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RESEARCH ARTICLE

THE EVALUATION OF HYOID BONE IN DIFFERENT SKELETAL MALOCCLUSIONS AND GROWTH PATTERNS IN INDIAN POPULATION.

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Abstract

Objective: The aim of the study was to investigate the relationship of the different skeletal malocclusions as well as various growth patterns to the position and orientation of the hyoid bone.
Materials and methods: A total of 60 pretreatment digital lateral cephalograms were selected according to the criteria and grouped into 3 groups, group 1: Class I (n=20), group 2: Class II (n=20) and group 3: Class III(n=20). The original 60 lateral cephalograms were also grouped under three different growth patterns into hyperdivergent (n=17), hypodivergent (n=24) and neutral (n=19) which were given according to Jarabak. Lateral cephalograms were traced and analysed on different linear and angular parameters such as H-NSL, H-FH, H-NL, H-Pog, H-Me, H-C3, NSH and MPH. The arithmetic mean and standard deviation values were calculated for each measurement. Independent sample *t*- test was performed to compare the difference between the skeletal classes as well as with the growth patterns.
Result: The linear measurements of H-FH, H-NL, H-Pog, H-Me, H-C3 showed statistically significant differences in Class I, Class II, and Class III (p-vaule=0.03, 0.01, 0.0, 0.0 and 0.009 respectively). The angular measurements of SNA, SNB, ANB, SNH were also statistically significant (p-value=0.006, 0.0, 0.0 and 0.030 respectively) indicating the differences in respective class malocclusions. However, in the study that was grouped according to different growth patterns, viz. hyperdivergent(Hp), hypodivergent(Ho), and neutral (Nt) did show statically significant differences. (p-value<0.05).
Conclusion: The hyoid bone position and orientation is different in different skeletal malocclusions. In class III malocclusion, the hyoid bone is more anteriorly and inferiorly placed. In class II malocclusion, the hyoid bone position is more posterior and more superior. The anteroposterior dimensions in different class malocclusions remained constant. No relationship could be found between different facial morphologies (growth patterns) and hyoid bone position as well as orientation.

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Introduction:-

Modern orthodontics takes into account of balance between dentofacial complex as a whole and the position of hyoid bone in relation to different malocclusion has intrigued and attracted many researchers. The attachment of muscles of tongues such as genioglossus and hyoglossus can be found on the hyoid bone and the position of the tongue apparently changes with the bone of its attachment. Such changes in position of tongue can affect the pharyngeal airway space and this is evident in orthognathic surgeries. Various authors[1,2] have proved that the mandibular changes influence hyoid bone position during the entire postsurgical period, whereas stretching of suprahyoidal musculature seems to contribute to skeletal relapse.

The hyoid bone is unique in that it has no bony articulation with any other bone but is instead suspended in the soft tissue via ligaments and muscles [3]. Different muscles such as infra and suprahyoid muscles and genioglossus muscle influence the position of the hyoid bone[4,5]. According to Brodie[6] the upright posture of the head involves the balance between the tensions of posterior neck muscles and anterior muscles such as masticatory, suprahyoid and infrahyoid groups in relative to occipital condyles. Hyoid bone position is, thus, a reflection of the relative tensions of the muscles, ligaments, and fascia attached to it. [7]

Being aware of the position of hyoid in different malocclusion and factors affecting its position can result in better orthodontic treatment without relapse and possible deficient pharyngeal airway space after orthodontic treatment as well as orthognathic surgery.

Various authors[8,9,10] have attempted to study the hyoid bone in different malocclusions in different population. Nevertheless, the correlation between hypodivergent, hyperdivergent and neutral groups and the hyoid bone orientation as well as position as a separate entity has never studied before.

Despite of the previous study conducted there are controversies on position and orientation of hyoid bone in relation to anatomical landmarks. The purpose of the present study is to evaluate the position and orientation of the hyoid bone in skeletal Class I, Class II and Class III malocclusion. This study also aims to examine the correlation of Jarabak ratio and the different growth patterns namely Hypodivergent, Hyperdivergent and Neutral growth patterns with the orientation and position of the hyoid bone.

