Quantitative Analysis of Body Posture and Its Correlation With Cervical Posture in Various Malocclusions

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Abstract

BACKGROUND: Considering that malocclusions can cause cervico-mandibular and cervico-cranial disorders, the aim of this study is to investigate whether there are significant differences in posture in subjects with skeletal class I, class II and skeletal class III malocclusion

METHODS: A clinical study conducted on 90 subjects with Angle`s class I, II, III skeletal malocclusion. Standardized Casts of the subjects were used to analyze the tooth characteristics. Lateral cephalograms were used to assess cervical posture through cervical skull Rocabado analysis. A customized force platform with pressure sensors were used for posture analysis.

RESULTS: There is a difference in body posture in subjects with skeletal class I, class II and class III malocclusion and a positive correlation between body posture and cervical posture is found in subjects with these classes of skeletal malocclusion. Subjects with class I malocclusion were found to have a normal cervical and body posture. Strain values from the force platform showed equal distribution of strain on both the feet. Subjects with class II malocclusion were found to have a forward cervical posture with the forward lean of body posture. Subjects with class III skeletal malocclusion were found to have a backward cervical posture with the posterior lean of body posture.

CONCLUSION: The results suggest that different classes of malocclusion present with an alteration in cervical and body posture. Correction of the malocclusion or an intervention plan for the prevailing malocclusion should be done as early as possible which can be used to correct the posture thereby restoring the equilibrium of the body.

Introduction

The stomatognathic system is an extremely complex system and is influenced and controlled by physiological as well as psychological factors. The disorders of the stomatognathic system are called as craniomandibular dysfunctions. [1] The head and the cervical part of the vertebral column form the functional biomechanical unit called as the cranial cervical mandibular system. This unit further consists of structures which include TMJ, Occipital Atlas Axis articulation and Hyoid bone with its suspensor system thus forming an inter relationship between the stomatognathic system and cervical posture.[2] Several structures like vertebrae, the mandible, and the skull along with their associated structures are involved in maintaining the central body balance.[3] Balance is the ability of the body to maintain the line along the centre of mass within the base of support with minimal postural sway.[4,5] Sway is the horizontal movement of the centre of gravity even when a person is standing still which can occur along any plane of motion. Proper balance with minimal sway defines the posture of the human body.

Posture refers to the position of the human body and its orientation in space.[1] A good posture is that with which the body is able to maintain the alignment of the body segments with a minimum expenditure of energy or minimum effort.[6] The body posture can be used as an indicator of efficacy, equilibrium and coordination because various interconnections between somatosensory system, the vestibular system and visual systems integrate into a complex regulatory system to maintain the body posture.[7,8]

It has been established that the stomatognathic system by way of muscle, ligaments, and nerves forms numerous connections with the cervical region and higher centres of the brain which also control postural stability. Several other aspects of the stomatognathic system have been found to have an association with body posture and dental or skeletal malocclusions are one among those. The posture of the head is maintained by the co-ordination between cranio-cervical bones, myo-facial structures and dental occlusion.[9] The upper cervical spine is the intermediary amid the head and trunk thereby forming an anatomical and functional interrelated system.[10] Neuroanatomical connections between the oral and cervical area have also been well recognized.[11] Hence, the functional and anatomical relationship between the masticatory system and posture control system gives the foundation for a possible association between postural disorders and malocclusions.

Solow and Tallgren in 1976 were among the first authors who reported associations between craniofacial morphology, head posture and cervical column [12] which was followed by Solow and Kreinborg in 1977 who proposed the soft tissue stretching hypothesis which showed a direct correlation between craniofacial structures and soft tissue activity influencing the cervical column and its orientation.[13] According to Rocabado et al, the proper coordination of 4 planes which include the vertical plane, the bi-pupilar line, the plane of the otic system, and the occlusal plane were necessary for the overall maintenance of harmony in the stomatognathic system.[14] Strong evidence was also given that TMD patients had a forward head posture revealing the interconnection between head posture and occlusal alterations.[15] Various studies followed later, provided evidence that head posture and occlusal alterations were interrelated. Logical questions then started arising that if occlusal alterations could alter head posture; compensations would arise in the vertebral column as well, which would alter the inclination and curvature of the entire spine and affect the overall body posture.

Innumerable number of controversies has been stated as to what could cause the body posture to modify itself. Mandibular position and size[16], state of mind[17], airway[16], muscular pattern and activity[18] are some of the factors which have been mentioned in previous studies. Looking into the broader aspect of what maybe the causative factor, the skeletal base is known to be very much influenced as well as influential when body posture is concerned. With regard to this background, the study was conducted with the objective to find the significant difference in body posture between subjects with skeletal class I, class II and Class III malocclusion and whether there is a positive correlation between body posture and cervical posture in these classes of malocclusion.

Materials And Methods

The clinical study was conducted on 126 subjects aged between 16 – 22 years who had reported to the dental office. Individuals with history of previous orthodontic, surgical or orthopaedic treatment; TMJ disorders, bruxism, nasal obstruction, orofacial and neurological pain, history of tooth extraction except 3rd molars, mutilated occlusion, spinal complications, syndromic conditions were excluded. Hence, 90 individuals were selected and divided into 3 groups as follows:

Group I – Skeletal Class I Malocclusion (ANB -2-4) – 31 individuals

Group II – Skeletal Class II Malocclusion (ANB >4) – 33 individuals

Group III – Skeletal Class III Malocclusion (ANB <2) – 26 individuals

Cast analysis, photographs, cervical posture analysis and body posture analysis were conducted for all the 90 individuals.

CAST ANALYSIS:

Standardised casts of the subjects were used to analyse the tooth characteristics, occlusal relationships, asymmetry in arch forms, occlusal roll, presence of pre-maturities and interferences.

PHOTOGRAPHS:

Postural analysis was performed using photographs to check for the shoulder tilt, pelvic tilt, deviation of the skull from vertical axis and leg asymmetry.

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CERVICAL POSTURE MEASUREMENT: (Fig 1)

Pre-treatment lateral cephalograms were used to assess the skeletal malocclusion and the cervical posture through cervical skull Rocabado analysis. The skeletal malocclusion was evaluated using ANB variable from Steiner`s analysis and using the witts appraisal.

BODY POSTURE ANALYSIS:

The static postural analysis was performed using a customized force platform (Fig 2) indigenously fabricated by Ratna Control Systems with pressure sensors.

The design of the sensors was in the form of an outline of a foot on which the sensors were present at 3 areas were maximum strain was expected to be measured. Foot sizes of 5-9 were available with 3 sensors per foot size. The sensors were located at the hallux region, the first metatarse region and at the medial calcaneous region.

The denotations of the sensors are as follows:

- LP1 denotes the sensor in the medial calcaneous region on the left leg
- LP2 denotes the sensor in the first metatarse on the left leg
- LP3 denotes the sensor in the hallux on the left leg.
- RP1 denotes the sensor in the medial calcaneous region on the right leg
- RP2 denotes the sensor in the first metatarse on the right leg
- RP3 denotes the sensor in the hallux on the right leg.

The sensors were connected to a strain gauge which recorded the strain at each pressure sensor.

The static posture analysis was done as follows

1. The patient was asked to stand on the force platform with their feet corresponding to the appropriate shoe size.
2. Each recording lasted for 50 seconds under the following standardized conditions: mandibular rest position with eyes open and the patient in natural head and body position.
3. The combined method was followed to make the patient rest his or her mandible in the rest position.
4. The study was conducted in quiet and calm surroundings and all the possible disturbing elements were removed from the examination room.
5. The patients were asked to remain as relaxed as possible with their hands hanging freely along their body.
6. Care was taken that the patients chosen for the study were devoid of alcohol or any other physical therapy 24hours before the recordings.
7. The force plate had the outline of the feet at 30 degree to the midline of the platform. This was the most stable rest position of the feet.
8. Calcaneal tendon was positioned corresponding to the length of the foot and the Malleolus was correspondence of the angle of the foot.
9. To reduce intersession variability a single examiner conducted the study.
10. The recordings were noted, and photographs were taken for each of the patients.

