EVALUATION OF RELATIONSHIP BETWEEN HEAD POSTURE AND MALOCCLUSION TRAITS IN UNTREATED SKELETAL CLASS II PATIENTS

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LIST OF ABBREVIATIONS

NHP	Natural head posture
VER	True vertical line
HOR	True horizontal line
S	Sella turcica
N	Nasion
ANS	Anterior nasal spine
PNS	Posterior nasal spine
Cv2tg	The tangent point of the superior, posterior extremity of the odontoid process of the second cervical vertebra.
Cv2ip	The most inferior posterior point on the body of the second cervical vertebra
Cv4ip	The most inferior posterior point on the body of the fourth cervical vertebra
NSL	Cranial base
NL	Palatal plane
FOP	Functional occlusal plane
ML	Mandibular plane
CVT	Cervical vertebra tangent
OPT	Odontoid process tangent
NSL/VER	Anterior cranial base inclination
NL/VER	Palatal line inclination
FOP/VER	Occlusal plane inclination
ML/VER	Mandibular plane inclination

NSL/OPT	Craniocervical posture
NSL/ CVT	Craniocervical posture
NL/OPT	Maxillary base inclination upon cervical column
NL/CVT	Maxillary base inclination upon cervical column
FOP/OPT	Functional occlusal plane inclination upon cervical column
FOP/CVT	Functional occlusal plane inclination upon cervical column
ML/OPT	Mandibular plane inclination upon cervical column
ML/CVT	Mandibular plane inclination upon cervical column
CVT/HOR	Craniohorizontal angle
OPT/HOR	Craniohorizontal angle
OPT/CVT	Cervical curvature angle
IMPA	Incisor mandibular plane angle

Introduction

The interdependence between the form and function i.e. structural condition and the action of the movement is well known. In other words, the muscle action, on which the performance of several functions of the organism depends, is determined by the muscle-skeletal balance relationship of the body segments observed in the posture called ideal[1]. The evolution of an upright posture and bipedal walking has been associated with notable changes that characterize many human bones and muscles.[2] In the course of developing an upright posture, the spinal column and skull, the pelvis and legs, and all of the related joints, ligaments, and muscles changed to accommodate the newly attained upright posture and bipedal stance of human being[2]. Accordingly the spine developed secondary curves in the lumbar and cervical vertebrae, the size of the vertebrae increased from top down, the rib cage flattened and the change in the relative size of the cranium and the jaws allowed the balance of the head to shift backward requiring less powerful muscles on the back of the neck.[2]

The most noteworthy changes that accompanied the development of a bipedal stance were those in the cranial base. The cranial base plays a key role in the craniofacial growth, helping to integrate, spatially and functionally, different patterns of growth in various adjoining regions of the skull such as the components of brain, the nasal cavity, the oral cavity and the pharynx. In addition the cranial base connects the skull to the vertebral column and the mandible, and in this role it is able to influence ontogenetic and interspecific patterns of variation in craniofacial morphology[2].

Cephalometric analyses of the cervical vertebral column area have previously been performed on profile radiographs. It was found that the horizontal and vertical dimensions of the first cervical vertebra (C1), atlas, were associated with head posture, cranial base angulation, and mandibular shape and growth Also, the dimensions of the first cervical vertebra (C1), atlas, as well as the posture of the head and neck are associated with factors such as craniofacial morphology, including the cranial base.[3]

Deviations of the cervical column morphology occur in healthy subjects with neutral occlusion and normal craniofacial morphology as well as in patients with craniofacial syndromes, deviating craniofacial morphology, and severe malocclusion traits[4]. A study found that fusions between the upper cervical vertebrae (C2 and C3) occurred in 14.3% of healthy subjects.[5] Fusions of the upper cervical column within that range are thus considered normal. Studies have found an association between malformations of the upper cervical vertebrae and patients with cleft lip and palate.[6-8] An association was also found between malformation of the upper cervical vertebrae not only in patients with condylar hypoplasia,[5] but also in adult orthodontic surgical patients with skeletal deep bite,[9] skeletal mandibular overjet,[10] skeletal horizontal overjet, and skeletal open bite.

An association between the morphology of the cervical column and the posture of the head and neck has also been demonstrated by Sonnesen[11] who in his study showed that fusion between C2 and C3 is associated with posture of the head and neck.

Solow and Tallgren have also previously shown in their studies that posture of the head and neck is associated with craniofacial morphology.[12]

The posture of the head is influenced primarily by the force of gravity, but nevertheless the physiologic demands of respiration, sight balance, and hearing also must affect cranial deportment.[2] Sollow and Tallgren and Posnick showed that statistical correlations exist between the predominant mode of respiration, head posture, and some facial features.[2] Similarly some studies showed that abnormal and prolonged changes in cranial posture during growth and maturation may have an effect on the expression of facial form.[12]

The relationship between head posture and craniofacial morphology was earlier investigated by Schwarz,[13] who contended that extension of the head led to the development of Class II malocclusion.

