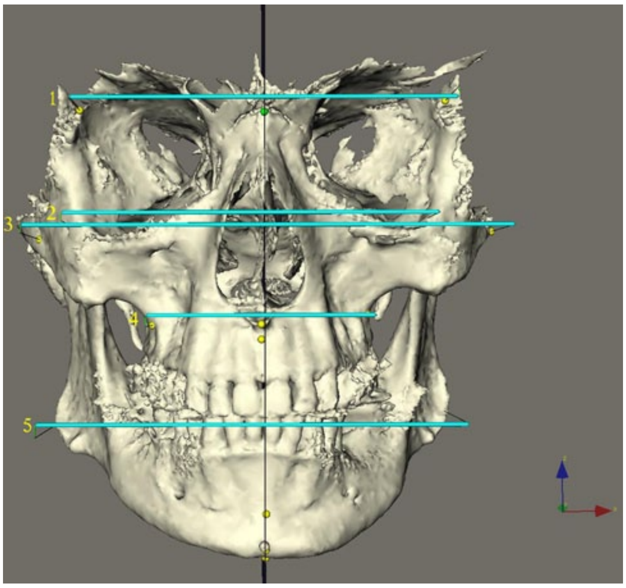

Fig. 9 Frontal view of width measurements: *1* Frz-Frz, *2* Co-Co, *3* Zyg-Zyg, *4* Max-Max, *5* Go-Go

items on 25 randomly selected CBCT images as described above at a 4-week interval to assess the intraobserver reproducibility. Random errors were estimated by correlation analysis and the reliability coefficient between the repeat measurements ranged from 0.893 to 0.991. Systematic errors were assessed using a paired *t*-test at the 10 % level of significance as Houston [13] suggested and no systematic errors were detected.

Table 3 Descriptive statistics of each measurement used in the study

Variable	*N*	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation (±mm)
Frz-Frz	43	84.60	99.90	92.99	3.52
Max-Max	43	54.30	70.00	61.71	3.74
Zyg-Zyg	43	116.10	138.40	124.75	5.32
Co-Co	43	82.50	99.30	92.81	4.67
Go-Go	43	81.70	107.80	94.25	6.26
MP-SN	43	19.35	39.00	29.86	5.18
S-Go/N-Me	43	59.40	80.20	69.13	4.44
N-Me	43	98.10	122.50	111.87	5.48
N-ANS	43	43.10	55.30	49.44	3.03
ANS-Me	43	53.50	79.40	62.44	5.65
S-Go	43	62.25	87.10	77.34	6.06
Co-Go	43	48.40	68.10	58.02	4.62
S-N	43	55.1	72.7	65.82	3.41
ANS-PNS	43	39.70	55.50	49.59	3.86
S-A	43	51.80	75.00	65.88	4.77
S-B	43	41.40	77.00	60.27	7.28
Go-Gn	43	77.35	98.55	87.02	4.79
S-Ba	43	17.90	32.90	25.30	3.59
Ba-N	43	78.60	101.70	90.71	5.03

For explanation of terms see Tables 1 and 2

Results

Table 3 shows the descriptive results of this study.

On the correlations among height measurements, MP-SN, S-Go/N-Me ratio (Table 4), Co-Go and S-Go moderately correlated with both MP-SN and the S-Go/N-Me ratio. The AFH, including anterior upper face height (AUFH measured between N and ANS), anterior lower face height (ALFH measured between ANS and Me) and anterior total face height (ATFH measured between N and Me) did not significantly correlate with either MP-SN or S-Go/N-Me, whereas ATFH and ALFH moderately and positively correlated with Co-Go and S-Go.

On the significant correlations between height and width (Table 5) the bizygomatic (Zyg-Zyg) distance significantly correlated with Co-Go, S-Go, S-Go/N-Me and MP-SN and Co-Go also showed low correlation with both the bicondylar (Co-Co) and the bigonial (Go-Go) width.

As for the statistically significant correlations between height and depth (Table 6), AFH, ATFH and ALFH showed moderate correlation with S-N and relatively

Table 4 Correlations between height measurements, MP-SN and S-Go/N-Me ratio

Variable	MP-SN	S-Go/N-Me	Co-Go	S-Go	N-ANS	N-Me
S-Go/N-Me	−0.902[a]	1				
Co-Go	−0.464[a]	0.635[a]	1			
S-Go	−0.572[a]	0.787[a]	0.846[a]	1		
N-ANS	0.035	0.083	0.155	0.204	1	
N-Me	0.262	−0.045	0.535[a]	0.580[a]	0.220	1
ANS-Me	0.239	−0.092	0.433[a]	0.450[a]	−0.321[b]	0.853[a]