STATISTICAL ANALYSIS:

Statistical analysis was done using the SPSS VERSION 16 (IBM Corp, Chicago, IL, USA). The results were statistically analysed using one-way analysis of variances (ANOVA). Multiple comparisons were analysed using the Tukey`s post hoc test. Independent sample t test was done to analyse whether gender played a significant role in hyoid angle for the three groups. In the present study, P[illegible]0.005 was considered as the level of statistical significance.

Results

A statistically significant difference was found for all the parameters which included the ANB angle (p=0.00), witts appraisal (P=0.00), PI angle (P 0.00), cervical curvature (P=0.00), C0-C1 (P=0.00), hyoid angle (P=0.03), and HC3 (P=0.00) between skeletal class I, II and III groups. HRGn showed no statistically significant results (P = 0.426) (Table 1).

Multiple comparison analysis using the Post Hoc Tukey HSD test showed statistically significant difference within each of the groups analysed (Table 2). The parameters ANB, PI angle, cervical curvature and HC3 were found to be statistically significant (P=0.00). The linear measurement C0-C1 between class I and class II (P=0.00), class II and class III (P=0.00) and class I and class III (P=0.008) were found to be clinically significant. The angular measurement hyoid angle between class I and class II (P=0.271), class I and class III (P= 0.124) were found to be statistically insignificant. The linear measurement HRGn between class I and class II (P=0.545), class I and class III (P=0.983), class II and class III (P=0.467) were also found statistically insignificant.

The independent "t" test performed in class I group and the results signify that the results were found to be statistically significant only for HC3 (P = 0.02) showing that HC3 was found to be greater in males than in females in class I group (Table 3). The independent "t" test performed in class II group and the results denotes that the results were statistically significant for HC3 (P=0.025) denoting that HC3 showed gender predilection in class II group (Table 4). The independent "t" test performed in class III group and the results signify that hyoid angle; HC3 and HRGn were not found to be statistically significant denoting that gender did not have any effect on these parameters in class III group (Table 5).

Comparison between the strain values obtained from the pressure sensors between the three groups was performed using ANOVA test (Table 6). The results show that difference in strain was found to be highly statistically significant between all three groups (P=0.00).

The comparison between the strain values obtained from the pressure sensors within the three groups evaluated using the post hoc tukey HSD test revealed that results were statistically significant for LP1, LP3, RP1, RP2 (Table 7).The significance for LP2 between class I and class II was found to statistically significant (P=0.001). Strain value at LP2 between class I and class III (P=0.050) and at RP3 between class I and class II (P=0.922) was found to be statistically insignificant.

TABLE 1: COMPARISON OF CEPHALOMETRIC VALUES OBTAINED FROM ROCABADO ANALYSIS BETWEEN THE THREE GROUPS (ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
ANB	Between Groups	675.499	2	337.750	230.861	.000
	Within Groups	127.281	87	1.463		
	Total	802.781	89			
WITTS	Between Groups	873.562	2	436.781	152.894	.000
	Within Groups	248.538	87	2.857		
	Total	1122.100	89			
PIANGLE	Between Groups	5233.341	2	2616.671	274.570	.000
	Within Groups	829.115	87	9.530		
	Total	6062.456	89			
CURVATURE	Between Groups	194.830	2	97.415	216.063	.000
	Within Groups	39.225	87	.451		
	Total	234.056	89			
C0C1	Between Groups	252.753	2	126.377	122.342	.000
	Within Groups	89.869	87	1.033		
	Total	342.622	89			
HYOIDANGLE	Between Groups	602.780	2	301.390	6.087	.003
	Within Groups	4307.709	87	49.514		
	Total	4910.489	89			
HC3	Between Groups	813.707	2	406.853	40.128	.000
	Within Groups	882.082	87	10.139		
	Total	1695.789	89			
HRGn	Between Groups	30.928	2	15.464	.862	.426
	Within Groups	1560.672	87	17.939		
	Total	1591.600	89			

TABLE 2: MULTIPLE COMPARISONS OF THE CEPHALOMETRIC VALUES OBTAINED FROM ROCABADO ANALYSIS BETWEEN THE THREE GROUPS (TUKEY'S POST HOC TEST)

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
ANB	Class I	Class II	-2.91642*	.30253	.000	-3.6378	-2.1950
		Class III	3.89826*	.32166	.000	3.1313	4.6652
	Class II	Class I	2.91642*	.30253	.000	2.1950	3.6378
		Class III	6.81469*	.31718	.000	6.0584	7.5710
	Class III	Class I	-3.89826*	.32166	.000	-4.6652	-3.1313
		Class II	-6.81469*	.31718	.000	-7.5710	-6.0584
WITTS	Class I	Class II	-3.07136*	.42275	.000	-4.0794	-2.0633
		Class III	4.66873*	.44948	.000	3.5970	5.7405
	Class II	Class I	3.07136*	.42275	.000	2.0633	4.0794
		Class III	7.74009*	.44322	.000	6.6832	8.7969
	Class III	Class I	-4.66873*	.44948	.000	-5.7405	-3.5970
		Class II	-7.74009*	.44322	.000	-8.7969	-6.6832
PI ANGLE	Class I	Class II	10.07136*	.77215	.000	8.2302	11.9125
		Class III	-8.78412*	.82095	.000	-10.7417	-6.8266
	Class II	Class I	-10.07136*	.77215	.000	-11.9125	-8.2302
		Class III	-18.85548*	.80952	.000	-20.7858	-16.9252
	Class III	Class I	8.78412*	.82095	.000	6.8266	10.7417
		Class II	18.85548*	.80952	.000	16.9252	20.7858
CURVATURE	Class I	Class II	-2.03421*	.16795	.000	-2.4347	-1.6337
		Class III	1.58933*	.17856	.000	1.1635	2.0151
	Class II	Class I	2.03421*	.16795	.000	1.6337	2.4347
		Class III	3.62354*	.17608	.000	3.2037	4.0434

	Class III	Class I	-1.58933*	.17856	.000	-2.0151	-1.1635
		Class II	-3.62354*	.17608	.000	-4.0434	-3.2037
C0-C1	Class I	Class II	3.03128*	.25421	.000	2.4251	3.6374
		Class III	-.83002*	.27028	.008	-1.4745	-.1855
	Class II	Class I	-3.03128*	.25421	.000	-3.6374	-2.4251
		Class III	-3.86131*	.26652	.000	-4.4968	-3.2258
	Class III	Class I	.83002*	.27028	.008	.1855	1.4745
		Class II	3.86131*	.26652	.000	3.2258	4.4968
HYOID ANGLE	Class I	Class II	2.73607	1.76001	.271	-1.4606	6.9328
		Class III	-3.70099	1.87126	.124	-8.1630	.7610
	Class II	Class I	-2.73607	1.76001	.271	-6.9328	1.4606
		Class III	-6.43706*	1.84521	.002	-10.8369	-2.0372
	Class III	Class I	3.70099	1.87126	.124	-.7610	8.1630
		Class II	6.43706*	1.84521	.002	2.0372	10.8369
HC3	Class I	Class II	3.45552*	.79643	.000	1.5565	5.3546
		Class III	-4.02233*	.84677	.000	-6.0414	-2.0032
	Class II	Class I	-3.45552*	.79643	.000	-5.3546	-1.5565
		Class III	-7.47786*	.83498	.000	-9.4689	-5.4869
	Class III	Class I	4.02233*	.84677	.000	2.0032	6.0414
		Class II	7.47786*	.83498	.000	5.4869	9.4689
HRGn	Class I	Class II	1.11632	1.05937	.545	-1.4097	3.6424
		Class III	-.19603	1.12633	.983	-2.8817	2.4897
	Class II	Class I	-1.11632	1.05937	.545	-3.6424	1.4097
		Class III	-1.31235	1.11065	.467	-3.9607	1.3360
	Class III	Class I	.19603	1.12633	.983	-2.4897	2.8817
		Class II	1.31235	1.11065	.467	-1.3360	3.9607

*. The mean difference is significant at the 0.05 level.