The head and cervical traits of the vertebral column are part of a functional biomechanical unit, the cranial cervical mandibular system. This system is made up of three main structures: TMJ, occipital atlas axis articulation, and hyoid bone with its suspensor system. These three structures are strictly interdependent. Consequently, it is not unreasonable to expect that cervical posture can be related to craniofacial morphology.[14]

Natural head posture has been defined as the head posture" when a man is standing with his visual axis horizontal" and measured by the angle between a constructed horizontal line and true vertical.[15,16] Variations in natural head position have been observed, ranging between extension and flexion. These postural features studied by Solow and Tallgren showed statistical associations with both craniofacial and dentofacial morphology.[17]

Changes in head posture also affects the upper and lower lip pressure which can presumably influence the inclination and position of the incisor leading to crowding or spacing.[18] The stretching of the soft tissue of the head and neck creates a dorsal force which, in turn, impedes the forward growth of the face, in particular the mandible which leads to the development of crowding.[14] Since crowding is common, it is of interest to determine whether any other malocclusion problem is related to differences in posture of the head and neck.

Despite these observations, little is known about the relationship between different malocclusion traits and head and neck posture in skeletal class II patients. The documentation often remains anecdotal and important questions are left unanswered: Is there in-fact a statistically significant association between skeletal class II patients different malocclusion traits (increased overjet, crowding, incisors inclination, crossbite, rotations, midline shift) and the posture of head and cervical column; and if so, how do different malocclusion traits influence postural angles in skeletal class II patients ?

In this digital era, Nemoceph, a 2-dimensional software has made analysis, diagnosis and treatment planning of the malocclusions and the dentofacial skeleton remarkably easier. Thus, the purpose of this study was to investigate the relationship between head posture and malocclusion traits in untreated skeletal class II patients and to determine which malocclusion trait was more strongly associated with the postural angles, in addition to finding out the relationship between incisor inclination and head posture.

Aim and Objectives

AIM :

To assess the relationship between head posture and different malocclusion traits in untreated skeletal class II patients.

OBJECTIVES :

- To assess the relationship between the head posture and malocclusion traits in untreated males and females skeletal Class II patients.
- To determine which malocclusion trait is strongly associated with the head posture
- To assess the relationship between head posture and inclination of upper and lower incisors in skeletal Class II untreated patients.

Review of Literature

Schwartz (1926)[13] suggested a relationship between head posture and craniofacial morphology and attributed the development of Class II malocclusion to hyperextension of the head relative to the cervical column during sleep. He also noted a vertical development of the face and a large prevalence of Class II malocclusion in subjects with poor neck posture.

Bjork (1951)[19] also noticed that people with a retrognathic facial profile and a flattened cranial base tend to hold their heads more upright, with their foreheads back and their chins protruding somewhat. On the other hand, those with prognathic facial profiles tend to have a more acute cranial base angle and hold their heads with chins somewhat tucked in. his opinion was that the relationship between form of the cranial base and that of craniofacial morphology is often visually masked by the posture of head on the vertebral column

Solow B, Tallgren A (1976)[12] examined the associations between craniofacial morphology and the posture of the head and the cervical column in a sample of 120 Danish male students aged 22-30 years. Two head positions (self-balance position and mirror position), were recorded on lateral cephalometric radiographs. A comprehensive set of correlations was found between craniofacial morphology and head posture. The correlations were similar for both head positions investigated. Of the postural variables, the position of the head in relation to the cervical column showed the largest set of correlations with craniofacial morphology. Extension of the head in relation to the cervical column was found in connection with large anterior and small posterior facial heights, small antero-posterior craniofacial dimensions, large inclination of the mandible to the anterior cranial base and to the nasal plane, facial retrognathism, a large cranial base angle, and a small nasopharyngeal space.

Solow and Kreiborg (1977)[20] given the Soft-tissue stretching ‘hypothesis which linked postural-induced stretching of soft-tissue facial layer, craniofacial morphology, and airway adequacy into a cycle of factors related to craniofacial morphogenesis. The hypothesis stated that the soft-tissue layer of facial skin and muscles would be passively stretched when the head is extended in relation to the cervical column, which would increase the forces on skeletal structures. Such forces would restrict forward growth of maxilla and mandible and redirect it caudally.

According to **Proffit WR (1978)[21],** the major primary factors in the dental equilibrium appear to be resting pressures of tongue and lips, and forces created within the periodontal membrane, analogous to the forces of eruption. Forces from occlusion probably also play a role in the vertical position of teeth by affecting eruption. Respiratory needs influence head, jaw and tongue posture and thereby alter the equilibrium. "Deviate swallowing" is more likely to be an adaptation than a cause of tooth changes. Patients with failure of eruption have been recognized and alterations in the eruption mechanism may be more important clinically than has been recognized previously.

Vig PJ et al (1980)[17] had evaluated experimental manipulation of head posture. The results showed that total nasal obstruction results in all cases in an extended head position. The concluded that experimentally induced conditions indicate a dominance of the respiratory adaptation in terms of postural response to these stimuli.

Weber Z J, Preston C. B and Wright P. G. (1981)[22] had conducted a study on resistance to nasal airflow related to changes in head posture to determine whether artificially induced extended head posture decreases the resistance to nasal airflow. This study included fifteen male students with normal vertical facial proportions and no history of chronic mouth breathing. Head posture was assessed by measuring the craniovertical angle by means of an angle finder. Nasal resistance units were calculated from the parameters of nasal airflow and differential pressure across the nasal airway during the complete respiratory cycle using an equation analogous to Ohm‘s law. Readings were obtained in both the normal and 10 degree extended head posture position and the results were compared. They concluded that there was no association found between an extended head posture position and a decreased resistance to nasal airflow.

Marcotte (1981)[16] conducted a study to find the relationship between head posture and dentofacial proportions on 136 patients from an orthodontic practice. Results of the study showed that when the lower jaw is protrusive relative to upper jaw, the posture of head was angled downward and vice versa.

