Age-related hypertrophy of adenoid and tonsil with its effects on craniofacial morphology

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Research Article

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Abstract

The present retrospective cross-sectional study was to compare craniofacial patterns resulted from different locations of upper airway obstruction. The study was conducted among 466 consecutive orthodontic patients who were divided into four groups: adenoid hypertrophy group (AG: 70 girls and 56 boys, 11.73±2.51 years), tonsillar hypertrophy group (TG: 38 girls and 21 boys, 12.47±2.72 years), adenotonsillar hypertrophy group (ATG: 36 girls and 33 boys, 11.07±3.35 years) and control group (CG: 151 girls and 61 boys, 12.92±2.34 years). Standard cephalometric examinations were used to compare the craniofacial differences between groups. The result indicated that adenoids and tonsils reached peak at around 6 years of age, after which the tonsils decreased more remarkably than the adenoids. Compared with CG, the proportions of skeletal class II in AG (43.7%) and ATG (44.9%) were significantly increased and the proportion of skeletal class III in TG (32.2%) was significantly increased. In age- and sex-adjusted linear regression models regarding CG as a benchmark, AG and ATG were positively correlated with ANB, MP/SN and FH/SGn but negatively correlated with SNB. In contrast, TG was positively correlated with SNA and SNB.

Conclusion: Adenoid hypertrophy tended to lead to mandibular retrusion and high mandibular plane angle. In contrast, tonsillar hypertrophy showed a trend in mandibular protrusion. However, children with adenotonsillar hypertrophy did not show a mean facial pattern of the above two but were rather similar to those with isolated adenoid hypertrophy. It seemed that adenoid hypertrophy lasted longer and played a greater role.

Introduction

Adenoid and tonsil constitute most of Waldeyer's ring[1]. Increased upper airway resistance related to adenotonsillar hypertrophy is the main pathogenetic abnormality in children with obstructive sleep-disordered breathing (SDB)[2–4]. In recent decades, the relationship between SDB and craniofacial morphology has been extensively studied[5–26]. However, few studies analyzed the craniofacial characteristics of patients with different locations of enlarged pharyngeal glands [11; 13; 27–29], which is critical in understanding the pathophysiology of SDB.

Linder-Aronson[30] first reported that mouth breathing caused by adenoid hypertrophy produced "adenoid face" which was characterized by an increased anterior facial height, a steep mandibular plane angle, and a retrognathic mandible when compared with healthy controls. In later researches, Trotman[27] found that there were two subtypes of craniofacial morphology. One was adenoid hypertrophy which was characterized by an en bloc backward rotation of the maxilla and mandible relative to the cranial base and by an increased mandibular plane angle. The other was tonsillar hypertrophy which was characterized by a forward relocation of the maxilla and mandible relative to the cranial base and by a decreased mandibular plane angle. However, Behlfelt[31] brought up the controversary that the craniofacial morphology in children with tonsillar hypertrophy were similar to those children with adenoid hypertrophy. Moreover, as for patients with not only adenoid hypertrophy but also tonsillar hypertrophy, it was reported that their craniofacial morphology was somewhere between adenoid hypertrophy and tonsillar hypertrophy[28; 29]. Thus, due to the inconsistent and conflicting results mentioned above, the craniofacial morphology of patients with different locations of enlarged pharyngeal glands is worth further investigation.

Based on the above researches and our previous clinical observations, we proposed that there would be craniofacial subtypes resulted from different locations of pharyngeal glands hypertrophy. We also hypothesized that adenotonsillar hypertrophy might has superimposed effects of adenoid hypertrophy and tonsillar hypertrophy to reach an intermediate state.

Materials And Methods

This is a retrospective cross-sectional study. The study was conducted according to the Declaration of Helsinki and approved by Peking University School and Hospital of Stomatology Ethics Committee (Issuing number: PKUSSIRB-202054046).