Materials and methods:-

60 Pretreatment digital lateral cephalograms were selected on the criteria as mentioned below. All cephalograms were of the same dimension, magnification and printed from the same machine.
Criteria for selection of the Cephalograms are as follows:

1) Subject should be of Indian Origin.
2) Subject should be healthy with no systemic diseases, signs of trauma or a congenital disease.
3) Subject should show no sign of previous orthodontic treatment.
4) Subject should be between the age group of 16years to 30years.
5) All Class I malocclusion patients had an ANB value between 1° to 4°.
6) All Class II malocclusion patients had an amplitude of ANB value more 4°.
7) All Class III malocclusion patients had an amplitude of ANB value less than 1°.

Cephalograms were categorised into 3 major groups Group 1: Class I malocclusion, Group 2: Class II malocclusion, Group 3: Class III malocclusion. The original 60 cephalograms were also divided into 3 other groups namely Hyperdivergent (Hp), Neutral (Nt) and Hypodivergent (Ho). The criteria for the Jarabak's ratio was Hyperdivergent: 54-58%, Neutral: 59-63% and Hyperdivergent 64-80%.[8] The number of Neutral growth patterns was 19, the number of Hyperdivergent growth patterns was 17 and the number of Hypodivergent growth patterns was 24. All Lateral cephalograms were taken by skilled and experienced technicians in a standard natural head position as recommended by Broadbent [11]. The cephalograms were manually traced by a single researcher with the help of a 0.5mm thick lead pencil and a millimetre scale for the planes on Orthodontic tracing paper. For the linear measurements a millimetre precision digital vernier calliper was used for the registration of the reading, for the angular measurements a geometric protractor was used with a half degree approximation. They were again evaluated by a second researcher and the arithmetical mean of these readings were taken as the standard value for statistical evaluation and assessment. Beside routine anatomical designs the Cephalometric points and planes traced are given in table 1 and diagrammatically shown in figure 1. The Cephalometric linear and angular measurements required are given in table 2.

Table 1:- Cephalometric landmarks and planes.

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 point on the inferior rim of the orbit.
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.
Me (menton)	the most inferior point on the symphysis of mandible.
H (hyoidale)	the most superior, anterior point on the body of the hyoid bone.
C3	the point at the most inferior and anterior position on the third cervical vertebrae.
Hy' (Hy'point)	The most posterior point of the greater horn of the hyoid bone.
ANS (anterior nasal spine)	Spina nasalis anterior
PNS (posterior nasal spine)	Spina nasalis posterior
SN (Sella-Nasion plane)	the line connecting points S and N.
FH (Frankfort horizontal plane)	the line connecting points P and Or.
MP (Mandibular plane)	the line connecting points Go and Gn
NL (Nasal line)	the line connecting through the points PNS and ANS.[7]
Hyoid axis (H axis)	The line that connects points H and Hy'

Table 2:- cephalometric angular and linear measurements.

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.
SNA:	the angle from sella to nasion to point A.
SNB	the angle from sella to nasion to point B.
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-NL perpendicular	linear distance along a perpendicular from H to the palatal plane/nasal line.
H-MP perpendicular	linear distance along a perpendicular from H to the mandibular plane (Go-Gn).
H-C3	linear distance between H and C3.
H-Me	linear distance between the hyoidale and mention.
H-Go	linear distance between the hyoidale and the gonion.
Jarabak ratio	the ratio between the posterior facial height (S- Go) to the anterior facial height (N- Me). (Given in percentage)

Statistical methods:-

The data was statistically analysed with NCSS 11 Software (NCSSST, Kaysville, Utah, USA). Data was subjected to descriptive analysis for mean and standard deviation of all variables and ranges. Multiple *t*-test (independent sample *t*-test) was used for analysis of variance and a post hoc test (Bonferroni) was used for multiple comparisons. $P<0.05$ was considered as the level for statistically significant data.