Solow et al. (1984)[23] had evaluated three sets of associations (craniocervical posture, craniofacial morphology and airway adequacy) in a single group of non-pathologic subjects with no history of airway obstruction. Cephalometric radiographs taken in the natural head position and rhinomanometric recordings were obtained from twenty- four children aged 7 to 9 years. The results show predicted patterns of association between craniofacial morphology, craniocervical angulation and airway resistance.

Solow and Nielsen (1986)[24] conducted a study to determine an association between craniocervical angulation with craniofacial morphology in a longitudinal analysis of growth changes in posture and craniofacial morphology. The sample comprised 43 children, 20 girls and 23 boys. Cephalometric radiographs obtained in the natural head position (mirror position) were taken on two occasions. Mean age at the first observation was 9.5 years; mean period of observation was 2.7 years with a range from 1 to 4 years. Correlation coefficients were calculated between growth changes in 11 postural and 35 morphologic variables. Correlations were found between the change in craniocervical angulation and the true growth rotation of the mandible as assessed by the method of structural superimposition. On an average, a reduction of the craniocervical angle was seen in connection with increased forward rotation of the mandible and an increased craniocervical angle was found in conjunction with a less- than-average forward rotation of the mandible. The true mandibular rotation was masked by remodeling of the lower mandibular border. The changes in the conventional measures of head posture the craniovertical angles during the observation period showed no associations with the growth changes in craniofacial morphology.

Archer and Vig (1985)[25] investigated the variations in resting lip and tongue pressures and their relationship to alterations in head posture in subjects with Class I (10 subjects) and Class II dental (11subjects) and skeletal morphology. Pressures were recorded in natural head position, with 20 degrees of head extension and 20 degrees of head flexion. The Friedman two-way analysis of variance using ranked data was used to compare transducer location and head posture within skeletal classes, Anterior pressures were found to differ from posterior pressures in both classes. In Class I subjects, posterior lingual pressures were consistently different from labial pressures in all head positions. In Class II subjects, posterior lingual pressures differed from labial pressures in flexion and natural head positions, and from anterior lingual pressures in flexion and natural head positions. No increase in labial pressures with head extension was found in either Class I or Class II samples. Since every subject showed pressure changes with changes in head position, the influence of posture should be considered in studies on facial morphology and dental equilibrium.

Hellsing E and Estrange PL (1987)[18] analyzed changes in upper and lower resting lip pressures following extension and flexion of the head and at changed mode of breathing in a sample of 15 adults with Class I molar relationship. The lip pressure was measured with bonded strain gauge transducers on the upper and lower central incisors. The upper and lower lip pressures during natural head posture had a mean value of 3.91 g/cm^2 and 8.5 g/cm^2 respectively. The mean values of the differences between pressures obtained during natural head posture and during 5˚, 10˚, and 20˚ of extension showed a continuously, highly significant increase in pressure. During 5˚, 10˚, and 20˚ of flexion, the upper lip pressure continuously decreased with highly significant values. Changes in the lower lip pressure during flexion were difficult to measure because of intense muscle activity. A significant decrease was shown for the difference in upper and lower lip pressures between nose breathing and mouth breathing, whereas there was increase in pressure when the subject extended the head 5˚ during mouth breathing.

Cheng et al. (1988)[26] had studied the developmental effects of impaired breathing in the face of the growing children**.** Craniofacial morphology and occlusal pattern were evaluated in 71 subjects having impaired breathing as diagnosed by an otolaryngologist, and in an equal number of controls. The impaired group demonstrated characteristic combinations of craniofacial deformities and malocclusions, with the younger individuals demonstrating a lesser expression of malocclusion progression and morphologic deformities. They concluded that early recognition of such facial patterns may be utilized to identify those breathing compromised individuals who have a likely tendency to develop certain types of malocclusion.

Surender Nanda (1990)[27], in his study found out that the cranial base angle demonstrated clear sexual dimorphism and its magnitude was not associated with vertical dysplasia.

Solow and Nielsen (1992)[28] conducted a study to determine whether growth changes in craniofacial structure could be predicted by variables expressing the postural relations of the head and the cervical column. The sample comprised 34 children, 16 girls and 18 boys with the mean age of 9.9 years (T1) and 12.7 years (T2). Selection of the sample was based on skeletal maturity at T2 indicating peak activity in pubertal growth. The results showed that there was a uniform field of low to moderate correlation coefficients significant, indicating that a small craniocervical angle and a backward-inclined upper cervical column at T1 was associated with horizontal facial development characterized by reduced backward displacement of the temporo-mandibular joint , large maxillary growth in length, increased facial prognathism and larger than average true forward rotation of the mandible; whereas , a large craniocervical angle and an upright position of the upper cervical column at T1 was associated with vertical facial development characterized by large backward displacement of the TMJ, reduced growth in length of the maxilla, reduced facial prognathism and less than average true forward rotation of the mandible.

Solow B et al. (1993)[29] had examined the effect of airway obstruction on craniocervical posture in a sample of 50 adult males aged 28-70 with severe obstructive sleep apnea. Lateral cephalometric radiographs taken in the natural head position and the Apnea Index ranged from 21 to 98 episodes per hour with a mean of

54.6. Control samples were available from previous cephalometric studies of head posture in five samples of healthy subjects and one sample of congenitally blind subjects. The average craniocervical angle was found to be extremely large exceeding the average values in the control samples by 1–2 standard deviations .The result showed that the large craniocervical angle in obstructive sleep apnea patients was a physiological adaptation aiming to maintain airway adequacy while the head, and thus the visual axis, is kept in its natural relationship to the true vertical. The result showed evidence for the hypothesis that upper airway obstruction may trigger an increase in the craniocervical angulation.