Subjects

The sample population was taken from consecutive orthodontic patients of two research members (X. Gao and X. Gong) from June 2014 to August 2019. Inclusion criteria were those under 18 years old with complete medical records and cephalograms. Exclusion criteria were as follows: previous orthodontic treatment, history of tonsillectomy or adenoidectomy, obesity according to the norm of Chinese children and adolescents[32], history of craniofacial injury, syndrome or congenital abnormality, cases of severe skeletal abnormalities requiring surgical treatment, with systemic disorders or neurological diseases, and with upper airway obstruction related diseases, such as nasal polyps, nasal tumor, nasal deformity, severe deviation of nasal septum, severe turbinate hypertrophy, severe allergic rhinitis, etc.

A sample of 466 Chinese children (171 boys and 295 girls) from 531 Chinese children aged 3 to 18 years were included in this study. The children were divided into four groups based on different obstructive sites. Details of demographic information of four groups are shown in

Table 1. Adenoid hypertrophy group (AG) consisted of 126 children with the adenoid more than half of the airway diameter and the tonsil less than half of the airway diameter. There were 70 girls and 56 boys with a mean age of 11.73 ± 2.51 years. Tonsillar hypertrophy group (TG) consisted of 59 children with the adenoid less than half of the airway diameter and the tonsil more than half of the airway diameter. There were 38 girls and 21 boys with a mean age of 12.47 ± 2.72 years. Adenotonsillar hypertrophy group (ATG) consisted of 69 children with both the adenoid and the tonsil more than half of the airway diameter. There were 36 girls and 33 boys with a mean age of 11.07 ± 3.35 years. Control group (CG) consisted of 212 children with both the adenoid and the tonsil less than half of the airway diameter. There were 151 girls and 61 boys with a mean age of 12.92 ± 2.34 years.

Table 1
Demographic characteristics and statistical comparisons of patients in adenoid hypertrophy group, tonsillar hypertrophy group, adenotonsillar hypertrophy group and control group

Variables	**AG**	**TG**	**ATG**	**CG**	***P* value**	**Multiple comparison**					
	(n = 126)	**(n = 59)**	**(n = 69)**	**(n = 212)**		**AG-TG**	**AG-ATG**	**AG-CG**	**TG-ATG**	**TG-CG**	**ATG-CG**
Age, y[a]	11.73 ± 2.51	12.47 ± 2.72	11.07 ± 3.35	12.92 ± 2.34	< 0.001***	0.290	0.485	< 0.001***	0.049*	0.663	< 0.001***
Gender, male(%)[b]	56(44.4%)	21(35.6%)	33(47.8%)	61(28.8%)	0.005**	0.255	0.650	0.003**	0.162	0.313	0.004**
BMI (kg/m^2)	18.67 ± 3.47	18.31 ± 2.84	17.54 ± 4.24	18.08 ± 2.80	0.386	-	-	-	-	-	-

Values are expressed as means ± standard deviations or frequencies (percentages).

AG, adenoid hypertrophy group, TG, tonsillar hypertrophy group, ATG, adenotonsillar hypertrophy group, CG, control Group, BMI, body mass index.

[a] Welch’s test followed by Games-Howell’s test

[b] Chi-square followed by partitioning chi-square

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Cephalometric analysis

All children had routine cephalometric examinations before treatment, performed by radiology specialists using orthopantomograph OC200 digital x-ray machine (Instrumentarium Dental, Tuusula, Finland). The lateral cephalograms were taken with children in an upright position and the Frankfort horizontal parallel to the floor. All children were instructed to remain still and to maintain centric occlusion without moving head or making speech or swallowing. Cephalometric analysis was performed by a single investigator. Craniofacial measurements were generated by selecting landmarks through self-developed software. Upper airway and glands measurements were obtained by tracing and measuring on sulfuric acid paper. Cephalometric landmarks and measurements used in this study are showed in Fig. 1. Ad/Np ratio more than 0.5 was considered to constitute adenoid hypertrophy. Tn/Op ratio more than 0.5 was considered to constitute tonsillar hypertrophy. According to the individual dentition stage, children were assigned to three sagittal skeletal patterns based on the cephalometric norm of Chinese children[33]: skeletal class I (3.3°≤ANB ≤ 6.1° in mixed dentition, 0.7°≤ANB ≤ 4.7° in permanent dentition), skeletal class II(ANB > 6.1° in mixed dentition, ANB > 4.7° in permanent dentition) and skeletal class III(ANB < 3.3° in mixed dentition, ANB < 0.7° in permanent dentition). To evaluate the error of the method, 20 lateral cephalograms selected randomly were re-traced and re-measured after 2 weeks by the same investigator. The intraclass correlation coefficients (ICCs) varied between 0.88 and 0.94 for the cephalometric measurements, indicating a satisfactory level of intra-investigator reliability.

