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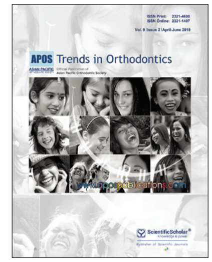

Original Article

Correlations between mandibular ramus height and occlusal planes in Han Chinese individuals with normal occlusion: A cross-sectional study

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ABSTRACT

Objectives: The objective of the study is to determine the relationships between ramus height and occlusal planes (OPs) in Han Chinese individuals with normal occlusion.

Materials and Methods: Two hundred and four participants with normal occlusion were included and their cephalograms were analyzed. The ramus height (Ar-Go), Frankfort horizontal plane-posterior OP (FH-POP), FH-anterior OP (FH-AOP) and FH-OP, anterior and posterior cranial base length, SNA, SNB, ANB, Frankfort-mandibular plane angle, SN-MP, jaw angle, and mandibular body length were measured on the subjects' cephalograms. Pearson correlation coefficients were calculated among continuous variables. The ramus height was considered as dependent variable and the OPs as independent variables. Age, sex, and other cephalometric parameters were considered as possible confounding factors. Univariate and multivariate analyses were performed to determine whether the relationships were significant.

Results: The FH-POP and FH-OP were moderately associated with ramus height, while the FH-AOP showed a weak association ($P < 0.001$). After adjusting age and sex, FH-POP, FH-AOP, and FH-OP showed significant negative associations with ramus height ($\beta = -0.36$, -0.28, and -0.37, respectively, $P < 0.001$). The OP flattened with the ramus height increased. After adjusting all the confounding factors, FH-POP and FH-OP showed significant negative associations with ramus height. The ramus height increased by 0.19 mm/1° flattening of FH-POP ($\beta = -0.19$, $P = 0.002$).

Conclusion: After adjust age, sex, and other possible confounding factors, the FH-POP and FH-OP were associated with the ramus height. The flattening of FH-POP was associated with the increase of ramus height. The results should be treated with caution since it's a cross-sectional study.

Keywords: Ramus height, Occlusal plane, Normal occlusion, Cephalometrics, Cross-sectional study

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INTRODUCTION

The mandible plays an important role in the growth of craniofacial structures. The condyle is a growth site of the mandible, and its growth affects the ramus height.[1] Condylar growth expressed more vertically.[2] Less condylar growth was related with the hyperdivergent facial type, which might impair the facial esthetics and occlusal functions.[3,4]

The occlusal plane (OP), which is another important factor associated with the vertical dimension of facial profile, is an imaginary plane at the level of occlusion. Downs defined the

OP as the line between the occlusal midpoint of the first permanent molars and the midpoint of the incisal edges.[5] In patients with severe curves of Spee, the inclination of the anterior and posterior teeth might be significantly different. Therefore, Fushima *et al*. determined the occlusal deviation in the upper dentition using posterior OP (POP) and anterior OP (AOP).[6] As the upper permanent molars erupt more than the upper incisors, during the normal growth, the OP becomes flatter gradually, especially the POP.[7]

Using lateral cephalograms or computed tomography scans, many researchers reported that mandible growth and counter-clockwise rotation were accompanied with the flattening of OP.[8,9] The increase of ramus height and the flattening of OP often occur simultaneously, which might both be the results of growth. Many studies reported that ramus height was closely related with chronological age.[10,11] Besides, males and females have different growth rates.[12] Sex is another associating factor with ramus height.

After adjusting the effect of age, sex, and other possible factors, the relationship between ramus height and OPs has not been fully explored yet. Therefore, the objective of the study was to determine the relationship between ramus height and OPs in Han Chinese individuals with normal occlusion. The null hypothesis was that there was no association between the ramus height and OPs after adjusting age, sex, and other factors.

MATERIALS AND METHODS

This cross-sectional research was approved by the Institutional Review Board of our Hospital. All participants and their patients or legal guardians were informed of the possibility that their records might be used for teaching and research purposes, and oral informed consent was obtained. All of the participants' personal information was deidentified.

We enrolled 204 participants (102 females and 102 males) consecutively from the patients who attended our hospital from January 2018 to October 2020. The selection criterion was: (1) of Han Chinese ancestry, (2) acceptable facial profile without facial asymmetry, (3) Angle Class I occlusion; (4) crowding or spacing no more than 3 mm, (5) the first molars had erupted and had occlusal contract with the opposite molars, (5) no history of orthodontic or orthognathic treatment; (6) no symptoms of temporomandibular disorders and no congenital craniofacial or teeth abnormalities (7) no history of systematic diseases.