Fricke B et al. (1993)[30] had conducted a study on Nasal airway, lip competence, and craniofacial morphology to demonstrate whether children selected by their open lip posture showed differences in their nasal airway resistance and facial morphology compared to children with closed lip closure. Thirty-two children with poor lip competence were compared to a control group of 20 with secure mouth closure. The result showed that the patients with poor lip competence showed a significantly higher mandibular plane angle and also mandibular plane to maxillary plane angle. Anterior rhinomanometry, as well as measurements of the pharyngeal space on lateral head films, displayed no significant differences between the two groups.

Ozbek MM and Koklu A. (1993)[31], conducted a study for the statistical associations between postural and morphologic variables of the head. Interpretation of the facial structure was made by using both intracranial and the extracranial reference lines. The sample comprised natural head posture (NHP) cephalograms of 106 dental students, aged 19 to 29 years. Results showed that, when the facial structure was evaluated by using a NHP analysis based on extracranial reference lines, it was associated with the inclination of the cervical column to the true horizontal. In addition, in the natural position of the head, inclination of the NSL reference was found to be associated with the vertical localization of sella turcica rather than the "extension" or "flexion" of the head. It was concluded that associations between posture and structure of the head are merely caused by the functional factors related to "forward cervical posture" and "vertical cervical posture".

Huggare and **Michael (1994)**[32], studied the separate and the combined influence of head posture and cervicovertebral anatomy on mandibular growth direction on a sample of 20 boys and 16 girls, of the age group 12-years all with initial and 2–5- year follow-up lateral cephalometric radiographs recorded in natural head position (NHP). Postural variables were measured in terms of craniovertical, craniocervical, and cervicohorizontal angulations. Morphological variables of the craniocervical junction region were measured in terms of intervertebral space and atlantoaxial dimensions. Mandibular growth was estimated as the direction of displacement of prognathion in relation to the sella nasion line when superimposing on stable cranial base structures. The data was analyzed separately for boys and girls and in both sexes the height of the atlas dorsal arch showed a statistically significant correlation with mandibular growth direction and while the craniovertical angulation correlated significantly only for the boys. However, atlas dorsal arch height (DORS C1) combined with cervicohorizontal angulation in girls and with craniovertical angulation in boys, displayed a significantly increased correlation. Combination of atlas morphology and head posture predicts mandibular growth direction better than either variable alone.

Sandikcioglu and **Beni Solow (1994)**[33] studied the associations between dimensions of the first cervical verebra, atlas, and a representative set of craniofacial and postural variables on cephalometric radiographs on a sample of 103 adult males aged 22–30 years, recorded in the natural head position (mirror position). Atlas morphology was expressed by nine variables, linear and angular craniofacial dimensions by 27 variables, and head and cervical posture by seven variables. Although the correlations were low, the study confirmed that the dimensions of the atlas verebra reflect associations between cranio-cervical posture and craniofacial morphology. Negative correlations were found between the height of the posterior arch of atlas and the inclination of the mandible and the maxilla to the anterior cranial base. Low positive correlations between the height of the anterior arch and vertical facial dimensions reflect the general co-ordination of the vertical growth of the face and the cervical column. Moreover, the pattern of correlations between the atlanto-cranial angle and facial morphology suggests that in changes of the cranio-cervical angle, atlas follows the cervical column.

Gonzalez HE, Manns A (1996)[34] : An extensive conceptual analysis to establish the primary role a forward head posture plays in the appearance of some craniomandibular dysfunctions and internal derangements of the temporomandibular joints, associated to craniocervical postural disturbances. The analysis was based on findings contributed by scientific investigations in the field of dentofacial orthopedics and dysfunction. Special emphasis had been put on the influence of forward head posture on the craniofacial growth as it can determine a morphoskeletal and neuromuscular pattern leading to a dysfunctional condition. A correlation was established between Class II Occlusion, forward head posture, and craniomandibular dysfunction. The concept of craniocervical postural position was defined, as well as its close relation to the mandibular postural position.

Huggare J and Houghton P (1996)[35] studied relationships between atlantoaxial and craniofacial morphology based on macroscopical observations of skeletal material derived from 38 prehistoric Polynesian and 53 prehistoric Thai people. The two uppermost cervical verebrae and the mandible of each individual were studied macroscopically and each skull base was analyzed on cephalometric X-rays in lateral projection. The height of the atlantal anterior and posterior arches displayed a significant negative correlation with the cranial base angulation, in that the higher the arches the steeper the flexure between the sphenoidal/clival and clival/foraminal planes. None of the axial variables were associated with the cranial base angulation. The height of the atlantal posterior arch was also associated with the mandibular length, ramal height and gonial angle. Thus, in general, a high arch was seen in conjunction with a long, high and square shaped mandible, whereas a low arch was usually found together with a short and low mandible characterized by an obtuse jaw angle. The anterior height of the axis (vertebral mass + dens) was significantly associated with mandibular length and ramal height. It is suggested that these results are evidence of the intimate ontogenetic development of the atlas and the cranial base, and a reflection of the functional relationship between atlas and cranium

B Solow, L Sonnesen (1998)[36] had examined whether any pattern of associations could be found between the posture of the head and neck and the occurrence of malocclusions. The sample comprised lateral cephalograms of 96 children, 45 and 51 female, aged 7-13 years. Malocclusions were diagnosed clinically and classified into occlusal, spacing, and dental anomalies and their subdivisions. The result showed a clear pattern of associations between crowding and craniocervical posture.