[a] Correlation is significant at the 0.01 level (2-tailed)
[b] Correlation is significant at the 0.05 level (2-tailed)
For explanation of terms see Tables 1 and 2

Table 5 Statistically significant correlations of height and width

Variable	Zyg-Zyg	Go-Go	Co-Co
Co-Go	0.390[a]	0.340[b]	0.349[b]
S-Go	0.371[b]	0.204	0.290
MP-SN	−0.401[a]	0.017	−0.181
S-Go/N-Me	0.414[a]	0.077	0.247

[a] Correlation is significant at the 0.01 level (2-tailed)
[b] Correlation is significant at the 0.05 level (2-tailed)
For explanation of terms see Tables 1 and 2

Table 6 Statistically significant correlations of facial height and depth

Variable	S-N	S-A	ANS-PNS	S-B	Go-Gn
N-Me	0.562[a]	0.498[a]	0.395[a]	0.282	0.241
ANS-Me	0.509[a]	0.382[b]	0.320[b]	0.274	0.258
S-Go	0.250	0.485[a]	0.304[b]	0.526[a]	0.288
Co-Go	0.277	0.435[a]	0.400[a]	0.361[b]	0.357[b]

[a] Correlation is significant at the 0.01 level (2-tailed)
[b] Correlation is significant at the 0.05 level (2-tailed)
For explanation of terms see Tables 1 and 2

lower correlation with ANS-PNS and S-A. On the other hand, Co-Go and S-Go correlated moderately with S-A and S-B and slightly with ANS-PNS and Go-Gn.

Discussion

Although it was reasonable to find that MP-SN and PFH/ATFH showed moderate correlation with the PFH and the ramus height, it was quite implausible to discover that neither MP-SN nor PFH/ATFH correlated with any AFH measurements (Table 4 and Fig. 10). Even as the denominator of PFH/ATFH, ATFH did not correlate with this ratio. This might suggest that in normal overbite case the PFH or the ramus height rather than AFH appears to play a key role in vertical facial type.

At the same time, PFH and ramus height moderately and positively correlated with ATFH and ALFH (Table 4) which means that a face with a long PFH is normally accompanied by a relatively long AFH and vice versa. Therefore, in a normal overbite case, mandibular forward rotation cannot be simply regarded as the growth result of relatively long PFH together with relatively short AFH. In other words, the reason for mandibular forward rotation is not because of increase of PFH together with a decrease of AFH but the different increased dimension of them. These study results showed that it is the underdevelopment or overdevelopment of PFH instead of AFH that plays a key role in mandibular rotation. This agrees with Björk [5] who stated that under ideal circumstances the fulcrum point for anterior or forward mandibular growth rotation is located at the incisors. Therefore, as the result of forward rotation both the AFH and PFH increase.

On the other hand, extreme short or long face syndrome is definitely always accompanied by low or high mandibular plane angle. However, in the extreme case, muscle or organ dysfunction, such as nasal obstruction is suggested to be always involved [39]. This kind of dysfunction probably interferes with the functional capacity of adaptation that normal faces are supposed to have. Van Spronsen et al. [38] argued that musculoskeletal interactions might differ between populations with normal faces and a select group of individuals with long