Results:-

The linear and angular measurements of the study have been tabulated in Table 3. The linear measurements of H-FH, H-NL, H-Pog, H-Me, H-C3 showed statistically significant differences in Class I, Class II and Class III (p-vaule = 0.03, 0.01, 0.0, 0.0 and 0.009 respectively). The angular measurements of SNA, SNB, ANB, SNH were statistically significant with p-value 0.006, 0.0, 0.0 and 0.030 respectively indicating the differences in respective skeletal malocclusions. P-values have been paired for comparing the measurements in different classes and have been shown in Table 3(i). These findings show that hyoid bone is more inferiorly placed in Class III malocclusion compared to Class II which is more superiorly placed. The position of hyoid in relation to mandible using H-Pog, H-Me, H-C3 as the parameters has shown that mandible is more anteriorly placed in Class III malocclusion; and it is more posteriorly placed in Class II.The angular measurements of SNH, MPH shows that hyoid bone is anteriorly and inferiorly placed in Class III malocclusion and is more posteriorly and superiorly placed in Class II malocclusions. Linear measurement from cervical vertebra to the symphysis was least in Class III and the most in Class I, indicating vertical growth of mandible in class III which approximate the level of the cervical vertebra. The anterior-posterior position of the hyoid bone in relation to the cervical vertebra (C3-H) again confirmed the previous reading that the patient with the class III malocclusion has more anteriorly placed hyoid bone. Class II, however, showed most close position with the cervical vertebra indicating its most posterior position among the classes.
However, in the study that was grouped according to different growth patterns or facial morphologies, viz. hyperdivergent(Hp), hypodivergent(Ho), and neutral (Nt), p-values were more than 0.05(p-value<0.05) as given in Table 4 and 4(i). Hence showing no statistically significant difference in any of the different growth patterns.

Discussion:

The statistically different values of the linear and angular measurements (eg. H-FH, H-NL, H-Pog, SNH, MPH) findings show that hyoid bone is more inferiorly placed in Class III malocclusion compared to Class II which is more superiorly placed. Similar observations were given by Mohammed Amayeri et al[13], also by Carlos Aranha et al [14]. Some authors [15-20] just used linear measurements and did not use angular integrations and hence the orientation of the hyoid couldn't be visualised in the 3rd dimension. While Ingervall [21] only used the mandible as a reference for the comparison which is not a stable landmark which was further changed by Bibby [7] in the introduction of the hyoid triangle. However previous studies have shown the controversies about different position of hyoid bone in skeletal's class malocclusions.

Some authors [22, 23, 24] reported the significant difference in position of hyoid bone depending upon the malocclusions. Adamidis et al[22],studied the cephalometric radiographs of two groups of exhibiting Class I and Class III malocclusions. He found that hyoid bone tends to be more anteriorly placed in the group exhibiting Class III malocclusions. Opdebeeck et al[23] analysed and compared linear and angular measurements for short face and long face syndrome and concluded that the characteristics of the long face and short face syndrome group can be explained by movement of hyoid bone in concert with the movement of mandible, tongue, cervical spine in both groups. According to them, the changes in mandibular position are related to hyoid bone changes and the hyoid position adapts to anterior-posterior changes in head posture[25, 22, 23]. On the other hands, some authors[18, 26, 27] had advocated there are no significant differences among different class malocclusions.

Galvao[14] was the first one to use the SN line which represented the anterior base of the skull because of its routinary use in the cephalometric tracing and effortless localization and stability of the involved structures. In previous discussion, the hyoid bone was said to play an important role in the physiology of the swallowing. The swallowing reflex repeats interleaf approximately twice a minute while one is asleep hence the role of the the hyoid bone is an important one.[28]
Graber[29] on the other hand found the correlation between the position of the hyoid bone and and the mandibular morphology and hence found an affirmative explanation between the positive correlation. Stepovich[20] also said that the hyoid bone assumes variable position from a person to another and the difference in it may also occur in a same

sample of the patients after a short space of time. The measurement between the hyoid bone and some cranial points relatively distant from the hyoid or the plane may cause a large variation even with slightest of the variation even thou the difference are just apparent ones. That is why the relation between the mandibular symphysis and the 3rd cervical vertebrae was considered into the relation by Bibby and Preston[7]. These slight variations hence did not cause a large variation in the samples. But in my relation the use of mobile structures will always cause a variation in the reading and hence the ideal head rest position and the use of non mobile skeletal tissue is a good factor to compare with. Eg. naso-maxiallry process.