Cephalometric analysis

All the cephalograms were taken according to standardized technique with natural head position and with teeth in centric occlusion.[13] The obtained digital cephalograms were traced by an experienced orthodontist and analyzed using Uceph software (version 961, Chengdu, China). Eleven cephalometric parameters were selected, including anterior and posterior cranial base length (S-N, S-Ar) SNA, SNB, ANB, Frankfort-mandibular plane angle (FMA), SN-MP, jaw angle (Ar-Go-Me), mandibular body length (Go-Me), ramus height (Ar-Go), Frankfort horizontal plane-POP (FH-POP), FH-AOP and FH-OP [Table 1 and Figure 1].[14] The intra and inter-rater reliability of cephalometric tracing were tested as previously described,[13,15] and all the intraclass correlation coefficients were >0.8.

Statistical analysis

Descriptive statistics were shown as mean ± standard deviation. Pearson correlation coefficients were calculated among continuous variables. The strength of the relationship is considered very weak with the absolute value of Pearson's r between 0~0.2, weak with r between 0.2~0.4, moderate with r between 0.4~0.6, and strong with r between 0.4~0.6.[16]

Table 1: Parameters measured from cephalograms.

Parameter	Definition
SNA (°)	Angle formed by the SN plane and the Nasion-A point line.
SNB (°)	Angle formed by the SN plane and the Nasion-B point line.
ANB (°)	Angle between Nasion-A point plane and the Nasion-B point plane.
FMA (°)	Angle formed by the FH plane and the mandibular plane.
SN-MP (°)	Angle formed by the SN plane and the mandibular plane.
Jaw angle(Ar-Go-Me)(°)	The angle between the line formed by Articulare and Gonion and the line formed by Gonion and Menton.
Mandibular body length(Go-Me)(mm)	The distance between Gonion and Menton.
Ramus height(Ar-Go)(mm)	The distance between Gonion and Articulare.
FH-POP (°)	The anterior angle between the POP and the FH plane. POP linked the averaged cusp tip of the maxillary second premolars and the midpoint between the averaged cusp tips of the maxillary second molar.[6]
FH-AOP (°)	The anterior angle between the AOP and the FH plane. AOP connected the maxillary incisal edge and the averaged cusp tip of the maxillary second premolars.[6]
FH-OP (°)	The anterior angle between the OP) and the FH plane.

SN: Sella-Nasion, OP: Occlusal plane, FH: Frankfort horizontal, POP: Posterior occlusal plane AOP: Anterior occlusal plane, FMA: Frankfort-mandibular plane angle

Ramus height was considered as dependent variable, FH-POP, FH-AOP, and FH-OP as independent variables. The other variables were considered as potential confounding factors. Univariate analysis was performed to determine whether the relationships were significant. Subsequently, multiple linear regression was performed to determine whether ramus height was independently associated with FH-POP, FH-AOP, or FH-OP after adjusting for the confounding factors. The variance inflation factor (VIF) among the confounding factors in the multivariate analysis was determined, and the variables with VIF more than 5 were considered to have severe multicollinearity.[17] The variables with severe multicollinearity were eliminated in the multivariate analysis. Smooth curve fitting based on a generalized additive model was performed to demonstrate the relation between ramus height and OPs. All statistical analyses were performed with the R packages (http://www.R-project. org, The R Foundation) and Empowerstats (http://www. empowerstats.com, X and Y Solutions, Inc., Boston, MA) with statistical significance determined at an α level of 0.05.

RESULTS

The mean age and cephalometric values were demonstrated in [Table 2]. Sex was related with the ramus height. Compared with female participants, males had significantly larger anterior and posterior cranial base length, mandibular body length and ramus height, smaller FMA and SN-MP angle, flatter FH-POP, FH-AOP, and FH-OP ($P < 0.05$).

The FMA and SN-MP angle showed strong negative correlations with ramus height ($P < 0.01$). Age, jaw angle, anterior and posterior cranial base length, mandibular body length, FH-POP, and FH-OP were moderately associated with ramus height. The SNA, SNB, and FH-AOP angle showed weak correlations with ramus height, and the ANB angle showed a very weak correlation with ramus height [Table 3].