TABLE 3: INDEPENDENT "t" TEST TO EVALUATE THE EFFECT OF GENDER ON HYOID ANGLE, HC3 AND HRGn IN CLASS I GROUP

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HYOIDANGLE	Equal variances assumed	.099	.755	.813	29	.423	2.07456	2.55048	-3.14176	7.29088
	Equal variances not assumed			.881	28.581	.386	2.07456	2.35578	-2.74662	6.89574
HC3	Equal variances assumed	.048	.828	2.340	29	.026	2.01316	.86050	.25323	3.77308
	Equal variances not assumed			2.352	23.946	.027	2.01316	.85602	.24622	3.78010
HRGn	Equal variances assumed	.240	.628	-.560	29	.580	-.68421	1.22124	-3.18192	1.81350
	Equal variances not assumed			-.549	21.982	.589	-.68421	1.24638	-3.26917	1.90075

a. Groups = Class I

TABLE 4: INDEPENDENT "t" TEST TO EVALUATE THE EFFECT OF GENDER ON HYOID ANGLE, HC3 AND HRGn IN CLASS II GROUP

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HYOIDANGLE	Equal variances assumed	.222	.641	-.119	31	.906	-.32222	2.70355	-5.83615	5.19171
	Equal variances not assumed			-.120	30.622	.905	-.32222	2.68406	-5.79914	5.15469
HC3	Equal variances assumed	.446	.509	2.353	31	.025	2.33333	.99148	.31119	4.35547
	Equal variances not assumed			2.294	25.688	.030	2.33333	1.01731	.24099	4.42568
HRGn	Equal variances assumed	.435	.515	-1.579	31	.125	-2.75556	1.74558	-6.31569	.80458
	Equal variances not assumed			-1.559	28.137	.130	-2.75556	1.76743	-6.37518	.86407

a. Groups = Class II

TABLE 5: INDEPENDENT "t" TEST TO EVALUATE THE EFFECT OF GENDER ON HYOID ANGLE, HC3 AND HRGn IN CLASS III GROUP

Independent Samples Test[a]

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HYOIDANGLE	Equal variances assumed	.148	.704	-1.116	24	**.275**	-2.80952	2.51754	-8.00548	2.38643
	Equal variances not assumed			-1.128	23.984	.270	-2.80952	2.49061	-7.95006	2.33101
HC3	Equal variances assumed	3.214	.086	.148	24	**.883**	.23810	1.60623	-3.07700	3.55319
	Equal variances not assumed			.144	18.521	.887	.23810	1.65806	-3.23835	3.71454
HRGn	Equal variances assumed	2.675	.115	-.037	24	.971	-.05952	1.61431	-3.39130	3.27225
	Equal variances not assumed			-.038	22.541	.970	-.05952	1.56302	-3.29652	3.17747

a. Groups = Class III

TABLE 6: COMPARISON BETWEEN THE STRAIN VALUES OBTAINED FROM THE PRESSURE SENSORS BETWEEN THE THREE GROUPS (ANOVA)

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
LP1	Between Groups	1.178	2	.589	825.987	.000
	Within Groups	.062	87	.001		
	Total	1.240	89			
LP2	Between Groups	.013	2	.006	18.514	.000
	Within Groups	.030	87	.000		
	Total	.043	89			
LP3	Between Groups	.050	2	.025	100.266	.000
	Within Groups	.022	87	.000		
	Total	.072	89			
RP1	Between Groups	1.798	2	.899	1.144E3	.000
	Within Groups	.068	87	.001		
	Total	1.866	89			
RP2	Between Groups	.237	2	.119	712.215	.000
	Within Groups	.014	87	.000		
	Total	.252	89			
RP3	Between Groups	.168	2	.084	165.912	.000
	Within Groups	.044	87	.001		
	Total	.212	89			

TABLE 7: COMPARISON BETWEEN THE STRAIN VALUES OBTAINED FROM THE PRESSURE SENSORS BETWEEN THE THREE GROUPS (POST HOC TUKEY HSD TEST)

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LP1	Class I	Class II	.17569*	.00668	.000	.1598	.1916
		Class III	-.10190*	.00710	.000	-.1188	-.0850
	Class II	Class I	-.17569*	.00668	.000	-.1916	-.1598
		Class III	-.27759*	.00700	.000	-.2943	-.2609
	Class III	Class I	.10190*	.00710	.000	.0850	.1188
		Class II	.27759*	.00700	.000	.2609	.2943
LP2	Class I	Class II	-.01742*	.00466	.001	-.0285	-.0063
		Class III	.01181*	.00495	.050	.0000	.0236
	Class II	Class I	.01742*	.00466	.001	.0063	.0285
		Class III	.02923*	.00488	.000	.0176	.0409
	Class III	Class I	-.01181*	.00495	.050	-.0236	.0000
		Class II	-.02923*	.00488	.000	-.0409	-.0176
LP3	Class I	Class II	.05584*	.00397	.000	.0464	.0653
		Class III	.02283*	.00422	.000	.0128	.0329
	Class II	Class I	-.05584*	.00397	.000	-.0653	-.0464
		Class III	-.03301*	.00416	.000	-.0429	-.0231
	Class III	Class I	-.02283*	.00422	.000	-.0329	-.0128
		Class II	.03301*	.00416	.000	.0231	.0429
RP1	Class I	Class II	.20335*	.00701	.000	.1866	.2201
		Class III	-.14314*	.00746	.000	-.1609	-.1254
	Class II	Class I	-.20335*	.00701	.000	-.2201	-.1866
		Class III	-.34649*	.00735	.000	-.3640	-.3290

	Class III	Class I	.14314*	.00746	.000	.1254	.1609
		Class II	.34649*	.00735	.000	.3290	.3640
RP2	Class I	Class II	-.05707*	.00323	.000	-.0648	-.0494
		Class III	.07069*	.00343	.000	.0625	.0789
	Class II	Class I	.05707*	.00323	.000	.0494	.0648
		Class III	.12776*	.00339	.000	.1197	.1358
	Class III	Class I	-.07069*	.00343	.000	-.0789	-.0625
		Class II	-.12776*	.00339	.000	-.1358	-.1197
RP3	Class I	Class II	.00216	.00563	.922	-.0113	.0156
		Class III	.09641*	.00598	.000	.0821	.1107
	Class II	Class I	-.00216	.00563	.922	-.0156	.0113
		Class III	.09425*	.00590	.000	.0802	.1083
	Class III	Class I	-.09641*	.00598	.000	-.1107	-.0821
		Class II	-.09425*	.00590	.000	-.1083	-.0802
*. The mean difference is significant at the 0.05 level.							

Discussion

The harmonious function of all the components of stomatognathic system lets a human perform different functions like speech, swallow, mastication, respiration, etc. Apart from performing all these functions, studies have revealed an association between the stomatognathic system and body posture.[1,9] Garrison and Read[19] stated that a good posture is the one in which power investment by the body is kept minimal and the mechanical efficiency is at the maximum. Walk et al[20] said that the posture of the human body is the upright position in which the arms are relaxed at the sides and the palms are pointed in the downward direction.