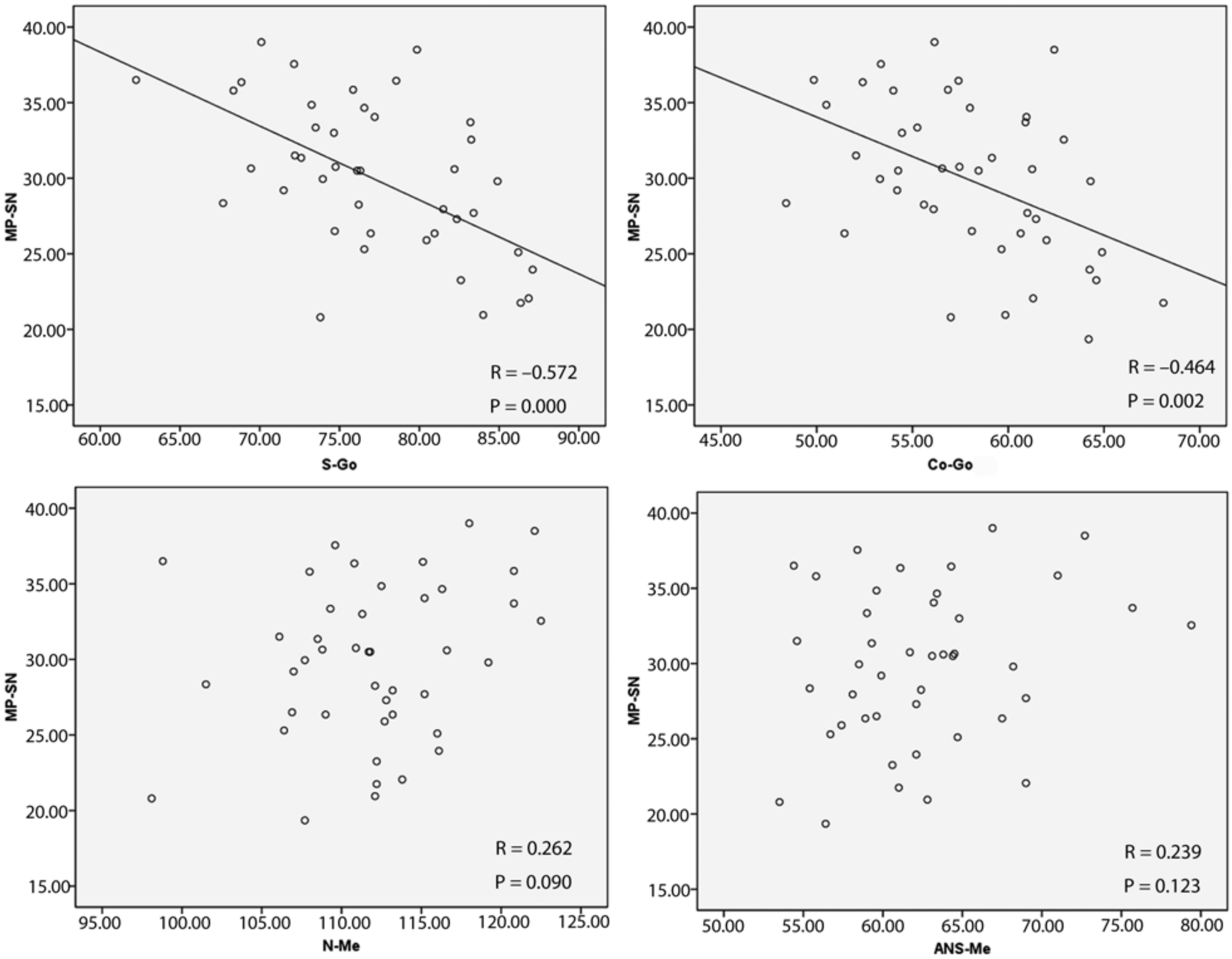

Fig. 10 Correlations between mandibular plane angle with posterior height (*upper left*), ramus height (*upper right*), anterior total face height (*lower left*) and anterior lower face height (*lower right*; for explanation of terms see Tables 1 and 2)

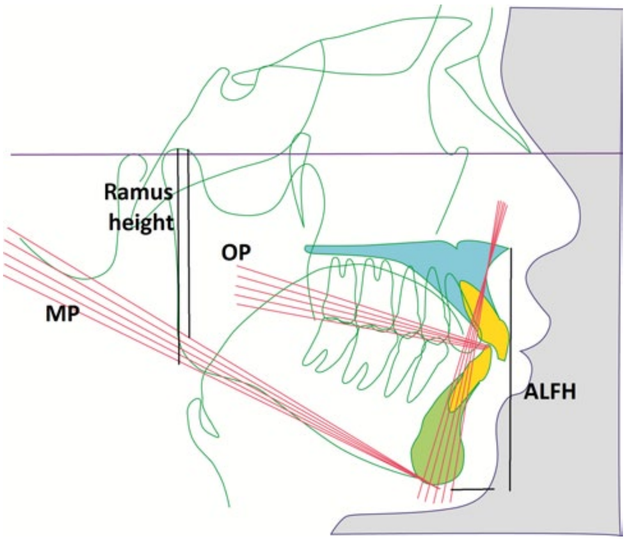

Fig. 11 Diagram of the lateral view of the skull showing that horizontalization of the posterior occlusal plane causes more vertical growth of mandible ramus and the mandibular plane will become flat. *ALFH* anterior lower face height, *OP* occlusal plane and MP mandibular plane

faces. As for the normal overbite person observed in this study, which can perfectly compensate some discrepancy within a certain extent, the mandibular plane angle was by no means associated with the anterior face height.

As for the reason why in relatively normal cases, the PFH instead of AFH plays a key role in mandibular rotation, the answer cannot be found in this study. In the literature several authors have stated that the morphology and position of the mandible should be adaptable to functional demand in the occlusal configuration [21, 31]. The posterior part of the dentition has furthermore been proposed as a main factor affecting the functional positioning of the mandible [14, 30, 8] The longitudinal growth studies conducted by Tanaka and Sato [37] revealed that continuous horizontalization of the posterior occlusal plane is accompanied by a simultaneous reduction in the mandibular plane angle during growth. They suggested that the posterior occlusal plane is the key point responsible for changes in mandibular position. If this assumption is valid, the possibility can be raised that with the horizontalization of the posterior occlusal plane, the vertical growth of mandible ramus might be obtained and as a result the mandibular plane will flatten (Fig. 11).

