THE POSITION OF HYOID BONE IN DIFFERENT FACIAL PATTERNS: A LATERAL CEPHALOMETRIC STUDY

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Abstract

Considerable attention has been given to the position of the hyoid bone in relation to the facial skeleton. Studies on various population samples have shown that changes in the hyoid bone position seem to be related to changes in the mandibular position in particular and other facial structures in general. The present study was undertaken to evaluate the changes in the position of the hyoid bone which might induce changes in the position of certain dentofacial structures and it could be instrumental in the establishment of specific structural elements of the jaws and occlusion of teeth which is of great interest to the orthodontists. Lateral cephalometric measurements successfully assessed the relationship between different skeletal patterns and the hyoid bone and allowed to correlate the hyoid bone position to other craniofacial parameters. Statistically significant differences existed among the three groups in measurements of SNB, ANB and NSH. Statistically significant differences among Classes I, II and III as regards H-SN perp, H-FH perp, H –C3, H- RGn and C3-Rgn.

Keywords: Hyoid bone, facial patterns, cephalometric

Introduction

During the last two decades, considerable attention has been given to the position of the hyoid bone in relation to the facial skeleton. Studies on various population samples have shown that changes in the hyoid bone

position seem to be related to changes in the mandibular position in particular and other facial structures in general.

Both groups of the muscles (infra and supra hyoid) connect the hyoid bone to different structures such as the tongue, the mandible, the base of the skull, the sternum, the scapula, the thyroid cartilage and the pharynx. Because of the complex attachments of the hyoid bone to different structures, changes in the position of those may influence its position in space (Gray H, 1954).

Hyoid bone had been studied by many researchers, as they are studying different factors which are very important to be known about hyoid bone such as, it's functional anatomy, the relationship between the anatomic position of hyoid bone and cervico-facial morphologic characteristics, the different factors affecting the position of the hyoid bone and the diagnostic value of the hyoid bone position in clinical orthodontics.

(Bibby and Preston 1981), (Michael and Donald, 1999) and (Maria et al, 2006) mentioned that the importance of the hyoid bone lied in its unique anatomic relationships. They remarked on the great variability of the hyoid position on even slight movement of the head. It appeared that the two may be intimately related. They determined the position of the hyoid bone by using the cervical vertebra and the mandible as the reference landmarks. In their studies analyzed the hyoid bone position by using the following points: Retrognation: RGn (the most posterior-inferior point of the mandibular symphysis), Hyoid point: H (the most anterior-superior point of the body of the hyoid bone), and C3: (the most anterior-inferior point of the third cervical vertebra). The study concluded with constant hyoid bone-cervical vertebra relationship. In another study had been conducted by (Ceylan and Oktay, 1995) showed that the distance from the hyoid bone to the fourth cervical vertebra was affected by the change in ANB angle as it became smaller with increase in the angle.

(Kuroda et al, 1966) studied the relationship between the hyoid bone, skull and mandible by using lateral cephalograms. The results showed difference in the hyoid bone position in relation to the anterior cranial base. The body of the hyoid bone located backward in Class II samples and forward in Class III samples in comparison with the control group.

 (Adamidis and Spyropoulos, 1992) reported a significant difference in the position of the hyoid bone found between class I and class III malocclusions. Class III group, showed a more anterior position of the hyoid bone as well as a decreased inclination, which was almost reverted in relation to hyoidal axis with mandibular plane.

In a longitudinal lateral cephalometric study done by (Kolias and Krogstad, 1999) investigated the hyoid bone position of 26 men and 24 women who were divided into three different age groups with 10-year

interval. The authors concluded that the horizontal position of the hyoid bone was stable.

The hyoid bone position had been examined in response to mandibular advancement in subjects with mild and moderate obstructive sleep apnoea (OSA). Pairs of lateral cephalograms were taken, the first in the maximum intercuspation and the second in the most comfortable protrusion position. All the patients were Caucasians of 13 female and 45 male. The study which conducted by (Battagel et al, 1999) showed that in the protruded mandible the hyoid bone became closer to the mandibular plane in the same time got more upward position.

(Arslan et al, 2007) investigated the change of hyoid bone position among patients with hypohidrotic ectodermal dysplasia (HED) who have the characteristic craniofacial features of class III malocclusion with maxillary retrognathia and deficiency in vertical, transversal and sagittal growth of the jaws and control group. It was reported that hyoid bone was more posteriorly positioned than class III in the control group.