NORMAL POSTURE AND ITS ESTABLISHMENT:

There are 4 natural curves of the vertebral column which represent or determine the overall body posture in a human – Cervical, thoracic, lumbar and sacral. When an infant is born, only the thoracic and the sacral curves are present. As the child passes through each of the developmental phase and gain sitting and standing balance, they develop secondary extensions of the spine in the form of lumbar and cervical curve. A normal child attains a normal spinal curvature at around 7 years of age. The rate of spinal growth is not constant. There is a period of accelerated growth between 10.5 and 15.5 years of age, and peak velocity occurs at an average of 12.2 years in girls and 13.9 years in boys.[21]

When the spine is viewed posteriorly, it should run straight down along the trunk of the body and when the spine is viewed laterally it should form a soft “S” shape.[21] Any alterations from this normal curvature are classified under spinal or postural disorders – lordosis, kyphosis, scoliosis[22].

RELATIONSHIP BETWEEN THE STOMATOGNATHIC SYSTEM AND POSTURE

Notochord, which is the future vertebral column, releases neural crest cells which migrate to the craniofacial area before it is surrounded by bone. The jaws are derived from the ectomesenchymal tissues that originate from these neural crest cells. Thus, any deviation in the timing or the amount of neural crest cell migration can cause alterations in the craniofacial area thus establishing a developmental association between the cranio-cervical area and craniofacial area.[23]

The afferent nerve fibres from the periodontium, muscles of mastication and the jaws (other nerves include cranial nerves, III, IV, VI and IX) converge at the trigeminal nuclei. The sensory information from the cervical part of the spine also converges at the trigeminal nuclei. The neurons then further descend down to C5, C6 and C7. Thus, any stimuli from the above-mentioned structures will cause ramifications in the postural system establishing a neuroanatomical relationship between posture and the stomatognathic system.[11]

A functional relationship also exists between the stomatognathic system and the body posture. Any modification in the activity of the muscles of mastication automatically causes an alteration in the anterior and posterior muscles of the neck and back due to their anatomic location and physiologic function. This disequilibrium is known to cause a collapse in the tonic postural system.[24]

FACTORS AFFECTING BODY POSTURE:

Postural adjustments are a result of multisensory inputs.[1] The afferent inputs are exteroceptive, proprioceptive, vestibular and visual. The body system is a single functional unit and body posture as mentioned above is linked by various systems. Any alterations in the postural system, will lead to multiple and continuous modifications by the other systems thus making posture evaluation and establishment of a cause - effect relationship very difficult.[25,26] The musculoskeletal system plays the most imperative role in maintaining the body posture.[17,25,27] The combined action of the muscular system and the skeletal system determines the body posture. Due to the anatomical and functional connection, it is said to form a chain between the skull, lower jaw, spine, limbs and pelvis. Any variation in any part of this chain, are said to alter the overall equilibrium of the body.[24] In addition to this, the daily activities like sitting, standing, walking also have an important role to play. Maintaining a body position for a long time can cause fatigue to the body muscles. Continuous fatigue of the muscles decreases the contractile power and strength which are also considered as abnormal. This is the reason why dentists, surgeons, tailors, drivers and subjects who sit or stand for a long time are more prone to postural disorders.

Age is another factor that affects body posture.[22] As age advances, the muscle mass, activity of the muscle, isometric contraction ability, and the muscle tone are known to decrease. Muscle fatigue is known to increase with age. In this study, subjects in 16-22yrs age group have been included. This is because in this age group, the posture as well as the skeletal base is established. The growth of the patient also is almost completed in this age group. Psychological factors also show considerable amount of changes in the body posture.

Patients with an altered state of mind characterised by either over-arousal or depression are known to be psychologically affected. The vestibulo- ocular reflexes in such patients are altered thereby affecting the somatosensory inputs which are responsible in maintaining the equilibrium of the body.[28] Anxiety and depression are known to be the most common mental disorders known to affect the body posture.[17]

The elasticity of the lungs and the mechanical resistance of the respiratory system are known to change with posture.[29] Thereby respiratory system and its pathologies also influence the overall posture of the body. Similarly, advanced stages of pregnancy, parturition,[30] any trauma to the body, hormonal imbalances due to systemic diseases or medications, orthopaedic disorders can cause alterations in the muscle and associated bone function. These changes can also affect the body posture. Due to the above-mentioned reasons the patients with these disorders were excluded from the study.

MALOCCLUSION AND BODY POSTURE:

Solow and Tallgren[12] were among the first authors to reveal that craniofacial morphology had a positive correlation with body posture. With the proposal of the soft tissue stretch hypothesis in 1977 by Solow and Kreinborg,[13] this school of thought got a new dimension. Various authors conducted multiple studies in this field.

Biomechanical concept theory of postural collapse[3] indicate that dentition is the major supporting element for the skull. Any damage to this dental unit can results in series of alterations resulting in the postural system to collapse.

An increased incidence of cervical lordosis was found in patients with class II malocclusions.[27] Postural changes were also documented in subjects who underwent orthognathic surgery,[31] functional appliance therapy,[32] and other orthodontic treatment[33] giving a possible indication that malocclusions could affect posture. An increased correlation was also found in patients with unilateral crossbites and scoliosis.[26] An asymmetry in occlusion caused due to the crossbite leads to an imbalance in the cervical spine which is the link between the upper body and the trunk. The imbalance in the cervical spine is noted as shoulder tilts. The imbalance is thus transmitted to the trunk causing pelvic tilts further destabilising the spine. The distribution of loads also becomes asymmetric leading to scoliosis.

TMDs are one of the most common disorders of the stomatognathic system and multiple associations between TMD and alterations in the body posture in the form of an extended head posture and increased lordosis were reported.[15] Two schools of thoughts were proposed by various authors regarding this topic. The first school of thought was that TMD caused alteration in the body posture. According to this concept, TMD caused an asymmetry in the activity of the muscles which led to modifications in the musculoskeletal system causing a change in the body posture.[34] The second school of thought said that body posture is established by the soft tissue stretching hypothesis. However, the occlusal support varies according to craniofacial morphology. In order to achieve the occlusal support, the mandible tries to reposition itself leading to TMJ disorders.[13] Thus, patients with TMDs, crossbites, occlusal interferences, dental or skeletal asymmetries, and functional retrusion were excluded from the study.

In 2012, Garcia et al[35] evaluated cervical posture in adolescents having class I, II and III malocclusions and found significant difference between the three classes. Posterior inferior angle represents the angulation of the cranium with respect to the cervical spine and the average is usually 101° and usually varies by 5° with flexion and extension. In the present study the posterior inferior angle was found to be within the normal limits for subjects in class I. However, the angle was found to be decreased in class II showing that these subjects posed with a forward extension of neck. In class III subjects, an increase in the posterior inferior angle with respect to the normal was noted which shows that the subjects in this group posed with a backward flexion of the neck. This was concordant with the study by Rocabado et al.[36]

The cervical curvature was found to be increased in class II skeletal base subjects and was decreased in skeletal class III subjects when compared to class I subjects. This was in accordance with previous studies by Nobili et al and D`Attilio which stated that patients with skeletal class II malocclusions had a forward posture whereas patients with class III had a backward posture.[37,38] The normal CO-C1(inter vertebral distance) distance is 4-9mm which was noted in subjects with class I skeletal malocclusion.[39] However this distance was found to be reduced in subjects with class II malocclusion and increased in subjects with class III malocclusion denoting that in class II malocclusion, the subjects tend to have a backward rotating cranium in compensation to the forward extension of the neck, whereas in class III malocclusion the subjects had a forward rotating cranium to compensate for the backward flexion of the neck. Very few studies have reported the clinical correlation between C0-C1 distance and skeletal malocclusions.