Statistics

The normality of the distribution of continuous variables were checked by Shapiro-Wilk test. Levene´s test was used to examine the homogeneity of variance. All the continuous variables approached a normal distribution but showed a heteroscedasticity. Thus, the continuous variables were expressed with means ± standard deviations. Welch’s test followed by Games-Howell´s test was used to detect statistically significant differences between groups. Categorical variables were expressed as frequencies and percentages. Chi-square for intergroup comparisons and partitioning chi-square for multiple comparisons ($p < 0.05$/the number of comparisons) were conducted. To detect craniofacial differences between groups, multiple linear regression analysis was performed, using every single cephalometric variable as a dependent variable and age, gender and the groups (converted to dummy variables) as independent variables. Unstandardized regression coefficients (B-value) were calculated, representing age- and sex-adjusted differences between groups. Then, when sample size was limited to AG and TG, stepwise multiple regression was conducted to find the variables that best differentiated adenoid hypertrophy and tonsillar hypertrophy in terms of craniofacial characteristics. Unless otherwise stated, $p < 0.05$ was regarded as indicating statistical significance. Cases with miss data were excluded. Statistical analyses were performed using IBM SPSS Statistics for Mac (Version 26.0.Armonk, NY: IBM Corp.)

Results

Due to the large age range, this study did not directly compare the physical measurements, but was analyzed by the ratio of skeletal patterns and by multiple regression models, in order to avoid the interference of physical factors in different stages of development.

Demographic Characteristics of the Patients

A total of 466 subjects were included in the study (Table 1). Of all the subjects, 126 (27.0%) had isolated adenoid hypertrophy, 59 (12.7%) had isolated tonsillar hypertrophy, 69 (14.8%) had adenotonsillar hypertrophy. AG and ATG exhibited a younger age than CG. There was a predominance of girls in CG while a relative high proportion of boys in AG and ATG. Body mass index did not differ within groups ($p = 0.386$). Thus, age and sex might be confounding variables which need to be controlled to reach a demographical equivalence.

Age-dependent changes in adenoid and tonsil

Age-dependent changes in adenoid and tonsil were different (Fig. 2). The peak size of the adenoid came at around 6 years of age, after which it decreased. There was a slight increase in the size of adenoid at 10 years of age and subsequently a progressive decrease. As for tonsils, the peak size occurred at around 5 or 6 years of age, after which the tonsil decreased remarkably and then stayed at a relative low size.

Associations between cephalometric variables and different obstructive sites of upper airway

The proportions of sagittal skeletal patterns in CG, AG, TG and ATG were examined (Fig. 3). Chi-square test showed that the proportions of sagittal skeletal patterns in different groups were statistically different ($p < 0.001$). Compared with CG, the proportions of skeletal class II in AG (43.7%) and ATG (44.9%) were significantly increased and the proportion of skeletal class III in TG (32.2%) was significantly increased. The proportion of skeletal class II reached the highest in ATG whereas the proportion of skeletal class III reached the highest in TG.

Multiple linear regression (Table 2, Fig. 4) showed that TG was positively correlated with SNA and SNB when using CG as a benchmark. Moreover, AG and ATG were positively correlated with ANB, MP/SN and FH/SGn but negatively correlated with SNB when using CG as a benchmark.