The non-adjusted model showed that the ramus height was negatively related with the FH-POP, FH-AOP, and FH-OP [Table 4]. After adjustment for age and sex, the associations were still evident [Table 4]. The FMA, SN-MP,

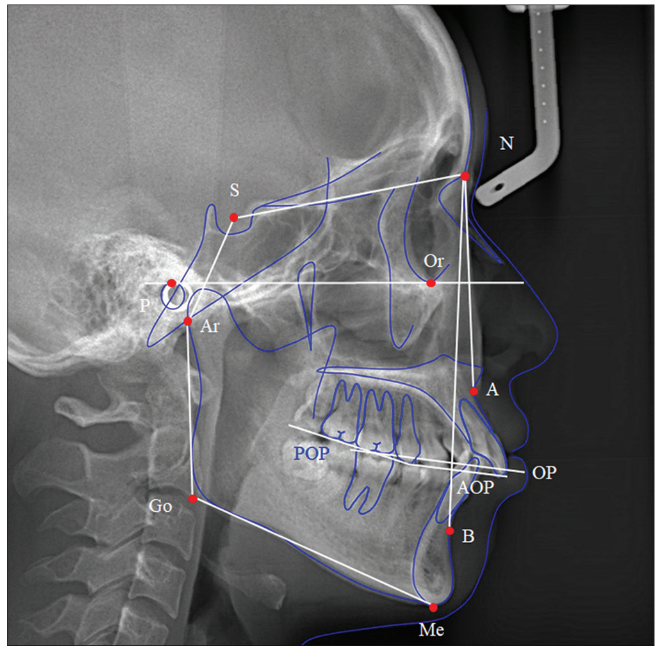

Figure 1: Cephalometric landmarks used in this study. S: Sella, N: Nasion, P: porion, Or: Orbitale, Ar: Articulare, Go: Gonion, A: Point A, B: Point B, Me: Menton, POP: Posterior occlusal plane, AOP: Anterior occlusal plane, OP: Occlusal plane.

Table 2: The mean age and cephalometric values of the included participants.

	Total (*n*=204)	Females (*n*=102)	Males (*n*=102)	*P* value
Age (year)	17.91±4.33	17.93±4.09	17.89±4.57	0.947
SNA (°)	81.94±3.53	81.95±3.45	81.94±3.62	0.978
SNB (°)	79.25±3.46	79.16±3.34	79.33±3.59	0.739
ANB (°)	2.70±1.87	2.79±1.84	2.61±1.90	0.487
FMA (°)	23.18±4.72	23.98±4.69	22.37±4.62	0.014
SN-MP (°)	32.33±5.21	33.14±4.83	31.51±5.47	0.025
Jaw angle (°)	119.11±6.24	119.55±5.96	118.66±6.51	0.313
Anterior cranial base length (mm)	63.86±3.33	62.30±2.83	65.43±3.07	<0.001
Posterior cranial base length (mm)	34.25±3.18	32.72±2.96	35.79±2.60	<0.001
Mandibular body length (mm)	70.46±4.68	68.78±3.93	72.15±4.79	<0.001
Ramus height (mm)	47.94±5.04	45.99±4.17	49.88±5.10	<0.001
FH-POP (°)	14.34±4.36	15.56±4.08	13.11±4.31	<0.001
FH-AOP (°)	8.73±4.14	9.21±4.20	8.25±4.04	0.097
FH-OP (°)	7.87±3.96	8.67±4.14	7.08±3.63	0.004

FMA: Frankfort-mandibular plane angle, FH-POP: Frankfort horizontal plane-posterior occlusal plane, FH-AOP: Frankfort horizontal plane-anterior occlusal plane, FH-OP: Frankfort horizontal plane occlusal plane

Table 3: The correlations between ramus height and other variables (ranked by the strength of the correlations).

Variable	Correlation	*P* value
FMA (°)	−0.632	<0.001
SN-MP (°)	−0.632	<0.001
Mandibular body length (mm)	0.495	<0.001
FH-POP (°)	−0.493	<0.001
Jaw angle (°)	−0.490	<0.001
Anterior cranial base length (mm)	0.480	<0.001
FH-OP (°)	−0.443	<0.001
Age	0.423	<0.001
Posterior cranial base length (mm)	0.416	<0.001
FH-AOP (°)	−0.315	<0.001
SNB (°)	0.309	<0.001
SNA (°)	0.205	0.003
ANB (°)	−0.187	0.008

FMA: Frankfort-mandibular plane angle, FH-POP: Frankfort horizontal plane-posterior occlusal plane, FH-AOP: Frankfort horizontal plane-anterior occlusal plane, FH-OP: Frankfort horizontal plane occlusal plane

Table 4: Associations of ramus height with occlusal planes.