The hyoid bone provides attachment for muscles, ligaments, and fascia of the pharynx, mandible, cranium, and cervical spine. Though it has no bony attachments, it is well-attached to the cervical spine through the cervical fascia.[36]The position of hyoid bone and its effects on cervical posture have been controversial. In the present study, the hyoid angle was found to be different in class I, II and III groups. However, Post Hoc Tukey`s HSD test revealed a statistical difference in hyoid angle was observed only between class II and class III groups. This was contradictory to the results obtained from previous study by Mortazavi et al[40] which stated that the angular measurements of the hyoid bone did not differ in any of the skeletal patterns. The parameter was found to be statistically insignificant between class I - class II and class I- class III. This may be attributed to the fact that the hyoid bone position depends on multiple factors like age, sex[41], craniofacial morphology[42], habits, rotations of the mandible, airway and kinematics of head, jaw and vertebrae.

HC3 is the linear distance from the cervical spine to the Hyoidale. Post hoc tukey HSD test and ANOVA tests revealed a statistical significance between the three classes of malocclusion. HC3 was found to be reduced in class II malocclusion group and it was found to be greater in class III skeletal group when compared to the other groups. The result was not in accordance with the study by Weber et al[43] and was in correlation with the study by other authors [40,44,] and was attributed to the fact that class II malocclusion is characterised by smaller mandible dimension whereas class III had a mandible which was longer in dimension when compared to the other two groups.

HRGn is the linear distance from the Hyoidale to the retrognation. This parameter was found to show no statistical difference between and within the three groups of malocclusions. This maybe because the region from Hyoidale to the retrognation has the muscles of the neck, tongue and genium are attached to it thereby increasing the muscle pull in this region when compared from C3 to Hyoidale where only the cervical facia tend to be active.[44]

The effect of gender on hyoid bone has been addressed in previous studies and has been controversial. Therefore; gender predilection was analyzed for hyoid angle, HC3 AND HRGn in the three groups of malocclusions. In class I and class II groups, HC3 was found to be higher in males as compared to females. This was in accordance with the study by Mortazavi et al[41] which stated that the hyoid bone was positioned more posteriorly in females thereby reducing the distance from H to C3. Considering the larger size of muscles, bones, and overall skeleton in males, it is expected that the distance from hyoid bone to adjacent structures will be more in males. On the other hands, a smaller distance in females from the hyoid bone to craniofacial structures is due to the difference in average gender size. HRGn and hyoid angle was found to be statistically insignificant between males and females in class I, II and III malocclusions. This was in concordance with the previous studies by Mortazavi et al[40], Haralabakis et al[45] and Jose et al[46] that HRGn and hyoid angle did not present with any gender predilection. Similarly, in class III group, all the three parameters showed statistically insignificant results. This may be attributed to the fact that the hyoid bone is positioned anteriorly in skeletal class III malocclusions and present with an overall increase in length of the mandible in both genders. More influence of the muscles of the genium and the digastric belly act on the hyoid bone than gender thereby not showing its effect on hyoid bone position in this group.[47]

The postural analysis was performed in this study using photographs and the force platform with pressure sensors on it. The photographs are assessed for any shoulder tilts, pelvic tilts, deviation of the skull from the vertical axis and leg asymmetry. These features are usually seen in a patient only when postural alterations have started taking place.[3] However, the numerical measurements of the changes in inclination and angulations in posture were not analyzed in the present study as it required the patients to be in minimal clothes or the lightest possible body suits which could not be provided. In the present study, these features were noted in minimal in class I patients. This is because a perfectly symmetrical and a body with ideal posture cannot be found. However, in class II and class III subjects, these features were very much significant when compared to class I group.

A force platform was customized with pressure sensors on it at the hallux, the first metatarse and the medial calcaneous region. Rai et al[48] reported that these areas were found to be the load bearing areas thereby the sensors were chosen to be placed in these areas on the feet. The force platform recorded the strain at each of the pressure sensors. In case of any alteration in body posture, it was hypothesized that the load distribution at the limbs would be uneven as various modifications in the postural system would have occurred in order to maintain the equilibrium of the body. In the present study it was noted that the strain values obtained at each of the sensors between each of the groups were statistically significant (ANOVA). The strain at all the sensors were found to be equally distributed in subjects with class I malocclusion which demonstrate that the postural alterations due to malocclusion were nil or minimal. The muscle activity and the equilibrium of the body were maintained which led to equal distribution of loads at the legs. In case of class II malocclusion, the sensors in the hallux and metatarse were found to show higher strain values, showing that subjects with a class II malocclusion tended to lean in the anterior direction. These results are in accordance with the study by Arumugam et al[49].In case of class III malocclusion, the sensors in the calcaneal region were found to have a higher strain value. This showed that patients with a class III malocclusion had a tendency to lean in the posterior direction.[50]

The reason for the backward sway in class III malocclusion group and a forward sway in the class II malocclusion group can be explained through the chain theory. According to this theory, the entire body system is divided into 3 rings. The upper ring consisted of muscles of head and neck and TMJ, the middle ring constituted the muscles of the back and vertebrae while the lower ring was made up of muscles of foot, ankle and legs. For a body to function perfectly, the 3 rings required to work in harmony and synchronisation. Any disturbance in any of the rings would create modifications in the other two rings. Patients with class II malocclusions were reported to have forward head posture placing the first ring in a forward position than the other two rings. The extension of the head and neck muscles lead to their fatigue and consequent reduction in their blood supply. In order to maintain the equilibrium of the body, the second ring modified itself and placed itself in a more backward position than the first ring, and to compensate for this change, the third ring was found to be in a more forward position than second ring. Similarly, patients with a class III malocclusion a backward head posture because of which the first ring was placed in a backward position leading to more forward position of the second ring and consequent backward position of the third ring. Post Hoc Tukey`s HDS test revealed that the results statistically significant for LP1, LP3, RP1, RP2 for all combinations of malocclusions. The sensor at the left metatarse (LP2) did not show statistically significant results between class I and class III. This meant that the strain value at LP2 was similar to the strain in class I malocclusion, but significantly higher strain was found at P3 sensor because of which the patient had a backward posture. Similarly, the sensor at right calcaneal region was found to be statistically insignificant between class I and class II group. This meant that strain value at RP3 was like the strain in class I malocclusion, but significantly higher strain was found at P1 and P sensors because of which the patient had a forward posture.

SKELETAL CLASS I MALOCCLUSION: (Fig 3)

All the cephalometric parameters assessed were found to be within normal limits in skeletal class I subjects. The photographs revealed no or minimal shoulder tilts, leg asymmetry and pelvic tilt, no deviation of the skull from the vertical axis. The strain values from the force platform revealed that subjects with a class I skeletal base showed an even distribution of loads.

The cervical curvature was found to be increased in subjects with class II malocclusion in comparison with class I and class III groups. As the cervical curvature increases, the head extends forward and the cranium rotates in backward direction reducing the PI angle, C0-C1 distance. The photographs revealed shoulder tilts, deviation of the skull from the vertical axis, pelvic tilt and leg asymmetry. The subjects with a class II skeletal base were found to have a forward extension of the head as well. The parameters were found have a correlation with the severity of the malocclusion. The strain values from the force platform revealed that subjects with a class II skeletal base tended to lean forward in order to maintain the overall balance of the body.