Table 2
Multiple linear regression analysis of cephalometric variables in adenoid hypertrophy group, tonsillar hypertrophy group, adenotonsillar hypertrophy group and control group

Dependent variable		AG[a]		TG[a]		ATG[a]	
		B value	*P* value	B value	*P* value	B value	*P* value
Sagittal	SNA(°)	-0.20	0.620	1.38	0.009**	-0.01	0.992
	SNB(°)	-0.94	0.036*	1.99	0.001**	-1.36	0.015*
	ANB(°)	0.74	0.014*	-0.61	0.114	1.35	< 0.001***
Vertical	MP/SN(°)	2.22	< 0.001***	-0.55	0.487	2.64	0.001**
	FH/SGn (°)	1.22	0.006**	-0.68	0.231	1.99	< 0.001***
AG, adenoid hypertrophy group, TG, tonsillar hypertrophy group, ATG, adenotonsillar hypertrophy group.							
B value: unstandardized regression coefficients representing age- and sex-adjusted differences between groups.							
[a] Reference group: control group							
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$							

When sample size was limited to AG and TG, stepwise multiple regression analysis tested the cephalometric variables that were significantly correlated to the size of adenoid and tonsil (Table 3). The result showed that SNB was the only significant cephalometric variable. Adenoid hypertrophy correlated with a decreased SNB while tonsillar hypertrophy correlated with an increased SNB.

Table 3
Stepwise multiple regression analysis of Ad/Np and Tn/Op on cephalometric variables

Stepwise multiple regression with Ad/Np as dependent variable					
	Unstandardized Coefficients B	Standard error	95% Confidence interval	*P* value	Adjusted R^2
Constant	1.50	0.196	1.11,1.89	< 0.001***	0.131
SNB	-0.01	0.003	-0.02,-0.01	< 0.001***	
Stepwise multiple regression with Tn/Op as dependent variable					
	Unstandardized Coefficients B	Standard error	95% Confidence interval	*P* value	Adjusted R^2
Constant	-1.21	0.429	-2.05,-0.36	0.005**	0.052
SNB	0.02	0.006	0.01,0.03	0.001**	
Ad/Np, the size of adenoid; Tn/Op, the size of tonsil.					
Regression analyses were performed in 185 patients with isolated adenoid hypertrophy or isolated tonsillar hypertrophy. Patients with adenotonsillar hypertrophy has been excluded. Age and sex have been adjusted. Only significant data are presented.					
* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$					

Discussion

It has been recognized that identifying the obstructive sites of the upper airway is important because different combinations of obstructive tissues from the Waldeyer's lymphatic ring may influence craniofacial growth in a different way[25; 27–29]. Nevertheless, some researchers debated that the respiratory mode[5] and obstruction sites[13; 31] were unrelated to craniofacial morphology.

The adenoid and tonsil are not the only determinants in craniofacial morphology which is also affected by other factors, such as family heredity, self-adaptability and so on. Therefore, conflicting conclusions may have been drawn in previous studies mainly because of the sample size and sample collection. In addition, the adenoid and tonsil have physiological hypertrophy and age-dependent characteristics, which was fully reflected in the current study. Thus, it is crucial to take the role of age into consideration.

In the present study, a relatively large sample size from consecutive orthodontic cases was used, aiming to represent the real world population. The population involved a large variety of phenomena from which a control group was set as a benchmark. In addition, statistical methods such as chi-square test and regression analysis were used to avoid the direct comparisons of quantitative measurements.

In this study, we showed that adenoid hypertrophy tended to lead to Class II maxillo-mandibular relationship with mandibular retrusion and high mandibular plane angle. While tonsillar hypertrophy showed a trend in the opposite direction, leading to Class III maxillo-mandibular relationship with mandibular protrusion. By stepwise regression, we found that SNB was the most sensitive variable which could best differentiate craniofacial characteristics of adenoid hypertrophy and tonsillar hypertrophy. Above all agreed with the previous studies. Moss[34] developed the widely discussed “functional matrix theory” suggesting that development of the craniofacial bones depends on the balance between different tissues within the “matrix” of oro-facial capsule. When the upper airway is obstructed, there are postural and functional alterations in the oro-facial system in order to search for a more efficient airflow [35–38]. For example, enlarged tonsils occupied a considerable space in the oropharynx and forced the tongue to be postured forward[10; 27–29; 36; 39]. The pressure of the tongue on the anterior portion of the mandible acted as a stimulation and activated forward growth of the mandible[13; 28; 29]. Thus, tonsillar hypertrophy might be related with horizontal craniofacial growth[27–29].