The lower hyoid position in Class III malocclusion in relation to the anterior cranial base (SN plane) and the Frankfort plane (FH plane) could justify that the hyoid bone did not follow the mandibular movements completely. Thus it appears that, as the mandible is moved posteriorly in relation to the other cranofacial 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 the stability and potency of the pharyngeal airway are primary factors in the hyoid bone position. This is consistent with the results of Tourne[20] and Battagel et al [31].

Large distance between the hyoid bone and the cervical vertebrae(C3) in Class III subjects were similar to the study conducted by Michael and Donald[32] and also Alhaija and Al Khateeb[33] that showed that the hyoid bone moves more posteriorly with the increase in ANB angle. The explanation of this phenomenon lies with the genioglossus muscle that protrudes the tongue and generates upper airway dilating forces to maintain the 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 spaces at the level of the base of the tongue. Hence the hyoid bone is represented as the postural behaviour of the tongue. Thou the relation in the vertical plane showed no significance of the mandible with the hyoid bone (MPH).

The present study revealed that the relationship among the ANB angle and the hyoid bone position was reversely correlated in healthy patients which was a disagreement with different studies like Abu Alhaija et al [33] and Arslan et al [12]. It also showed no significant statistical difference between different facial morphologies or growth patterns and the position of the hyoid bone and hence proving wrong in the basis of Jarabak's ratio which is one of the oldest and commonest used ratios for growth patterns and facial morphologies. The position of the Hyoid bone in class III patients is more anteriorly and inferiorly placed due to the prognathic mandible. According to the functional matrix theory the supra hyoid muscles that attach to the mandible and the tongue causes the hyoid bone to be more anteriorly placed and hence changes the position of the bone in relation to Class I patients. While in Class II the contracture of the supra hyoid muscles is lesser and the hence the hyoid is more posteriorly and superiorly placed. The role of the functional matrix theory can hence be described well with the correlation of the hyoid bone with the different skeletal malocclusion.

On the contrary due to the negative results of the position and orientation of the hyoid bone in various growth patterns the functional matrix theory can be contradicted on the same basis and stating that due to the rotation of the mandible the position of the hyoid bone and orientation to the mandible should change but this isn't so and hence gives a statistically non significant data and hence contradicts the theory otherwise.

If the hyoid bone is in the same position before and after orthodontic treatment, the soft tissue must still be in the same balance, thus possibly reducing the chance of relapse from the soft tissue forces. If the hyoid position is altered, a longer retention period than normal may be indicated. Any alteration in the hyoid position following mandibular surgery may be indicated for the balancing of the muscles forces to be made more favourable by myectomy or myotomy to reduce surgical relapse.

Conclusion:-

1. The hyoid bone position and orientation is different according to different skeletal malocclusions.
2. In class III malocclusion, the hyoid bone is more anteriorly and inferiorly placed.
3. In class II malocclusion, the hyoid bone position is more posterior and more superior.
4. The anteroposterior dimensions in different class malocclusions is constant
5. No relationship could be found between different facial morphologies and hyoid bone position and orientation.

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Table 3:- Hyoid data – mean & standard deviation.

		N		Mean	Std. Deviation
H-SN	Class I	20		89.40	± 7.694
	Class II	20		84.85	± 7.755
	Class III	20		90.20	± 7.150
	Total	60		88.15	± 7.781
H-FH	Class I	20		74.75	± 7.587
	Class II	20		68.00	± 7.553
	Class III	20		71.80	± 8.618
	Total	60		71.52	± 8.282
H-NL	Class I	20		54.75	± 8.873
	Class II	20		46.50	± 5.624
	Class III	20		51.60	± 4.235
	Total	60		50.95	± 7.285
H-Pog	Class I	20		51.25	± 7.840
	Class II	20		43.40	± 5.315
	Class III	20		40.50	± 4.007
	Total	60		45.05	± 7.418
H-Me	Class I	20		47.65	± 7.982
	Class II	20		39.35	± 4.859
	Class III	20		37.80	± 4.047
	Total	60		41.60	± 7.240
H-ML	Class I	20		11.40	± 3.803
	Class II	20		9.80	± 2.821
	Class III	20		10.90	± 1.334
	Total	60		10.70	± 2.872
H-C3	Class I	20		31.60	± 3.378
	Class II	20		29.35	± 2.498
	Class III	20		32.00	± 2.471
	Total	60		30.98	± 3.006
ANB	Class I	20		2.70	± 1.865
	Class II	20		6.10	± 1.334
	Class III	20		-4.25	± 2.863
	Total	60		1.52	± 4.725
SNA	Class I	20		79.60	± 3.440
	Class II	20		83.75	± 4.767
	Class III	20		80.50	± 3.954
	Total	60		81.28	± 4.404
SNB	Class I	20		76.90	± 3.493
	Class II	20		77.85	± 4.727
	Class III	20		84.80	± 4.851
	Total	60		79.85	± 5.596
SNH	Class I	20		50.50	± 3.692
	Class II	20		53.90	± 4.266
	Class III	20		60.10	± 4.436
	Total	60		54.83	± 5.714
MPH	Class I	20		15.25	± 5.250
	Class II	20		13.05	± 4.032
	Class III	20		14.60	± 3.050
	Total	60		14.30	± 4.240