(Ferraz et al, 2007) assessed cephalometrically the hyoid bone position in relation to the respiratory pattern. The study consisted of 28 samples of nasal breather and 25 samples of oral breather. All the samples were female. The study concluded that no statistical significant differences in the mandible and hyoid bone position and the respiratory pattern so the hyoid bone kept a stable position and it did not depend on the respiratory pattern.

(Bibby, 1984) assessed the hyoid bone position among mouth breathers and tongue-thrusters found that it had a very constant resting position which is not permanently affected by habitual tongue-thrusting or mouth breathing so it could be used as a reference landmark in cephalometric analysis for orthodontic treatment purposes.

(Tourne, 1991) reported that as the mandible moved posteriorly to the other craniofacial structures, the tongue and hyoid bone did not follow this movement in a similar manner, otherwise they will encroach on the vital oropharyngeal and laryngeal spaces. In order to alleviate this problem, the hyoid bone and associated structures guided to inferior position to avoid compromising the airway. This suggests that stability and patency of the pharyngeal airway are primary factors in hyoid positioning.

Cephalometrics was introduced to orthodontics by (Broadbent BH, 1931) as a complement to craniofacial analysis and got wider acceptance in the last twenty years.

In this study, lateral cephalometric measurements successfully assessed the relationship between different skeletal patterns and the hyoid bone and allowed to correlate the hyoid bone position to other craniofacial parameters. The present study was undertaken to evaluate the changes in the position of the hyoid bone which might induce changes in the position of

certain dentofacial structures and it could be instrumental in the establishment of specific structural elements of the jaws and occlusion of teeth which is of great interest to the orthodontists.

Materials and methods

Sixty five lateral cephalograms were randomly selected from a pool of radiographs for Lebanese patients admitted to the orthodontic clinic in the Faculty of Dentistry, Beirut Arab University. The age of participants ranged between 12-17 years with average of 14 years. The tracings of these cephalograms were divided into three sagittal skeletal facial patterns, Class I as a control group, Class II and Class III according to the atlas authored by (Saleh. F, 1996).

Criteria of selection:
1. The subjects should be of Lebanese origin.
2. The subjects should be healthy, with no systemic diseases, congenital abnormalities or traumas.
3. No history of previous orthodontic treatment.
4. Breathing comfortably through the nose.
5. Not to have any wound, burn and scar tissues in the neck region that can affect their craniofacial growth.
6. Normal vertical occlusal relationship.
7. Class II malocclusion with mandibular retrognathism.
8. Class III malocclusion with mandibular prognathism.

All lateral cephalograms were taken by experienced clinician in a standard natural head position as recommended by (Broadbent et al. 1975) and manually traced with the follows selected anatomical landmarks from which planes, lines and angles were drawn.

- The cephalometric points (Figure.1):

S (sella turcica): the centre of the bony crypt occupied by the hypophysis cerebri.

N (nasion): the anterior limit of the frontonasal suture.

P (porion): the midpoint on the upper edge of the ear rod in the external meatus.

Or (orbitale): the lower most part of the bony crypt.

A (subspinale): the deepest midline point on the premaxilla between the anterior nasal spine and prosthion.

B (supramentale): the most posterior point in the concavity between the infradentale and pogonion.

Go (gonion): the midpoint of the contour connecting the ramus and body of the mandible.

Gn (gnathion): the most anterior and inferior point on the symphysis of mandible.

RGn (retrognathion): the most posterior and inferior point on the mandibular symphysis.

Me (menton): the most inferior point on the symphysis of mandible.

H (hyoidale): the most anterior superior point on the body of the hyoid bone.

C3: the point at the most inferior and anterior position on the third cervical vertebrae.

- The cephalometric lines and planes (Figure 2):

SN: Sella-Nasion plane, the line connecting S and N.

FH: Frankfort horizontal plane, the line connecting P and Or.

Mandibular plane: a line connecting points Go and Gn.

- The cephalometric angular measurements (Figure.3):

SNA: the angle from sella to nasion to point A.

SNB: the angle from sella to nasion to point B.

ANB: the angle joining point A to nasion (N) to point B, SNA-SNB difference.

NSH : the angle from nasion to sella to hyoidale.

MPH : the angle from gonion to gnathion to hyoidale.