As for adenotonsillar hypertrophy, we found that it did not show a mean facial profile of adenoid hypertrophy and tonsillar hypertrophy but were rather similar to adenoid hypertrophy, which rejected the null hypothesis. Both subjects with isolated adenoid hypertrophy and adenotonsillar hypertrophy had a retrognathic mandible, an increased maxillo-mandibular sagittal discrepancy and an increased mandibular plane angle, which was known as the “adenoid face” [14; 15; 21; 25; 40]. Moreover, compared with isolated adenoid hypertrophy, subjects with adenotonsillar hypertrophy tended to have a more severe skeletal class II relationship and a larger mandibular plane angle, although it was not significant. It indicated that the obstruction would be more severe when both adenoid and tonsil were hypertrophied. As a consequence, children could adopt a position with larger mouth opening to cope with a more severe airway obstruction and they preferred the posture of opening mouth which led to an clock-wise rotation of the mandible and an inferior position of the tongue.[15] This result is further confirmed by one study concerning dental occlusion and obstruction sites of upper airway[41]. In the study, the highest rate of class II relationship was detected in adenotonsillar hypertrophy, higher than isolated adenoid hypertrophy[41].

It needs to be pointed out that the craniofacial patterns mentioned above only represents population characteristics. Even though a certain group of people might share specific craniofacial features, individual’s growth and development varies. In our study, there was a relatively high proportion of skeletal class III in subjects with isolated tonsillar hypertrophy, but skeletal class I and skeletal class II still accounted for a large proportion. The same was true for isolated adenoid hypertrophy.

It should also be noted that growth patterns of adenoid and tonsil were observed in our study. Hypertrophy of adenoid and tonsil was normal in early childhood and probably was an index of immunological activity[42]. Growing adenotonsillar tissue narrowed the upper airway to variable degrees in early childhood and the degree of airway obstruction decreased with age, which was supported by another study[43]. The adenoid reached peak at age 6 and showed small increases at age 10 (possibly associated with the sex hormones at puberty), which was consistent with the Linder-Aronson’s longitudinal study[44]. The tonsil reached peak at 5 to 6 years of age, which was supported by Shintani's findings[45]. The adenoid hypertrophy lasted longer than tonsil hypertrophy, which might be the reason for that the “adenoid face” is more common in patients.

The present study surely could not avoid limitations. First, since it was a retrospective study, there might be some inadequacies in documentations and special condition controlling. For example, respiratory control during cephalometric scanning might have some impact on upper airway.[46] Second, this study was based on lateral cephalograms, which could be further carried out with cone beam computer tomography (CBCT) and with evaluations of upper airway resistance and ventilation functions. Third, influenced by ethical aspects, although we tried to exclude syndromes, congenital malformation and severe bone deformity and so on, samples from orthodontic population were not a fair representation of the healthy population. Fourth, household hereditary should be considered in the facial pattern analysis in future studies. Last, the study was based on Asian children and may not be applicable to other populations.

Conclusion

Different locations of upper airway obstruction had a tendency to lead to different craniofacial patterns. Among them, adenoid hypertrophy lasted longer and played a greater role.