Table 3(i):- p-values.

Dependent Variable	Pairs	p-value	Significance
H-NSL 0.061	Class I & II	0.145	NS
	Class I & III	0.940	NS
	Class II & III	0.072	NS
H-FH **0.033***	Class I & II	0.025	Significant
	Class I & III	0.472	NS
	Class II & III	0.292	NS
H-NL **0.001***	Class I & II	0.001	Significant
	Class I & III	0.288	NS
	Class II & III	0.043	Significant
H-POG **0.000***	Class I & II	0.000	Significant
	Class I & III	0.000	Significant
	Class II & III	0.278	NS
H-ME **0.000***	Class I & II	0.000	Significant
	Class I & III	0.000	Significant
	Class II & III	0.684	NS
H-ML 0.199	Class I & II	0.185	NS
	Class I & III	0.843	NS
	Class II & III	0.444	NS
H-C3 **0.009***	Class I & II	0.037	Significant
	Class I & III	0.895	NS
	Class II & III	0.012	Significant
ANB **0.000***	Class I & II	0.000	Significant
	Class I & III	0.000	Significant
	Class II & III	0.000	Significant
SNA **0.006***	Class I & II	0.006	Significant
	Class I & III	0.767	NS
	Class II & III	0.039	Significant
SNB **0.000***	Class I & II	0.774	NS
	Class I & III	0.000	Significant
	Class II & III	0.000	Significant
SNH **0.000***	Class I & II	0.032	Significant
	Class I & III	0.000	Significant
	Class II & III	0.000	Significant
MPH 0.245	Class I & II	0.232	NS
	Class I & III	0.877	NS
	Class II & III	0.479	NS