- Cephalometric linear measurements (Figure.4):

H-SN perpendicular: linear distance along a perpendicular from H to the S-N plane.

H-FH perpendicular: linear distance along a perpendicular from H to the Frankfort plane.

H-MP perpendicular : linear distance along a perpendicular from H to the mandibular plane (Go-Gn).

H-H': linear distance between H and a perpendicular to the C3- RGn line.

H-C3: linear distance between H and C3.

H-RGn: linear distance between H and RGn.

C3-Rgn: linear distance between C3 and RGn.

H-N perpendicular: linear distance along a perpendicular from H to N perpendicular on Frankfort plane.

Jarabak ratio: the ratio between the posterior facial height (S- Go) to the anterior facial height (N- Me).

Measurement errors

In order to evaluate the reliability of the cephalometric measures, the tracings performed twice by a single researcher at 1-week interval under the same conditions of investigation. The average of the values found in the two tracings used for assessment. Ten days after the tracing ten lateral radiographs randomly chosen for examining the error made between the two periods of tracing.

Results

This study was conducted to evaluate the position of the hyoid bone in different facial patterns: class I, class II and class III. Sixty lateral cephalograms randomly selected from pool of radiographs for patients with median age of 14 years. Ten cephalograms were selected after 10 days and analyzed again to check the reliability of the angular and linear measurements were measured before.

The data reliability, (Figures 5-a to 5-n) showed the Bland- Altman plots for reliability of different measurements. All figures showed that negligible error was included between the upper and lower confidence limits denoting that there were no differences between measurements on the first and the second times indicating reliability of measurements according to (Dewitte K et al, 2002) .

The comparison of angular measurements among the three study groups as in Table 1 and Figure 6 showed statistically significant differences existed among the three groups in measurement of SNB, ANB and NSH (P<0.0001, <0.0001 and 0.03 respectively). In these three cases, measurements of Class I were intermediate between measurements of Class II and Class III.

The paired comparison between study groups as regards SNB, ANB and NSH as in Table 2 revealed Statistically significant differences were observed between all pairs (Class I and Class II, Class I and Class III and Class II and Class III) as regards values of SNB and ANB (P< 0.0001 in all cases). Significant Differences were observed only between Classes II and III (P= 0.03) but not between Classes I and each of Classes II and III (P= 0.53 and 0.25 respectively) regarding NSH.

The comparison among study groups as regards normal values of SNA, SNB and ANB as in Table 3 and Figure 7-9 showed significant differences existed among Classes I, II and III as regards the distribution of normal values of SNB and ANB (P<0.0001 for both). As regards SNB, only normal values were observed in Class I while most cases in Class II were with normal values (80%) compared to Class III where 80% of cases had values above normal. As regards values of ANB, most cases in Class I were normal (92%), compared to Class II where all cases were with values above normal (100%) and Class III where most cases were with values below normal (75%).

The comparison of linear measurements among the three study groups showed statistically significant differences among Classes I, II and III as regards H-SN perp, H-FH perp, H –C3, H- RGn and C3-Rgn (P= 0.02, 0.05, 0.01, 0.03 and 0.04 respectively) as shown in Table 4 and Figure 10.

Table 5 showed the paired comparison between study groups as regards H-SN perp, H-FH perp, H –C3, H- RGn and C3-Rgn. In all these

linear measurements, statistically significant different existed between classes I and III (P= 0.03, 0.05, 0.03, 0.03 and 0.01 respectively). On the other hand, differences between classes I and II were not statistically significant (P=0.92, 0.71, 0.99, 0.58 and 0.81 respectively). The only significant difference between classes II and III was observed in the measurement of H –C3.

The comparison among study groups as regards normal values of Jarabak ratio. In Classes I, II and III, all cases had normal values as shown in Table 6.

Discussion

In the present study, the results revealed that a significant difference existed among the control group (Class I) and the study groups (Class II and Class III) in both sagittal and vertical planes.

The analyzed data showed a significant difference in the angular measurement of the hyoid bone in relation to the anterior cranial base (S-N plane) in the sagittal plane. The hyoid bone moved backward in Class II malocclusion cases (91.21± 4.86) and moved forward in Class III cases (87.65± 3.38), as compared to the Class I control group (89.78±4.18). This was in agreement with (Battagel et al, 1999) and (Kuroda et al, 1966) who documented a more posterior position of the hyoid bone in Class II skeletal malocclusion subjects. This result was also consistent with (Adamidis and Spyropoulos, 1992) who reported a significant difference in the position of the hyoid bone between Class I and Class III malocclusions as the hyoid bone laid more anteriorly in Class III than in Class I. This finding could be attributed to the muscular attachment to the hyoid bone and the mandible, so it is moving backward and forward following the mandibular movement in the sagittal plane.