Independent variable	Non-adjusted		Adjust I		Adjust II	
	β	*P*	β	*P*	β	*P*
FH-POP	−0.57 (−0.71, −0.43)	<0.001	−0.36 (−0.50, −0.23)	<0.001	−0.19 (−0.31, −0.07)	0.002
FH-AOP	−0.38 (−0.54, −0.22)	<0.001	−0.28 (−0.41, −0.15)	<0.001	−0.07 (−0.20, 0.06)	0.317
FH-OP	−0.56 (−0.72, −0.41)	<0.001	−0.37 (−0.51, −0.22)	<0.001	−0.15 (−0.29, −0.00)	0.047

FH-POP: Frankfort horizontal-Posterior occlusal plane,
FH-AOP: Frankfort horizontal-Anterior occlusal plane,
FH-OP: Frankfort horizontal-Occlusal plane, Non-adjusted model adjusts for: None, Adjust I model adjusts for: Age, Sex, Adjust II model adjusts for: Age, Sex, Mandibular body length; Jaw angle, Anterior cranial base length, Posterior cranial base length, SNB, ANB.

and SNA angles were eliminated in the multivariate analysis due to severe multicollinearity. After adjustment for all the confounding factors, the association between the ramus height and FH-AOP became insignificant. The ramus height increased by 0.19 mm/1° flattening of FH-POP (β = −0.19; 95% CI −0.31~−0.07), and the ramus height increased by 0.15 mm/1° flattening of FH-OP (β = −0.15; 95% CI −0.29~0.00) [Table 4].

[Figure 2] showed the linear relationship between ramus height and FH-POP, FH-AOP and FH-OP for Adjust I model [Table 4]. [Figure 2] showed the linear relationship between ramus height and FH-POP, FH-AOP, and FH-OP for Adjust II model [Table 4]. After all the adjustments, all the slopes of the lines became less steep, and the changes of FH-AOP and FH-OP were more evident.

DISCUSSION

In our study, the associations between ramus height and OPs were investigated. With no other variable adjusted, the ramus height was negatively related with the FH-POP, FH-AOP, and FH-OP and these associations were still evident after adjusting age and sex. However, after adjusting all the confounding factors, including age, sex, mandibular body length, jaw angle, and the rest, the association between the ramus height and FH-AOP became insignificant. Therefore, part of the null hypothesis was rejected.

Gu *et al*. reported the norms of the ANB angle of sixty-five typical Chinese adults were 3.8 ± 1.8° for the females and 3.5 ± 1.4° for the males; FMA, 30.4 ± 5.9° for the females and 28.2 ± 6.6° for the males.[18] which were relatively larger than the values from our results. Wu et al. reported the norms the ANB angle of 405 12-year-old southern Chinese children were 3.8 ± 1.8° for the females and 3.5 ± 1.4° for the males; FMA, 26.10 ± 5.07° for the females and 27.81 ± 5.19° for the males.[19] Since the value of ANB angle and SN-MP tends to be smaller with age, our results were more close to the values reported by Wu *et al*.[19] The difference of reported value might be due to the differences of sample selection and sample size. With relatively large sample size, the reported values might be more reliable.

Our results indicated that males were more hypodivergent and had larger ramus height and mandibular body length than females, in accordance with previous studies.[20,21] de Oliveira *et al*. reported a very strong positive correlation between age and ramus height (r = 0.90),[10] while the correlation in our study was moderate. The reason might be that de Oliveira *et al*. chose patients between 6 and 20 years and the number of patients in every year was almost even, while the participants in our study were unevenly distributed in every year.

The superior growth of ramus was related with forward rotation and inferior displacement of the mandible.[22] Therefore, the increase of ramus height was strongly associated with the decrease of the mandibular plane in our study. Buschang *et al*. reported that the growth and modeling changes for the ramus and mandibular body were relatively independent,[22] and our results also demonstrated a moderate correlation between ramus height and mandibular body length.