With respect to the correlation between face height and depth, ATFH and ALFH moderately correlated with anterior cranial base length (S-N), whereas PFH and anterior cranial base length did not correlate. As S-N is generally considered stable and reliable, environmental or functional factors seem less likely to change the S-N length. This might suggest that in normal cases, AFH is more likely to undergo relatively intrinsic growth than PFH or it is not easily influenced by functional factors such as changes in the posterior occlusal plane as noted above.

With respect to the posterior height, it weakly associated with the actual mandibular length and maxilla length and moderately and positively correlated with the anteroposterior position of the mandible and maxilla. Schudy [33] depicted the vertical and anteroposterior growth as opposing forces. That sounds reasonable with AFH being regarded as vertical height in the extreme case of long or short face type. In relative normal overbite case, however, as this study showed the vertical growth of PFH is consistent with anteroposterior growth.

In order to correct the anteroposterior discrepancy, orthodontists have tried to stimulate the capacity of adaptation to changes in mandibular position and nonhuman primate studies have demonstrated that the temporomandibular joint in the condylar region definitely has such functional capacity [22, 12]. According to McNamara and Bryan [21] and McNamara [19] the dentofacial complex is adaptable to the functional demands in the occlusal configuration even in young adult monkeys. Clinical studies, however, also by McNamara [20] using a functional regulator on adult humans, manifested that only minimal skeletal and dental adaptation occurred and that adaptation were considered insufficient to completely resolve patient malocclusions. It seems that for adults the protrusive function only is not enough to maintain the mandible in the forward position. Sato et al. [29], Sasaguri et al. [26] and Tanaka et al. [36] tried to maintain the mandible in the forward position by changing the occlusal configuration not only anterioposteriorly but also vertically. As a result, obvious remodelling of the condyle in adults has been found [26, 29, 36]. They suggested that the stable condyle adaptation might be available when the occlusal plane was reconstructed with either an orthodontic or prosthetic approach by increasing posterior teeth support, horizontalizing posterior occlusal plane and as a result the mandible being forward rotated. Together with the present study it can be deduced that to obtain enough mandible anteroposterior growth or forward adaptation a correct increase of posterior height might be an important factor.

As for the correlation between height and width, the ramus height together with the mandibular plane angle and the PFH/ATFH moderately correlated with the bizygomatic width and the width of Co-Co and Go-Go also correlated with ramus height to some extent, which implies that the bicondylar and bigonial width of the mandible is related to the height of the mandibular ramus. Thus, a face with a low angle, normally accompanied by a long ramus and a wide frontal region (wide bizygomatic and bigonial) can easily produce an illusion of a short face, although the anterior lower face height could be normal. This also explains why many faces with a low angle are taken for granted to be assumed as a short face, whereas a wide face and a square profile are responsible for making faces appear short.

In this study, depending on different purposes, direct or projected measurement was selected as the research method. The direct measurement method was used when the complete structure was evaluated, for instance, in measuring ramus length, mandibular corpus length and anterior cranial base length. The reason was that in this situation the study was more concerned with the real length of the structures than the projected ones and the direct measurement results could not be influenced by a poor position of the skull. In previous 2D cephalometric studies, however, as there is no way to measure the true length of any structure, observers had to make use of the projected length. The projected measurement was used here in the width measurement because only the width of identical anatomic structures on bilateral sides was made and direct measurements indicate not only width but also the vertical and anteroposterior difference between them. The larger vertical and anteroposterior difference of bilateral sides was, the more enlarged value was obtained compared with the actual result.

In this study Pearson correlation coefficients were used to find out the interrelationship among 3D structures. With these findings human craniofacial architecture and its multiple interactions among structures can be better understood but correlation studies cannot answer the cause and effect relationship among structures and also that between the skeletal morphology and jaw muscle function remain unclear. Further studies are needed to confirm some hypothesis made in this research.

Conclusions

Within the limitations of this 3D CBCT study on skulls of relatively normal adult Caucasian males it was concluded that low or high mandibular plane angle might not necessarily be accompanied by short or long AFH, respectively as has commonly been believed. The PFH rather than AFH is assumed to play a key role in the vertical facial type, whereas AFH seems to undergo relatively intrinsic growth.

Conflict of interest

The authors declare that there are no actual or potential conflicts of interest in relation to this article.

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