Additionally, the analyzed linear measurements showed significant differences among the control and study groups in the following parameters: H-SN perpendicular, H-FH perpendicular, H –C3, H-RGn, and C3-RGn.

 The hyoid bone position was lower in Class III malocclusion than in Class I and Class II malocclusions in relation to the anterior cranial base (S-N plane) and the Frankfort plane (P-Or plane) in the vertical plane. This could be justified that the hyoid bone did not follow completely the mandibular movements. Thus it appears that, as the mandible is moved posteriorly in relation to the other craniofacial structures, the tongue and the hyoid bone do not follow this movement in a similar manner. Otherwise it would encroach upon the vital oropharyngeal and laryngeal spaces. As a functional compensation, the hyoid bone and related structures are guided to an inferior position to avoid compromising the airway space. This suggests that stability and patency of the pharyngeal airway are primary factors in the

hyoid bone positioning. This is in consistency with the results of (Tourne, 1991), (Battagel et al, 1999).

A large distance alteration was noticed between the hyoid bone and the third cervical vertebra in Class III cases than in Class I and Class II cases. The results revealed that the distance between the hyoid bone and the third cervical vertebra in Class III (38.88±5.36) respectively, was larger than the distances in Class I (35.20±4.31) and Class II (35.03±3.48).This was in agreement with (Ceylan and Oktay, 1995) who related the distance among the hyoid bone and the cervical vertebra to be reversely affected by ANB angle changes. The result was similar to the study conducted by (Michael and Donald, 1999) who reported a positive correlation of the distance between the hyoid bone and the third cervical vertebra as well with (Abu Al Haija and Al Khateeb, 2005) who concluded that as ANB angle increased, the hyoid bone moved more posterior. The explanation of thus phenomenon could be that the genioglossus muscle as the main protruder of the tongue will generate upper airway dilating forces to maintain upper airway patency and as the hyoid bone moved forward would pull the tongue anteriorly en mass, leading to increase in tongue pressure and maintaining the pharyngeal space at the level of the base of the tongue. This revealed that the hyoid bone might be regarded as representative of the postural behavior of the tongue. In contrast to other studies using lateral cephalometry, (Maria et al, 2006) reported a constant relation between the hyoid bone and the third cervical vertebra in a study conducted to establish normal values for the position of the hyoid bone in a Brazilian group as well (Bibby & Preston, 1981), (Bibby, 1984) and (Kolias and Krogstad, 1999).

The analyzed linear measurements in relation to the anterior cranial base in the anteroposterior direction (H-N perpendicular) showed statistically insignificant among the study groups and the control group. This was in disagreement with a study conducted by (Adamidis and Spyropoulos, 1992) who reported that the distance between the hyoid bone and the nasion was smaller in Class III patients.

In relation of the hyoid bone with the mandible, the results showed statistically significant data in the sagittal plane only by measuring the distance from the hyoid bone to the retrognathion. It was smaller in Class I patients (36.58± 6.05) and larger in Class III group (42.03± 5.75) so the hyoid bone moved backward as the mandible moved forward. This was in agreement with (Maria et al, 2006) who found a statistical significant result regarding H-RGn with P value < 0.05, however a disagreement was noticed with (Ferraz et al, 2007) who concluded in their study with a static hyoidal bone position in relation to the mandible and as concluded that the hyoid bone position did not depend on the type of the respiratory pattern.

The angular and linear measurements however showed no significant difference in relation of the hyoid bone to the mandible in the vertical plane. The measured angle (MPH) with P value = 0.95 and the measured distance H-MP Perpendicular with P value = 0.53 indicated a stable hyoid bone position in the vertical plane in the three different skeletal facial profiles in relation to the mandible. This can be explained by the statistical insignificant Jarabak ratio (P value = 0.36) as all the studied cephalograms in this study were chosen to have a normal vertical dimension lied within the normal ratio of the Lebanese population studied by (Saleh F, 1996), so we can measure the sagittal effect of the mandibular growth on the hyoid bone position in the anteroposterior and vertical planes. In my opinion as an explanation of this, the position of the hyoid bone is more determined by the musculature rather than the mandibular position.