After adjusting age and sex and the other variables, the association between ramus height and FH-AOP became statistically insignificant, indicating that the FH-AOP was not a determining factor associated with ramus height. The AOP,

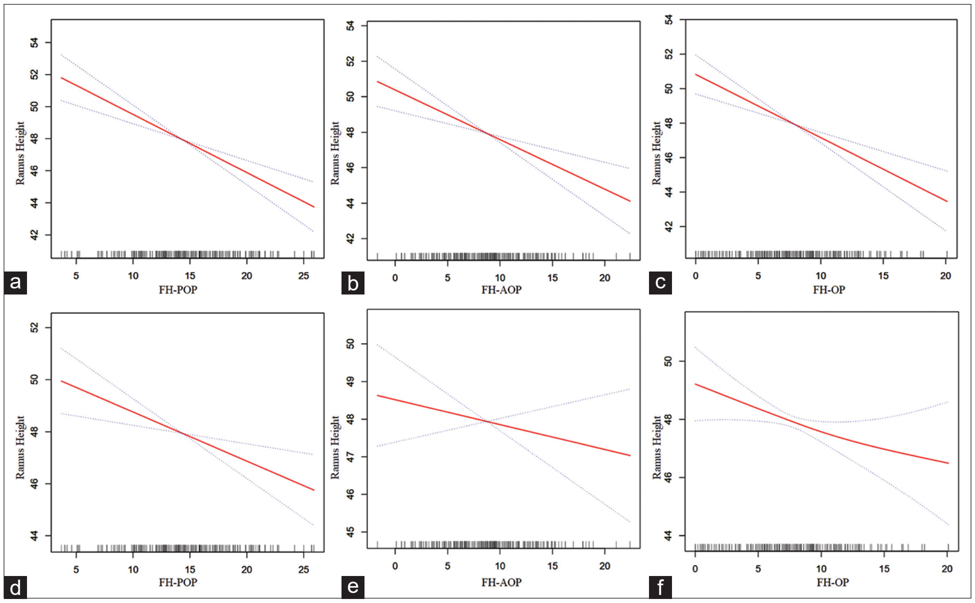

Figure 2: Smooth curve fitting for the associations between ramus height and FH-POP, FH-AOP, and FH-OP for the Adjust I model (a-c) and the Adjust II model (d-f). The blue bands represent the 95% confidence interval from the fit. FH-POP: Frankfort horizontal plane-posterior occlusal plane, FH-POP: Frankfort horizontal plane-posterior occlusal plane, FH-AOP: Frankfort horizontal plane-anterior occlusal plane, FH-OP: Frankfort horizontal plane occlusal plane.

as part of the anterior face, might be more associated with growth and remodeling of the maxillary anterior alveolar process and the anterior facial height.[23] The Downs OP was affected by the anterior and posterior part of the dentition; therefore, its effect was between the effects of POP and AOP. Clinicians might better use the AOP and POP separately instead of using the FH-OP solely for measurement.

Fushima, *et al.* found that skeletal Class II girls have significantly steeper POP and smaller ramus height compared with normal occlusion subjects.[6] A longitudinal research on untreated subjects demonstrated that Class II patients had steeper and Class III had flatter POP compared with Class I patients,[24] and another cross-sectional study using three-dimensional scans had similar results.[8] Sato proposed that there was a relationship between the POP and mandibular position.[8] Our study found a significant relationship between the POP and the ramus height after adjusting all the possible confounder factors, furtherly supporting the theory proposed by Sato.

Although there were cases demonstrating that the flattening of the POP could promote the growth of mandibular ramus and improve the skeletal Class II facial profile,[25] there is no high-quality evidence supporting these treatment outcomes. As a cross-sectional study, our results could not produce any causal relationship and should be treated with caution, which was one of the limitations of this study. However, these results could pave the way for future studies. Secondary analyses of previous longitudinal data regarding the OPs and future well-designed longitudinal studies could help to clarify the cause-and-effect relationship. In addition, considering the results and previous studies,[26,27] for hyperdivergent patients with insufficient ramus heights, it was important to maintain or increase the ramus height during treatment. Therefore, the clockwise rotation of the POP might be avoided for better treatment outcomes, since the clockwise rotation might be unfavorable to the growth of the ramus.

Another limitation of this study was that we adopted two-dimensional cephalograms for analysis instead of three-dimensional computed tomography scans due to the ethical considerations. Although the subjects included in this research did not show any significant facial asymmetry, there might still be slight differences in the ramus height and OPs between the left and right sides. The results could be more accurate with three-dimensional scans used for analysis in further studies.

CONCLUSION

The FH-POP and FH-OP showed moderate negative associations with the ramus height, while the FH-AOP only showed weak association with the ramus height. After adjusting age and sex, the associations between ramus height and FH-POP, FH-AOP, and FH-OP were statistically significant. After adjusting all the confounding factors, the FH-POP and FH-OP showed significant associations with the ramus height, and the ramus height increased by 0.19 mm/1° flattening of FH-POP.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Conflicts of interest

There are no conflicts of interest.

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