The cervical curvature was found to be decreased than the normal in subjects with class III malocclusion. The PI angle, C0-C1 distance, hyoid angle as well as HC3 were found to be increased in class II malocclusion. The photographs revealed shoulder tilts, deviation of the skull from the vertical axis, pelvic tilt and leg asymmetry. The subjects with a class III skeletal base were found to have a backward extension of the head. The parameters were found to be dependent on the severity of the malocclusion. The strain values from the force platform revealed that subjects with a class III skeletal base tended to lean backwards in posterior direction in order to maintain the overall balance of the body

Another possible explanation between malocclusion and body posture is the soft tissue stretching hypothesis by Solow and Kreinborg in 1998.[13] D Attilio et al[39] evaluated cervical posture in 120 children and stated that mandibular position and size were the two important factors that were responsible for change in posture. These two factors in turn influence the neural-muscular system thereby causing a change in cervical posture and finally the body posture. Studies which evaluated postural changes after orthognathic surgery have revealed a persistent postural change after surgery, however the neck posture was found to relapse to its pre-surgical position within 1 year.[32] This creates a controversy whether malocclusion influences body posture.

CLINICAL RELEVANCE:

Postural alterations can lead to a series of complications. Constant headaches, back pain and nerve compressions and other symptoms have been reported in patients with postural collapse.[3,14]

The mechanism of how malocclusion creates postural collapse is explained through the biomechanical concept theory of postural collapse.[3] This also explains the need to correct any postural alterations as early as possible probably during the younger age group so that the deformations are further not aggravated, as well as the physiological growth spurts and existing functional efficiency of the musculo-skeletal other systems can be utilised to the maximum.

DRAWBACKS OF THE STUDY:

Postural evaluation requires a subject to be in minimal clothes or the lightest possible bodysuits. This was not practical as the patients were reluctant and appropriate private rooms were also not available.

Posture in Class II and Class III subjects have been analysed as a whole. Individual analysis whether the skeletal base is abnormal because of defect in maxilla or mandible has not been evaluated in this study.

The strain value in the horizontal dimension (mesial and distal part of the leg) has not been evaluated in this study. This evaluation would give more insight into the overall load distribution on the leg.

Subjects with shoe size 5-9 were included in the study. The subjects who had shoe size less or more than the above-mentioned size had to be excluded from the study.

Conclusion

- A positive correlation has been found between cervical posture and body posture in subjects with skeletal class I, II and III malocclusions.
- Subjects with a class I skeletal base have been found to have a no or minimal alteration in body posture and cervical posture. More significant alterations in posture are noted in subjects of the other two classes of malocclusion.
- Subjects with skeletal class II malocclusion have been found to have increased cervical curvature and a tendency to lean in the anterior direction with a forward extension of the head
- Subjects with skeletal class III malocclusion have been noted to have a decrease in cervical curvature when in comparison to class I and class II skeletal base and subjects have been seen to have a tendency to lean in the posterior direction with backward flexion of head.

Abbreviations

Not applicable

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE:

The study was approved by the Institutional review board of Meenakshi Ammal Dental College & Hospital, Chennai, India. Individuals participating in the study provided a written informed consent. In case of 18 yrs and above, the informed consent was obtained from the individuals themselves. Individuals in the age group of 16 – 18 years, the consent was received from their respective guardian/parent.

CONSENT FOR PUBLICATION:

Consent for publication was obtained from all the participants to provide their images

AVAILABILITY OF DATA AND MATERIAL:

All data generated or analysed during this study are included in this published article [and its supplementary information files].

COMPETING INTERESTS:

The authors declare that they have no competing interests.

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AUTHOR`S CONTRIBUTIONS:

SP: Conceptualization, methodology, Investigation, resources, Writing – Original draft

PV: Methodology, Validation, Investigation, resources, Writing – original draft

RP– Conceptualization, resources, Writing – review and editing, supervision, project administration

DV – Resources, Writing – review and editing, supervision, Project administration

STATEMENT FOR GUIDELINES:

All procedures were followed in accordance with relevant guidelines.