The present study revealed that the relationship among ANB angle and the hyoid bone position was reversely correlated in healthy patients with normal Jarabak facial ratio, which is in disagreement with different comparative studies (Abu Al Haija et al, 2002) and (Arslan et al, 2007) conducted on subjects with conginetal diseases as (B- thalassaemia and hypohidrotic ectodermal dysplasia) and varied Jarabak facial ratio who documented that as ANB angle increased the hyoidal bone position situated more anterior and correct vice versa.

Conclusion
In the light of above, the following conclusions were drawn:
- In the sagittal plane:
1. There was a significant difference in the angular measurement of the hyoid bone in relation to the anterior cranial base (S-N plane) where the hyoid bone moved backward in Class II malocclusion cases and foreword in Class III cases.
2. The linear measurements in relation to the anterior cranial base in the anteroposterior direction (H-N perpendicular) showed statistically insignificance among the study groups and the control group.
3. The sagittal position of the hyoid bone in relation to the mandible, the results showed statistically significant difference in the sagittal plane only by measuring the distance from the hyoid bone to the retrognathion. The distance was shorter in Class I patients and longer in Class III group so the hyoid bone moved backward as the mandible moved forward.
4. A large distance alteration was noticed between the hyoid bone and the third cervical vertebra in Class III cases than in Class I and Class II cases.
- In the vertical plane:

5. The analyzed linear measurements showed a significant difference among the control and study groups where the hyoid bone position was lower in Class III malocclusion cases than in Class I and Class II malocclusions in relation to the anterior cranial base (S-N plane) and the Frankfort plane (P-Or plane).

6. The angular and linear measurements showed no statistically significant difference results in relation of the hyoid bone to the mandible in the vertical plane.

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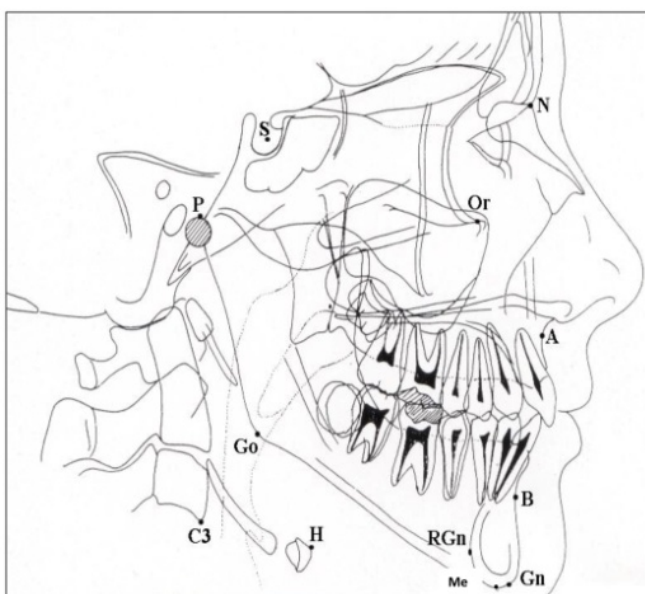
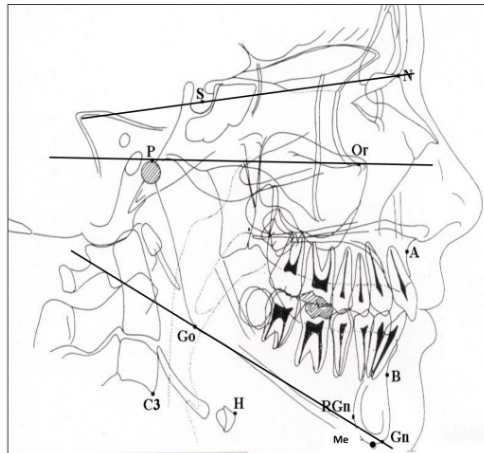Fig.1- The cephalometric reference points used in the study.