B Lofstrand-Tidestrom et al. (1999)[37] had carried out a study on breathing obstruction in relation to craniofacial and dental arch morphology in 4-year-old children. The 'snoring group' comprised of 48 children who, based on parental report, snored every night or stopped breathing when snoring, showed a higher rate of disturbed sleep, mouth-breathing, and a history of throat infections as compared with the rest of the cohort. Twenty-eight of the children were diagnosed as having a breathing obstruction and six children had sleep apnea. The result showed that the children with obstructive breathing had a narrower maxilla, a deeper palatal height, and a shorter lower dental arch and in addition, the prevalence of lateral cross bite was also significantly higher among these children when compared with 48 asymptomatic children from the same cohort.

Milani RS et al. (2000)[38] The purpose of this study was to show the effects of dental occlusion on postural position. Thirty subjects were divided into two groups: an experimental group who wore mandibular orthopedic repositioning appliances (MORA) and a control group who wore no oral device. All of the subjects underwent the same Fukuda-Unterberger experimental stepping test to check their postural attitude.. The results seemed to confirm that altering dental occlusion by wearing an oral appliance could induce some fluctuations in dynamic postural attitude. The phenomenon occurs after prolonged wearing of a MORA. Feedback effects are gradual after removing the mandibular splint.

Pedro Leitao and Ram S. Nanda (2000)[39] aimed at discussing the utility of natural head position–based cephalometric variables and to evaluate the relationship between natural head position and craniofacial morphology. Lateral facial photographs and cephalograms of 284 young adult males taken in a natural head position were analyzed. The average inclination of the intracranial reference planes, Frankfurt horizontal, and palatal plane, in relation to the true horizontal were nearly similar and smaller than 1°. Variables based on the true vertical to describe mandibular sagittal position like B-N(ver) and Pg-N(ver) had very high variances. The "extenders" had higher values for the facial axis and lower face height, and smaller for the face height ratio. Besides these 3 measurements, there was a tendency for the extenders to have increased anterior vertical height, distal sagittal relations, and smaller and retrognathic mandibles.

Motoyoshi et al (2002)[40] The biomechanical influences of head posture on the cervical column and craniofacial complex during masticatory simulation were quantified using three-dimensional (3D) finite element analysis (FEA). Three types of finite element model (FEM) were designed to examine relationships between the position of the head and malocclusion. Model A was constructed to have a standardized cervical column curve, model B a forward inclined posture, and model C a backward inclined posture. The results showed that alteration of head posture was directly related to stress distribution on the cervical column, but may not always directly influence the occlusal state.

Dhopatkar A, Bhatia S and Rock P (2002)[41] carried out retrospective cephalometric study to examine the contribution of cranial base angle in four groups of incisor malocclusion as classified by the British Standards Institution. Results showed that the cranial base flexure does not play a pivotal role in determining malocclusion. Jaw size, however, was significantly different between the main classes of malocclusion. The maxilla was found to be longer in class II subjects and the mandible longer in class III subjects.

Festa F et al. (2003)[42] evaluate the association between cervical lordosis angle and mandibular length from lateral skull radiographs, and to investigate the relationship between mandibular retrusion and cervical lordosis angle decreasing. The sample comprised 70 Caucasian adult women, average 27.4, in skeletal class II and Angle class II. Lateral skull radiographs were obtained in natural head position (mirror position). Ten morphological variables were individuated on tracings. Results showed a negative correlation ($P < 0.01$) between cervical lordosis and mandibular length (compensatory curvature of the cervical spine) and positive correlation between anterior cranial base and maxillary length ($P < 0.05$). Based upon the cross-sectional method, no conclusion was possible about the mechanism concerning these results.

Michele DÕAttilio et al. (2004)[43] investigated whether there are significant differences in cervical posture in subjects with a different sagittal morphology of the face, i.e., a different skeletal class. One hundred twenty (120) children (60males and 60 females, average age 9.5 yrs) were admitted for orthodontic treatment. Lateral skull radiographs were taken in mirror position. Subjects were divided into three groups based on their skeletal class. The cephalometric tracings included postural variables. Children in skeletal class II showed a significantly higher extension of the head upon the spinal column compared to children in skeletal class I and skeletal class III. This is probably because the lower part of their spinal column was straighter than those of subjects in skeletal class I and II. Significant differences among the three groups were also observed in the inclination of maxillary and mandibular bases to the spinal column. The posture of the neck seems to be strongly associated with the sagittal as well as the vertical structure of the face

Sonnesen L et al. (2007)[5] had done a study on cervical column morphology related to head posture, cranial base angle and condylar malformation. Sample comprised 21 subjects, 15 females aged 23 - 40 years and six males aged 25 - 44 years with neutral occlusion and normal craniofacial morphology. The condylar hypoplasia group comprised of the lateral profile radiographs of 11 patients, eight females, and three males, aged 12 – 38 years. The results showed that morphological deviations of the cervical column occurred significantly more often in the subjects with condylar hypoplasia compared with the normal group and the pattern of morphological deviations was significantly more severe in the subjects with condylar hypoplasia compared with the normal group. When cervical column was related to head posture and cranial base, the cervicohorizontal and cranial base angles were statistically larger in females than in males. No statistically significant age differences were found. Only in females the cervical lordosis angle, the inclination of the upper cervical spine, and the cranial base angle was positively correlated with fusion of the cervical column. These associations were not due to the effect of age.