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Figures

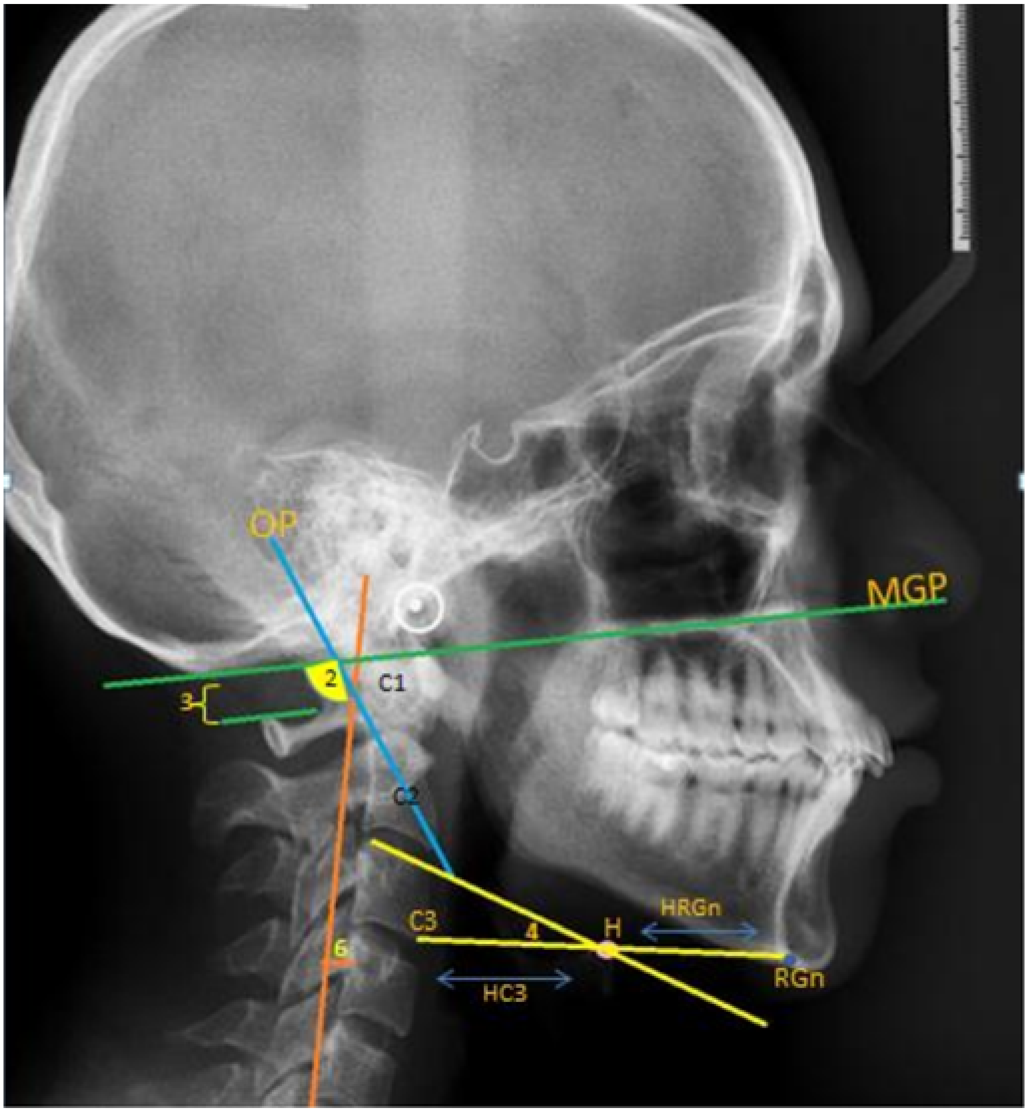

Figure 1

Cephalometric rocabado analysis

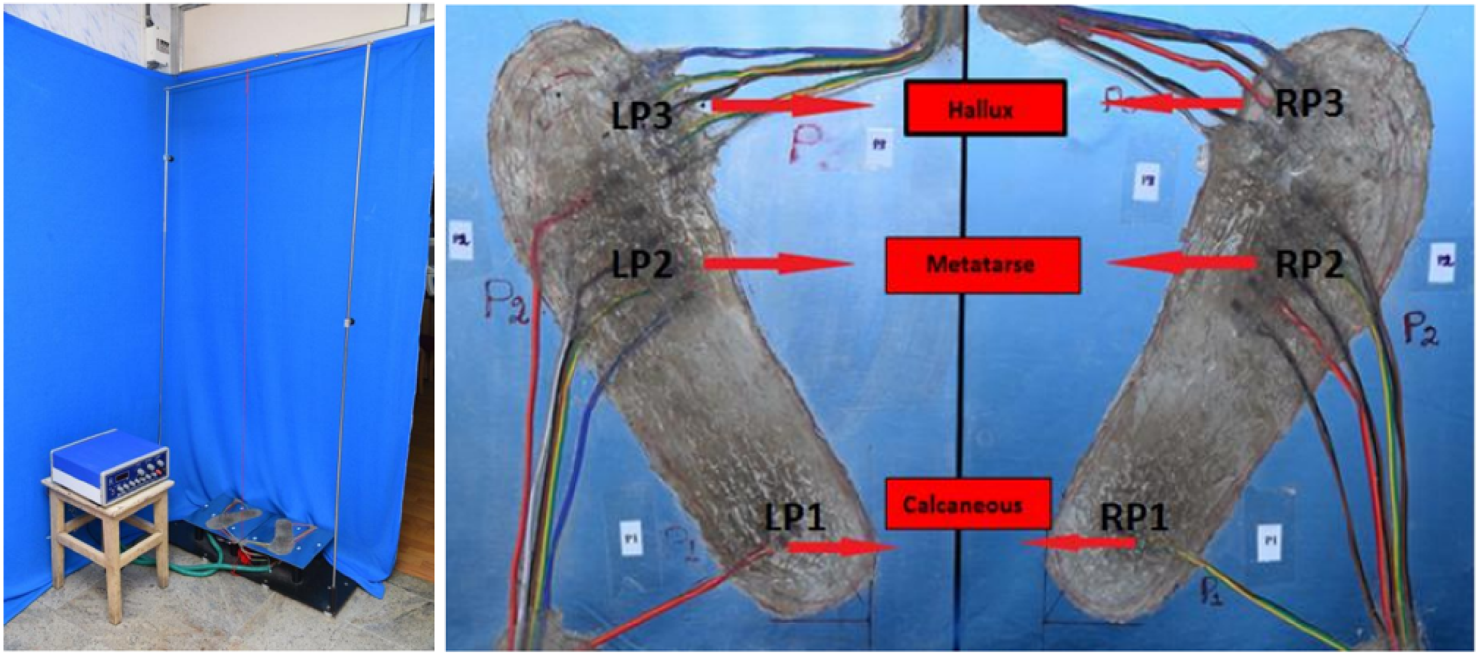

Figure 2

FORCE PLATFORM

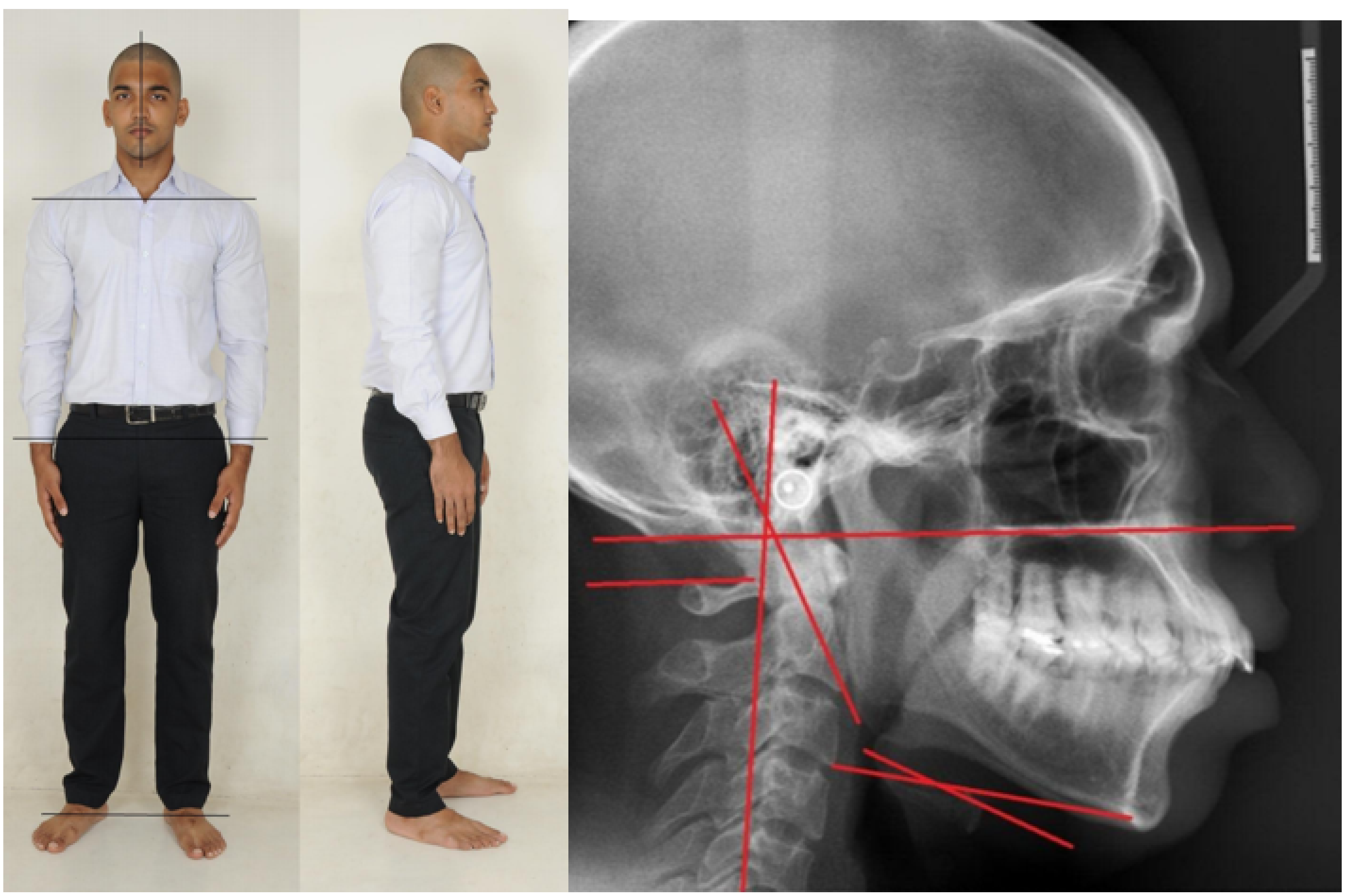

Figure 3

(Left) POSTURAL ANALYSIS OF SUBJECT WITH CLASS I SKELETAL MALOCCLUSION (Right) LATERAL CEPHALOGRAM OF SUBJECT WITH CLASS I MALOCCLUSION – ROCABADO CEPHALOMETRIC ANALYSIS.