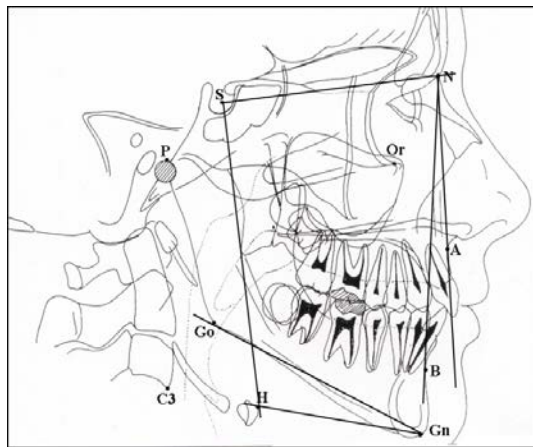Fig.2- The cephalometric lines and planes used in the study.

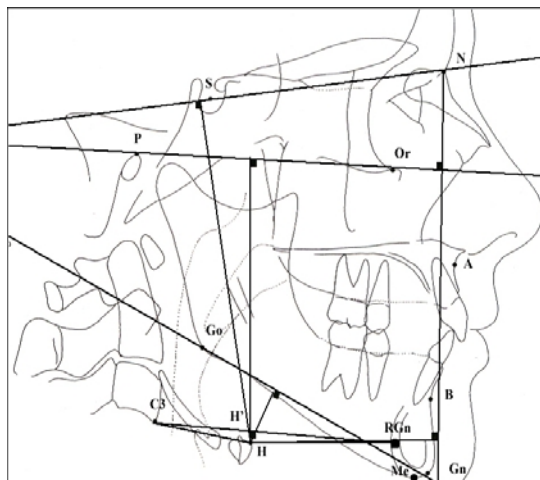Fig.3- The angular measurements used in the study.

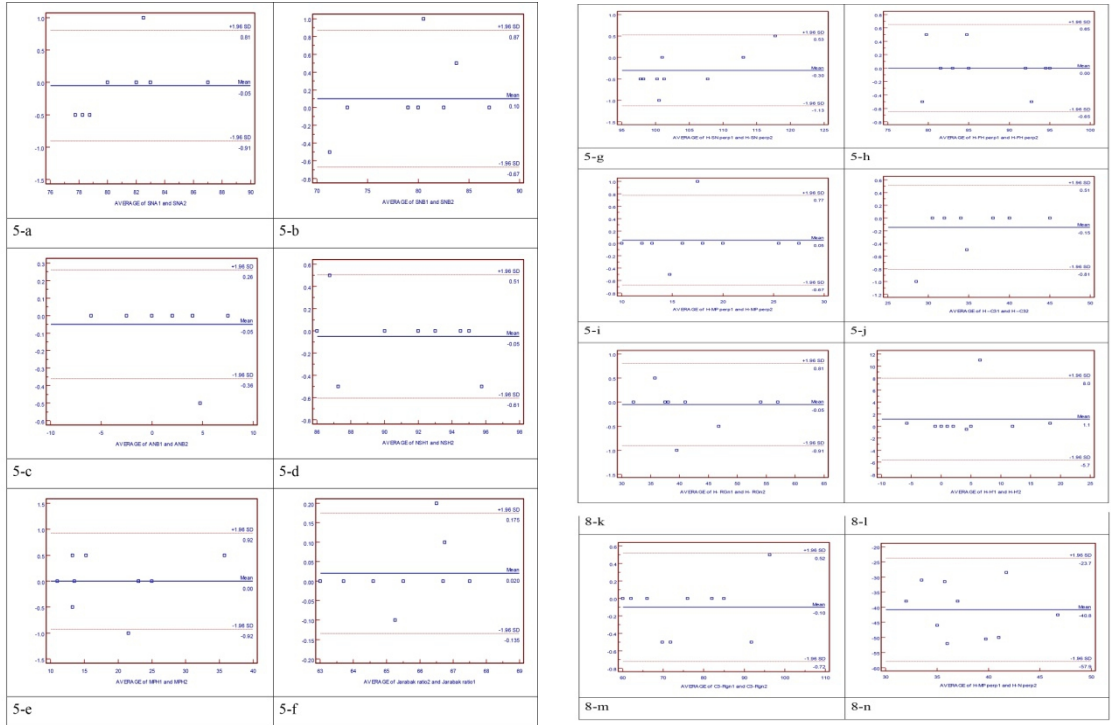
Fig.4-Cephalometric linear measurements used in the study.

Fig. 5- Bland Altman plots for reliability of measurements.