Sonnesen L and Kjaer I (2007)[9] examined cervical column morphology in 41 adult patients with a skeletal deep bite consisting of 23 females aged 22 - 42 years (mean 27.9 years) and 18 males aged 21 - 44 years (mean 30.8 years) and compared with the cervical column morphology in an adult control group consisting of 21 subjects, 15 females, aged 23 - 40 years (mean 29.2 years) and six males aged 25 - 44 years (mean 32.8 years) with neutral occlusion and normal craniofacial morphology. None of the patients or control subjects had received orthodontic treatment. For each individual, a visual assessment of the cervical column and measurements of the cranial base angle, vertical craniofacial dimensions, and morphology of the mandible were performed on a profile radiograph. In the deep bite group, 41.5 per cent had fusion of the cervical verebrae and 9.8 per cent had posterior arch deficiency. The fusion always occurred between C2 and C3. No statistically significant gender differences were found in the occurrence of morphological characteristics of the cervical column (females 43.5 per cent, males 38.9 per cent). Morphological deviations of the cervical column occurred significantly more often in the deep bite group compared with the control group. Logistic regression analysis showed that the vertical jaw relationship, overbite and upper incisor inclination were significantly correlated with fusion of the cervical verebrae.

Peltomaki T (2007)[44] had conducted a study on the effect of mode of breathing on craniofacial growth-revisited. On evaluation they found that because of large adenoids, nasal breathing is obstructed leading to mouth breathing and an ‗adenoid face' characterized by an incompetent lip seal, a narrow upper dental arch, increased anterior face height, a steep mandibular plane angle, and a retrognathic mandible. Children with obstructive sleep apnea (OSA) have similar craniofacial characteristics as those with large adenoids and tonsils, and the first treatment of choice of OSA children is removal of adenoids and tonsils. It is probable that some children with an adenoid face would nowadays be diagnosed as having OSA. These children also have abnormal nocturnal growth hormone (GH) secretion and somatic growth impairment, which is normalized following adeno-tonsillectomy. It is hypothesized that decreased mandibular growth in adenoid face children is due to abnormal secretion of growth hormone and its mediators. After normalization of hormonal status, ramus growth is enhanced by more intensive endochondral bone formation in the condylar cartilage and/or by appositional bone growth in the lower border of the mandible. They concluded that the acceleration in the growth of the mandible and alteration in its growth direction, following the change in the mode of breathing after adeno- tonsillectomy.

Cuccia AM, Lotti M and Caradonna D (2008)[45] had done a study to determine the head posture and cephalometric characteristics in oral breathing children. Lateral cephalograms taken in natural head posture of 35 oral breathing patients (OB) and of 35 patients with varied malocclusions and physiological breathing (PB) were examined. The results showed that children with oral breathing showed greater extension of the head related to the cervical spine, reduced cervical lordosis, and more skeletal divergence when compared with physiological breathing subjects.

L. Sonnesen and I. Kjær (2008)[46] Cervical column morphology was examined in adult patients with skeletal Class II malocclusion and horizontal maxillary overjet; the findings were compared with cervical column morphology in an adult control group with neutral occlusion and normal craniofacial morphology. The overjet group (5.47 to 15.29 mm) consisted of 34 patients: 28 women (ages, 18-42 years) and 6 men (ages, 18-38 years) and control group consisted of 21 subjects: 15 women (ages, 23-40 years) and 6 men (ages, 25-44 years). A visual assessment of the cervical column was made, and craniofacial dimensions were measured on each subject's profile radiograph. In the overjet group, 52.9% had fusion of the cervical column, and 5.9% had posterior arch deficiency. Fusions occurred significantly more often in the overjet group compared with the control group. Associations were found between fusions of the cervical column and mandibular retrognathia, large cranial base angle, and large horizontal overjet.

Pachi F, Turla R, Checchi AP (2009)[14] had done a study to test the null hypothesis that there is no relationship between the posture of the head and the neck and late lower arch crowding The sample comprised 55 subjects 23 female and 32 male, age 12-18 years, with complete permanent dentition and without previous orthodontic treatment. Craniovertical, craniocervical, and craniohorizontal postural variables were recorded from lateral cephalograms. The results showed that the differences of the postural variables between the two groups were statistically significant. Subjects with more than 2 mm dental crowding had mean craniocervical angles that were 5˚to 6˚ larger than the subjects with the space conditions smaller than 2 mm. In addition, the mean craniohorizontal angles in the subjects with lower dental crowding were 4˚ smaller than subjects without dental crowding. They concluded that there was a clear pattern of association between extended head posture and lower arch dental crowding.

Svanholt P et al. (2009)[47] analyzed craniofacial profiles and head posture in patients with obstructive sleep apnea(OSA) sub grouped according to cervical column morphology. Seventy four white men aged 27 to 65 years (mean = 49 years) diagnosed with OSA in sleep studies by using overnight polysomnography were included. Only patients with apnea – hypopnea index scores between 5.1 and 92.7 were included. Lateral profile radiographs in standardized head posture were taken and cephalometric analyses of sagittal and vertical jaw relationships were made. The patients were divided into four groups according to fusion in the cervical verebrae: group 1, no fusion (42 subjects); group 2, fusion of cervical verebrae 2 and 3 (15 subjects); group 3, occipitalizaton (10 subjects); and group 4, block fusion (11 subjects). Mean differences of craniofacial dimensions between the groups was done by unpaired t-test. No significant differences were seen between groups 1 and 3. Between groups 1 and 2 significant differences were seen in jaw relationship. Between groups 1 and 4 anterior face height and mandibular length deviated significantly. No significant differences were seen in head posture.