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Figures

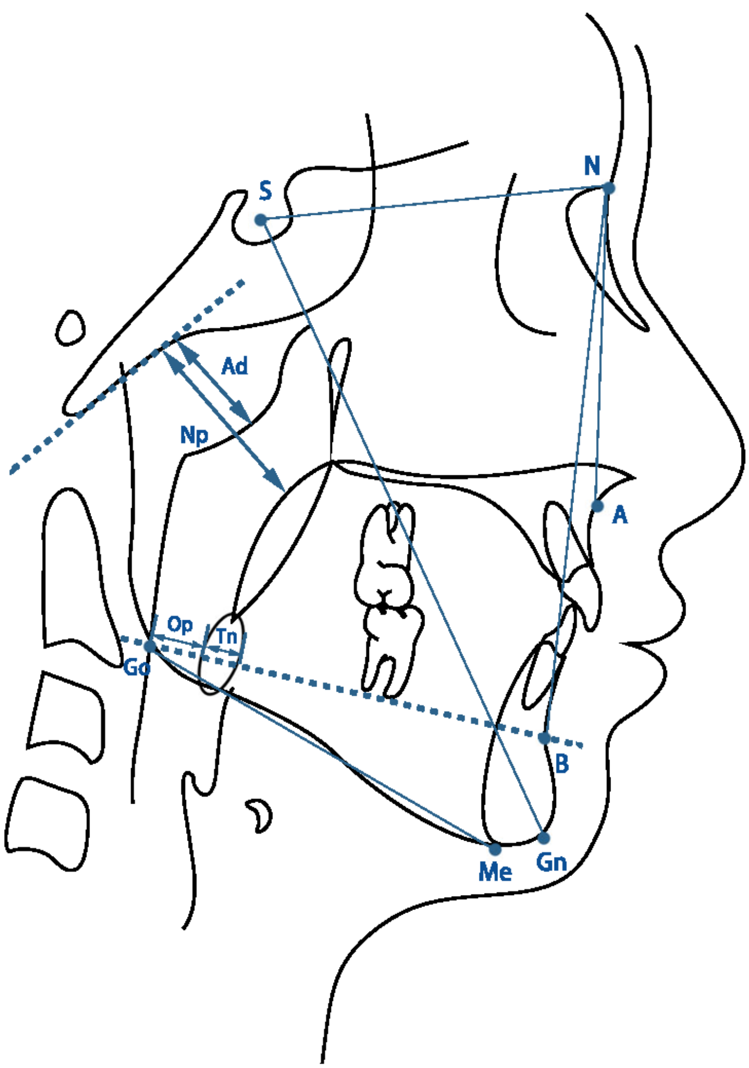

Figure 1

Cephalogram illustrating the cephalometric landmarks and measurements of adenoid and tonsil S, sella; N, nasion; A, subspinale; B, supramentale; Go, gonion; Me, menton; Gn, gnathion; Ad, distance from the outermost point of convexity of adenoid shadow to basiocciput, representing the width of adenoidal tissue; Np, the width of nasopharynx; Tn, the width of the tonsil on the B-Go line; Op, the width of oropharynx; Ad/Np, the size of adenoid; Tn/Op, the size of tonsil.

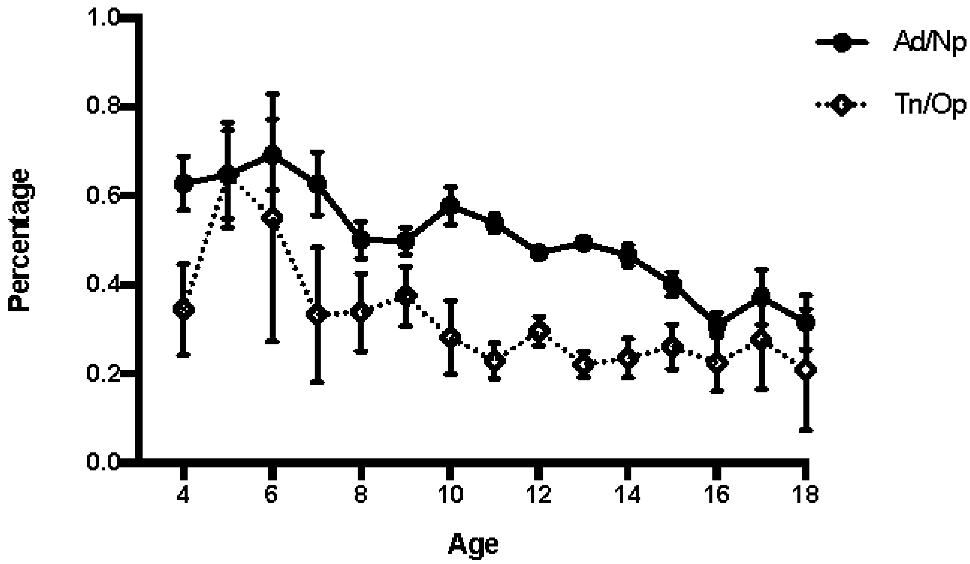

Figure 2

Age-dependent changes in adenoids and tonsils Ad/Np, the size of adenoid; Tn/Op, the size of tonsil. Dots and error bars represent mean ± standard error.