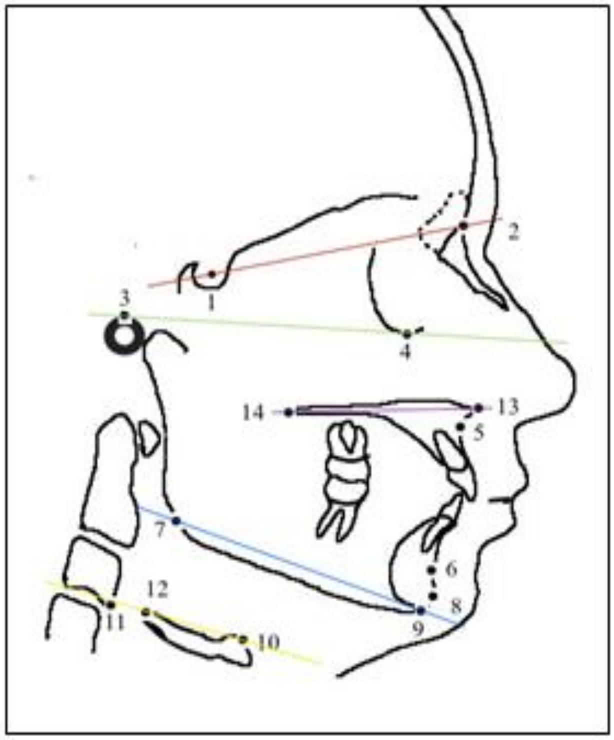

Fig 1:-Various cephalometric landmarks and planes thats are required for tracing of the cephalograms. 1: Sella Turcica (S), 2: Nasion (N), 3: Porion (P), 4: Orbitale (O), 5: Subspinale (point A), 6: Supramentale (point B), 7: Gonion (Go), 8: Gnathion (Gn), 9: Menton (Me), 10: Hyoidale (H), 11: C3, 12: Hy'(Hy'point), 13: Anterior Nasal Spine (ANS), 14: Posterior Nasal Spine (PNS).Red line: SN plane, Green line: FH plane, Purple line: Nasal Line, Blue line: Mandibular plane, Yellow Line: Hyoid Axis.

Graph 1: Mean Hyoid Parameters by Angle's malocclusion

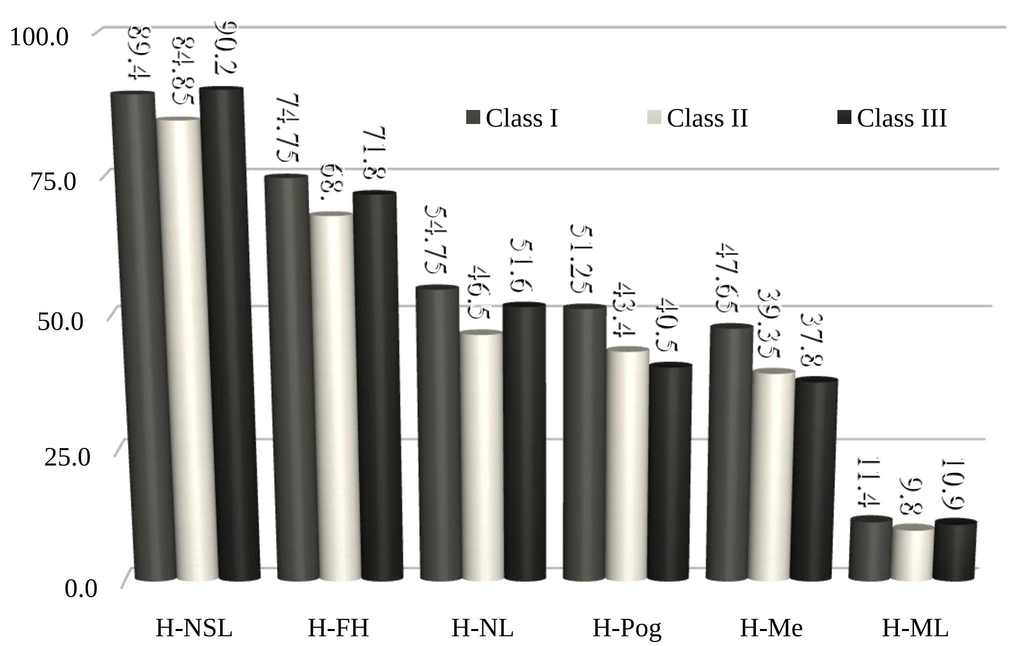

Table 4:- Growth Patterns - mean & standard deviation.

		N	Mean	Std. Deviation
H-NSL	Hypodivergent(Ho)	24	87.63	8.968
	Hyperdivergent(Hp)	16	92.56	5.876
	Neutral (Nt)	17	87.53	7.169
	Total	57	88.98	7.877
H-FH	Hypodivergent(Ho)	24	71.38	8.096
	Hyperdivergent(Hp)	16	73.75	7.878
	Neutral (Nt)	17	70.76	8.920
	Total	57	71.86	8.232
H-NL	Hypodivergent(Ho)	24	50.79	8.209
	Hyperdivergent(Hp)	16	52.75	6.777
	Neutral (Nt)	17	50.65	6.451
	Total	57	51.30	7.260
H-Pog	Hypodivergent(Ho)	24	44.33	9.102
	Hyperdivergent(Hp)	16	44.44	5.416
	Neutral (Nt)	17	45.29	7.218
	Total	57	44.65	7.546
H-Me	Hypodivergent(Ho)	24	41.17	8.991
	Hyperdivergent(Hp)	16	41.75	4.389
	Neutral (Nt)	17	41.76	7.049
	Total	57	41.51	7.256
H-ML	Hypodivergent(Ho)	24	10.29	3.420
	Hyperdivergent(Hp)	16	11.38	1.857
	Neutral (Nt)	17	10.59	2.526
	Total	57	10.68	2.785
H-C3	Hypodivergent(Ho)	24	31.04	3.884
	Hyperdivergent(Hp)	16	30.25	1.342
	Neutral (Nt)	17	30.71	1.160
	Total	57	30.72	2.678
SNH	Hypodivergent(Ho)	24	55.83	5.088
	Hyperdivergent(Hp)	16	55.19	6.002
	Neutral (Nt)	17	54.82	6.167
	Total	57	55.35	5.598
MPH	Hypodivergent(Ho)	24	13.88	3.768
	Hyperdivergent(Hp)	16	14.81	2.689
	Neutral (Nt)	17	14.88	5.743
	Total	57	14.44	4.175