Sonnesen L (2010)[11] analyzed associations between the cervical vertebral column and craniofacial morphology. The purpose of this study was to summarize recent studies on morphological deviations of the cervical vertebral column and associations with craniofacial morphology and head posture in non-syndromic patients and in patients with obstructive sleep apnea (OSA). Material from human triploid fetuses and mouse embryos were analyzed histologically. The result showed that the recent studies have documented associations between fusion of the cervical vertebral column and craniofacial morphology, including head posture in patients with severe skeletal malocclusions. Histological studies on prenatal material supported these findings. They concluded that fusion of the cervical vertebral column is associated with development and function of the craniofacial morphology.

This finding is expected to have importance for diagnostics and elucidation of etiology and thereby for optimal treatment.

Arntsen T and Sonnesen L (2011)[48], examined cervical column morphology in preorthodontic children with Class II malocclusion and horizontal maxillary overjet and related it to craniofacial morphology and head posture. Two hundred thirteen children (aged 7-15 years) with a horizontal maxillary overjet of more than 6 mm were divided into 2 groups of skeletal and dentoalveolar overjets. The skeletal overjet group comprised 99 patients (43 girls, 56 boys). The dentoalveolar overjet group comprised 114 subjects (58 girls, 56 boys). Visual assessments of the cervical column and measurements of craniofacial morphology and head posture were made on profile radiographs. Deviations in the cervical vertebral column morphology occurred significantly more often in the skeletal overjet group (28%) compared with the dentoalveolar overjet group (17%). Fusion anomalies were associated with a large sagittal jaw relationship, retrognathia of the jaws, large inclination of the jaws, and extended head posture. Furthermore, a partial cleft was significantly associated with a large cranial base angle. New associations were found between cervical column morphology, craniofacial morphology, and head posture in preorthodontic children with horizontal maxillary overjet. These findings are considered important for diagnostics and thus for a more accurate treatment plan of these patients.

Shrivastava T, Thomas M (2012)[49] had conducted a study to determine the head posture in oral breathing children and compared variations in head posture between physiologic breathing and mouth breathing children and then analyzed the influence of mouth breathing related to an upper airway obstruction, on the head posture in growing children within the age group of 8 to 14 years. This study included 50 children between the age group of 8 and 14 years and was divided into two groups based on the type of breathing pattern, Physiologic breathing with 25 subjects and Mouth breathing with -25 subjects. The results revealed that craniofacial morphology in mouth breathers differs profoundly when compared to that of the physiologic breathers. They concluded that there should be an early interception of mouth breathing in growing children as these postural changes, if maintained for long periods could lead to severe skeletal deformities.

Springate (2012)[50] had conducted a re-investigation of the relationship between head posture and craniofacial growth. The material comprised of the cephalometric radiographs of 59 children 34 males and 25 females recorded in natural head posture. Correlation analysis showed the strongest associations to be found between growth direction of the face and the change in posture. No association was found between growth in direction or magnitude and pre-observation posture.. They concluded that there was pattern of the correlations and the inter-relationships between the main growth variables suggesting that this linkage arises from the coordinated changes that occur in the posture of the mandible and tongue and these coordinated postural changes appear to determine the growth direction of the mandible and, at the same time, influence cranio cervical posture (CCP), possibly via an effect on pharyngeal patency.

Rana T and Khanna R (2012)[51] conducted a cephalometric study to determine the relationship of maxilla with cranial base in different facial types. The sample consists of 120 pretreatment lateral cephalogram, which were categorized into three groups, normodivergent, hypodivergent, and hyperdivergent. Each group consisted of 20 males and 20 females. The result of this study implied that in hyperdivergent subjects' sagittal maxillary base size was smaller and upper posterior facial height (UPFH) was increased in comparison to hypodivergent and normodivergent subjects. Upper posterior facial height has positive correlation with anterior facial height. Posterior maxillary position in relation to cranial base increases with increase in cranial flexural angle in hypodivergent subjects and vice versa in hyperdivergent subjects. Upper posterior facial height decreases with increase in cranial flexural angle in hypodivergent subjects and vice versa in hyperdivergent subjects.

Kim P, Sarauw MT and Sonnesen L (2014)[52] analyzed one hundred eleven patients (ages, 6-18 years) with an anterior open bite of more than 0 mm and divided them inton 2 groups, skeletal or dentoalveolar open bite. The skeletal open-bite group comprised of 38 subjects (19 girls, 19 boys) and the dento-alveolar open-bite group comprised of 73 subjects (43 girls, 30 boys). Visual assessment of the cervical column and measurements of craniofacial morphology and head posture were made on profile radiographs. They found that deviations in the cervical vertebral column morphology occurred in 23.7% of the subjects in the skeletal open-bite group and in 19.2% in the dentoalveolar open-bite group, but the difference was not significant. Head posture was significantly more extended in the skeletal open-bite group compared with the dentoalveolar open-bite group. They found out that only head posture was associated with craniofacial morphology: extended posture was associated with a large cranial base angle, large vertical craniofacial dimensions, and retrognathia of the jaws. No significant differences in the cervical vertebral column's morphologic deviations were found between the skeletal and the dentoalveolar open-bite groups. Significant differences were found in head posture between the groups and with regard to associations with craniofacial dimensions. This might indicate a respiratory etiologic component in children with anterior open bite.