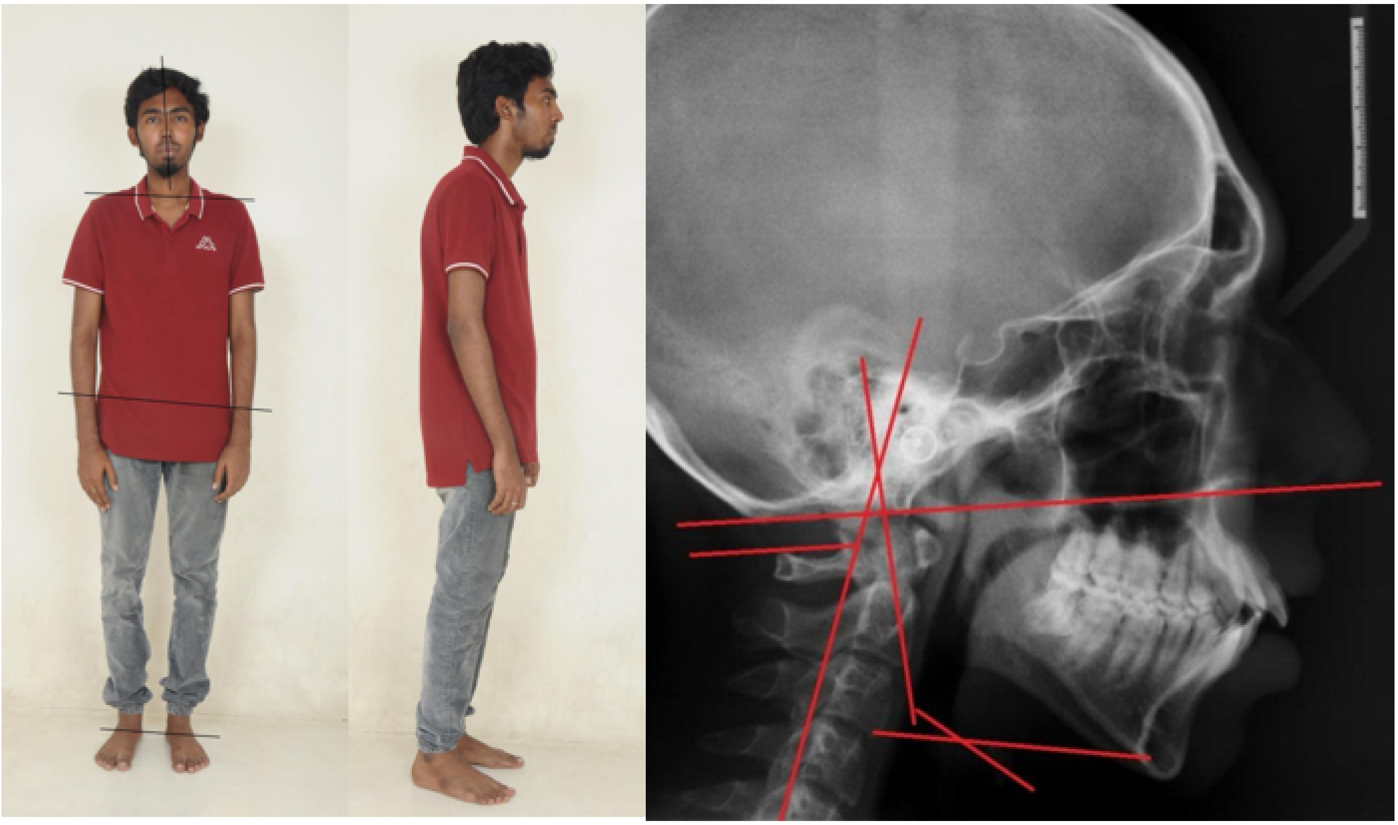

Figure 4

(Left) POSTURAL ANALYSIS OF SUBJECT WITH CLASS II SKELETAL MALOCCLUSION (Right) LATERAL CEPHALOGRAM OF SUBJECT WITH CLASS II MALOCCLUSION – ROCABADO CEPHALOMETRIC ANALYSIS.

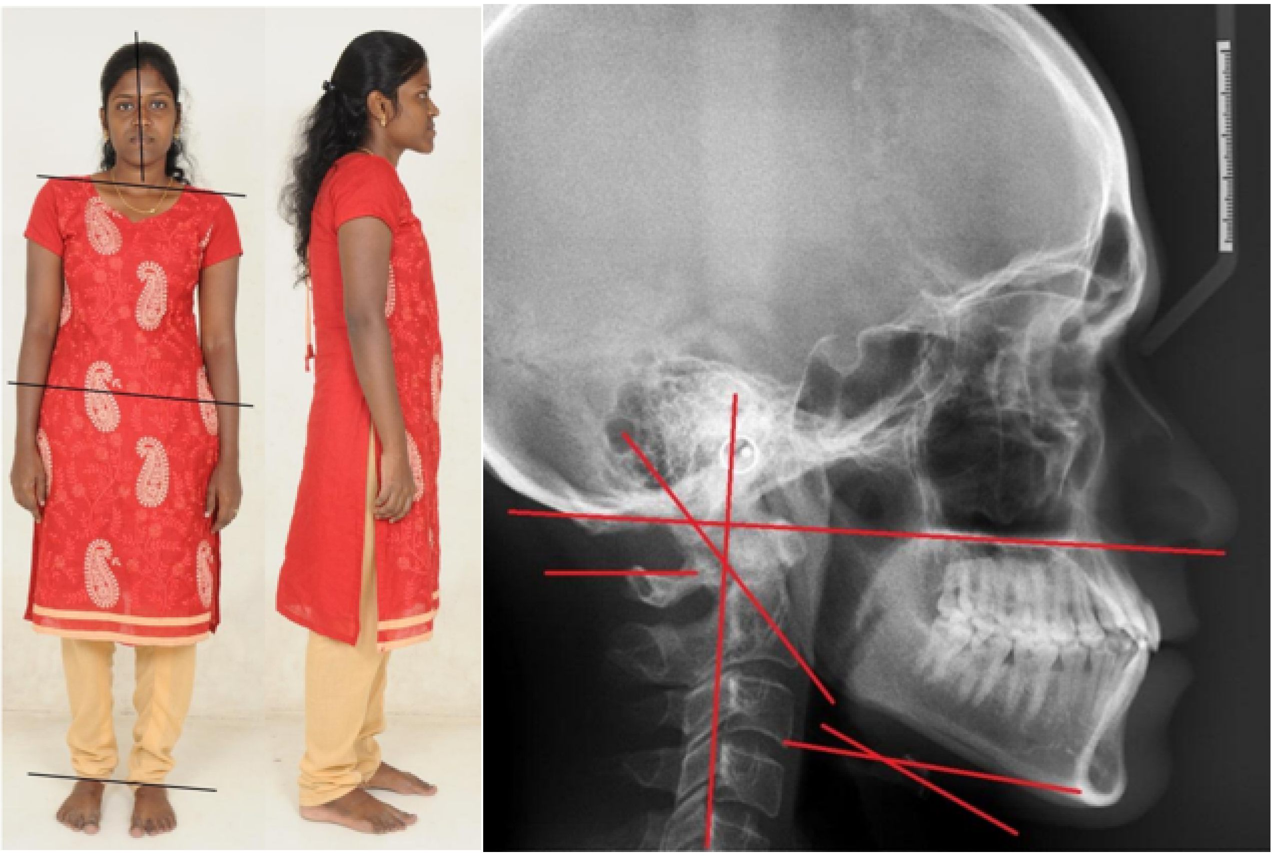

Figure 5

(Left) POSTURAL ANALYSIS OF SUBJECT WITH CLASS III SKELETAL MALOCCLUSION (Right) LATERAL CEPHALOGRAM OF SUBJECT WITH CLASS III MALOCCLUSION – ROCABADO CEPHALOMETRIC ANALYSIS.