	Class I Mean ± SD	Class II Mean ± SD	Class III Mean ± SD	ANOVA P value
SNA	81.72 ± 1.54	82.54 ± 1.41	82.13 ± 2.73	0.98 0.38 NS
SNB	79.04 ±1.51	75.75 ± 1.51	83.32 ± 1.32	136.17<0.0001*
ANB	2.68 ± 0.69	6.82 ± 0.81	-1.20 ± 2.36	153.25<0.0001*
NSH	89.78 ± 4.18	91.21 ± 4.86	87.65 ± 3.38	3.670.03*
MPH	18.40 ± 6.35	19.10 ± 9.91	18.88 ± 5.88	0.050.95 NS

Tab. 1- Comparison of angular measurements among the three study groups.
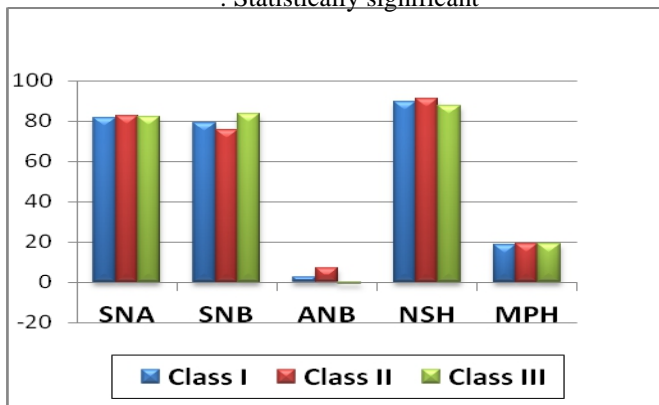NS: Not statistically significant
*: Statistically significant

Figure 6: Comparison of angular measurements among the three study groups.

Group	Compared to group	SNB	ANB	NSH
Class I	Class II	<0.0001*	<0.0001*	0.53 NS
	Class III	<0.0001*	<0.0001*	0.25 NS
Class II	Class III	<0.0001*	<0.0001*	0.03*

Tab. 2- Paired comparison between study groups as regards SNB, ANB and NSH.

NS: Not statistically significant

*: Statistically significant

Angles	Ranges	Class I N (%)	Class II N (%)	Class III N (%)	Kruskal Wallis test P value
SNA	Below normal	1 (4)	1 (5)	2 (10)	0.220.90 NS
	Normal	24 (96)	18 (90)	16 (80)	
	Above normal	0	1 (5)	2 (10)	
SNB	Below normal	0	4 (20)	0	43.03<0.0001*
	Normal	25 (100)	16 (80)	4 (20)	
	Above normal	0	0	16 (80)	
ANB	Below normal	0	0	15 (75)	54.72<0.0001*
	Normal	23 (92)	0	5 (25)	
	Above normal	2 (8)	20 (100)	0	
Total		25 (100)	20 (100)	20 (100)	

Tab.3- Comparison among study groups as regards normal values of SNA, SNB and ANB.

NS: Not statistically significant
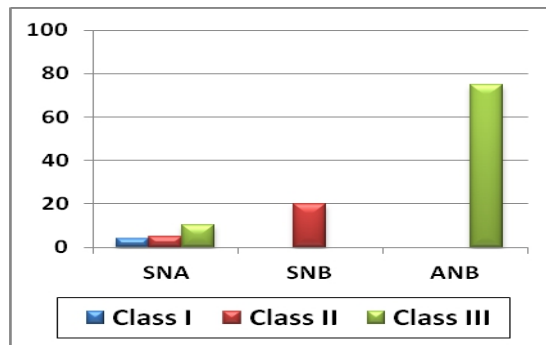
*: Statistically significant

Fig.7- Comparison among study groups as regards below normal values of SNA, SNB and ANB.
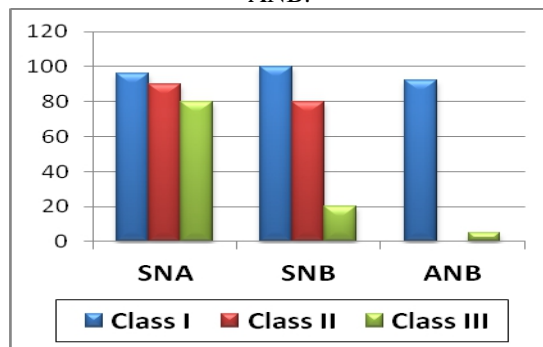