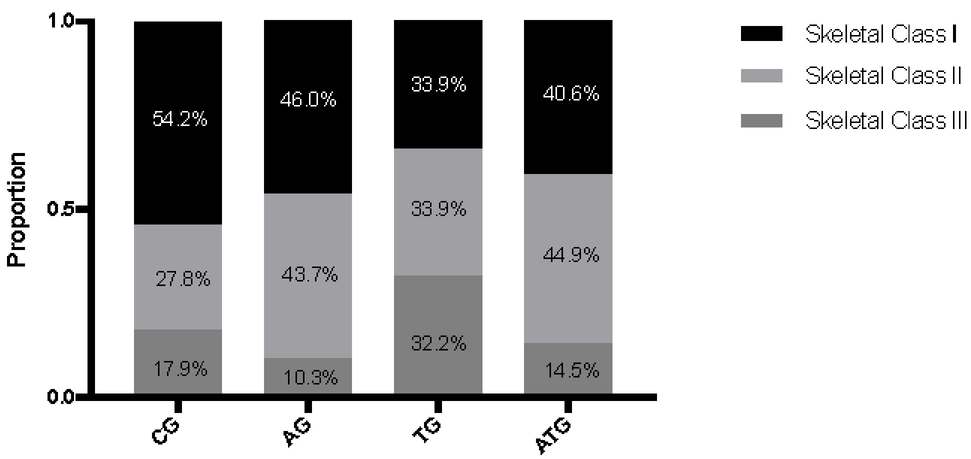

Figure 3

Different sagittal skeletal patterns in adenoid hypertrophy group, tonsillar hypertrophy group, adenotonsillar hypertrophy group and control group AG, adenoid hypertrophy group; TG, tonsillar hypertrophy group; ATG, adenotonsillar hypertrophy group; CG, control Group.

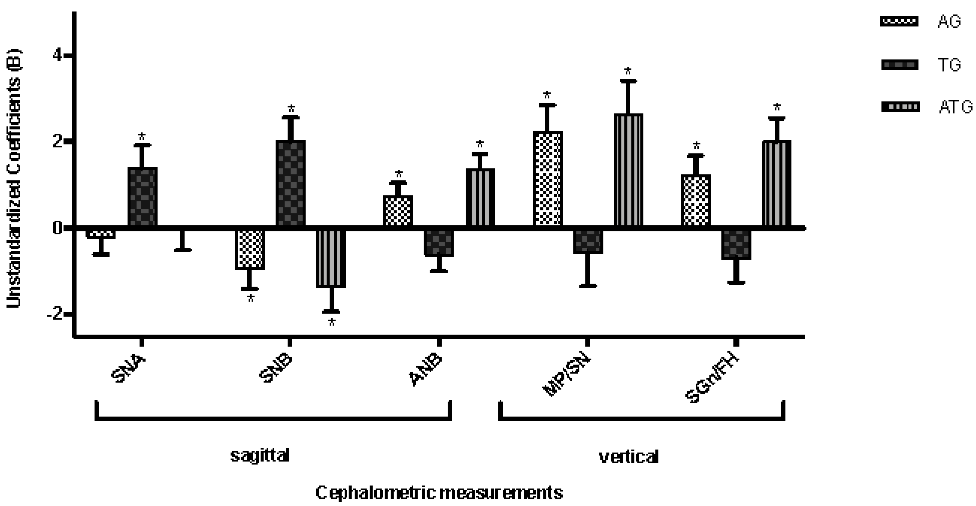

Figure 4

Comparisons of multiple linear regression analysis of cephalometric variables AG, adenoid hypertrophy group; TG, tonsillar hypertrophy group; ATG, adenotonsillar hypertrophy group. The zero line represents the control group, and the difference between each angle measurements and the control is displayed as a histogram. * represents statistically significant.