Graph 2: Mean Hyoid Parameters by Facial morphologies

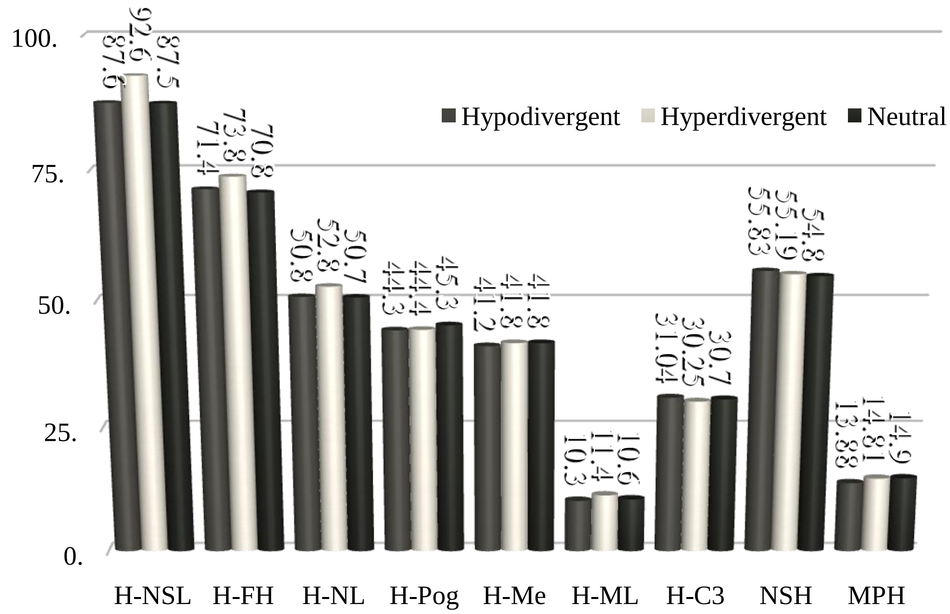

Table 4 (i):- p-values.

Dependent Variable	Pairs	p-value	Significance
H-NSL 0.099	Ho & Hp	0.124	NS
	Ho & Nt	0.999	NS
	Hp & Nt	0.154	NS
H-FH 0.550	Ho & Hp	0.650	NS
	Ho & Nt	0.971	NS
	Hp & Nt	0.559	NS
H-NL 0.648	Ho & Hp	0.688	NS
	Ho & Nt	0.998	NS
	Hp & Nt	0.690	NS
H-POG 0.917	Ho & Hp	0.999	NS
	Ho & Nt	0.918	NS
	Hp & Nt	0.945	NS
H-Me 0.956	Ho & Hp	0.968	NS
	Ho & Nt	0.965	NS
	Hp & Nt	1.000	NS
H-ML 0.485	Ho & Hp	0.459	NS
	Ho & Nt	0.940	NS
	Hp & Nt	0.700	NS
H-C3 0.665	Ho & Hp	0.639	NS
	Ho & Nt	0.919	NS
	Hp & Nt	0.879	NS
SNH 0.847	Ho & Hp	0.934	NS
	Ho & Nt	0.842	NS
	Hp & Nt	0.982	NS
MPH 0.692	Ho & Hp	0.772	NS
	Ho & Nt	0.733	NS
	Hp & Nt	0.999	NS