Fig. 8- Comparison among study groups as regards normal values of SNA, SNB and ANB.
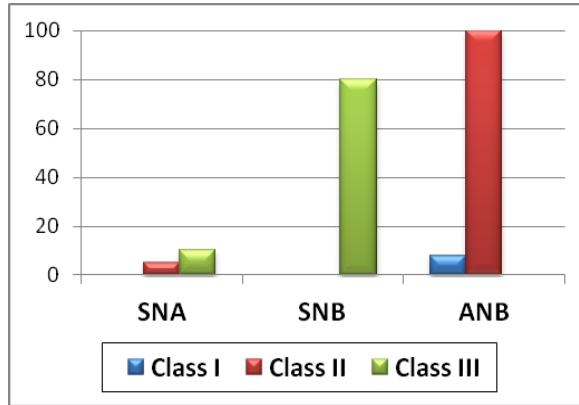
Figure 9: Comparison among study groups as regards above normal values of SNA, SNB and ANB.

	Class I Mean ± SD	Class II Mean ± SD	Class III Mean ± SD	ANOVA P value
Jarabak ratio	65.12 ± 1.28	64.98 ± 1.65	64.50 ± 1.48	1.040.36 NS
H-SN perp	104.44 ± 7.02	105.53 ± 9.66	111.55 ± 10.08	3.940.02*
H-FH perp	84.14 ± 7.14	86.18 ± 8.48	90.23 ± 8.79	3.190.05*
H-MP perp¶	15.42 ± 5.26	18.08 ± 11.00	17.48 ± 4.25	1.280.53 NS
H –C3	35.20 ± 4.31	35.03 ± 3.48	38.88 ± 5.36	4.960.01*
H- RGn	36.58 ± 6.05	38.63 ± 7.69	42.03 ± 5.75	3.900.03*
H-H'	6.00 ± 6.10	6.70 ± 6.56	7.10 ± 5.98	0.180.84 NS
C3-Rgn¶	69.66 ± 7.62	71.25 ± 9.26	76.05 ± 12.77	6.390.04*
H-N perp	53.26 ± 7.59	55.68 ± 9.25	55.15 ± 5.34	0.650.53 NS

Tab.4- Comparison of linear measurements among the three study groups.

NS: Not statistically significant

*: Statistically significant

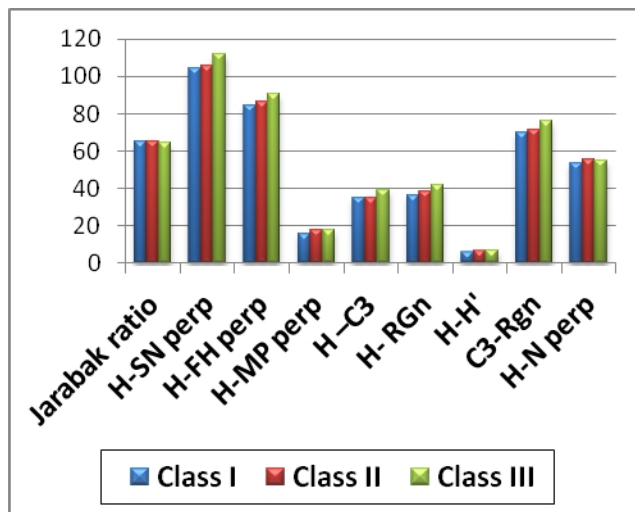¶: Kruskal Wallis test used instead of ANOVA

Fig.10- Comparison of linear measurements among the three study groups.

Group	Compared to group	H-SN perp	H-FH perp	H –C3	H-RGn	C3-Rgn
Class I	Class II	0.92NS	0.71NS	0.99NS	0.58NS	0.81NS
	Class III	0.03*	0.05*	0.03*	0.03*	0.01*
Class II	Class III	0.11NS	0.29NS	0.03*	0.26NS	0.07NS

Tab. 5- Paired comparison between study groups as regards H-SN perp, H-FH perp, H –C3,
H- RGn and C3-Rgn.

NS: Not statistically significant

*: Statistically significant

Jarabak ratio ranges	Class I	Class II	Class III
Below normal	0	0	0
Normal	25 (100)	20 (100)	20 (100)
Above normal	0	0	0
Kruskal Wallis test P value	-		

Tab.6- Comparison among study groups as regards normal values of Jarabak ratio.