Gomes et al. (2014)[53] did a study to investigate the published evidence regarding the association between head and cervical posture and craniofacial morphology. An electronic search was conducted in PubMed, Medline, Embase, Scopus, and Cochrane databases up to 23 March 2012. On the basis of the data obtained from the literature, they concluded that significant associations were found between variables concerning head and cervical posture and craniofacial morphology. However, the results suggested that such associations should be carefully interpreted, considering that correlation coefficients found ranged from low to moderate.

Bhattacharya et al. (2014)[54] carried out a study to investigate the role played by the cranial base flexure in influencing the sagittal and vertical position of the jaws in Indian population. Lateral cephalograms of 108 subjects were divided into three categories (Group A: NSAr > 125°, Group B: NSAr-120°-125°, Group C: NSAr <120°) according to value of saddle angle (NSAr). The results of the study showed that cranial base angle has a determinant role in influencing the mandibular position and it also affects both the mandibular plane angle and y-axis. Flattening of the cranial base angle caused a clockwise rotation of the mandible. The jaw relation tends to change from class III to class II, with progressive flattening of the cranial base and vice-versa.

Ansar J et al. (2014)[55] compared the dimensions of the nasopharynx and oropharynx of subjects with different growth patterns and determined whether any correlation exists with their craniocervical posture. Cephalometric radiograph of 60 subjects (16–25 years old), taken in natural head position, were divided into three groups according to the mandibular plane angle: hypodivergent (SN/MP less than 26 degrees), normodivergent (SN/MP 26–38 degrees), and hyperdivergent (SN/MP more than 38 degrees). Patients in the hyperdivergent group were found to have significantly smaller nasopharyngeal and oropharyngeal areas than the other groups. Similarly, the oropharyngeal area in the normodivergent group was significantly smaller than that in the hypodivergent group. However, no significant differences were found in the nasopharyngeal area between the hypodivergent and normodivergent groups and between the hyperdivergent and normodivergent groups. Reduced pharyngeal airways were typically seen in patients with a large craniocervical angle and a large mandibular inclination.

Ying Liu et al. (2015)[57] investigated the relationships of sagittal skeletal discrepancy, natural head position (NHP), and craniocervical posture in young Chinese children with average vertical facial pattern. Ninety patients with average Frankfort mandibular plane angle (FH/ML) were classified into skeletal class I, II, and III relationships according to their ANB angle. Cephalometric radiographs in NHP were taken. Variables representing sagittal and vertical craniofacial morphology, head posture, and craniocervical posture were measured and compared. Subjects in the skeletal class II group showed the largest craniovertical angles and craniocervical angles, while subjects in the skeletal class III group exhibited the smallest craniovertical angles and craniocervical angles. The angle formed by the nasion-sella line and the tangent to the posterior border of the mandibular ramus (NSL/RL) was largest in the skeletal class II group and smallest in the skeletal class III group ($p = 0.05$). Significant differences exist in NHP and craniocervical posture among skeletal class I, II, and III relationships in young Chinese children. Subjects with skeletal class II relationship tended to exhibit more extended head, and children with skeletal class III relationship often exhibited flexed head.

Gong et al. (2016)[56] carried out a study to investigate cranial base characteristics in malocclusions with sagittal discrepancies. Their meta-analysis showed that anterior and total cranial base length and cranial base angle were significantly smaller in Class III malocclusion than in Class I and Class II malocclusions, and that they were greater in Class II subjects compared to controls.

Cahide Aglarci (2017)[58] investigated the effect of the twin-block appliances to the cervical spine posture. Twenty-one skeletal Class II patients (11 female, 10 male; 13.31 ± 0.92) with mandibular retrusion were included in the study. Twin-block appliances with no expansion protocol were applied to all individuals. Cervical spine posture changes after treatment were evaluated by cephalograms. No significant differences were observed after treatment, in the angle between the horizontal lines of the head (sella-nasion, anterior nasal spine-posterior nasal spine, and gonion and gnathion) and the upper and middle section of the spinal column (odontoid process tangent [OPT] and cerebral venous thrombosis [CVT]) while the increase of cervical curvature angle (OPT/CVT°) was found significant after the treatment. A backward inclination of the middle segment of cervical column seems to be associated with the advancement of the mandible by twin-block treatment.

V. Ferrara, E. Accivile, C. Di Paolo (2017)[59] assessed possible changes in the posture of the head, neck and hyoid bone position in patients with Class II malocclusion with and without TMD. The cephalometric tracings of 59 subjects with Class II occlusion were evaluated and compared. The patients studied were divided into two subgroups: subgroup A patients with TMD and subgroup B without TMD. Results indicated modest correlation between Class II occlusion and abnormalities of the cervical spine. The analysis appears to be more consistent in the TMD group emphasizing the possibility that back rotation of the head on the neck might be related to joint dysfunction.

Aditya Tankhiwale et al. (2018)[60] evaluated effects of extended head posture on dental and skeletal malocclusions. Lateral cephalograms and study models of 60 patients were divided into two groups, group I [n=30 with extended head posture (NSL-CVT angle > 106)] and group II [n=30 without extended head posture (NSL-CVT angle less than 106)]. Patients with extended head posture showed class II skeletal malocclusion and a vertical growth pattern as compared to patients with normal head posture. There was statistically significant correlation of crowding with extended head posture as compared to that in patients with normal head posture. Overjet and overbite was found to be significantly more in patients with extended head posture as compared to that in patients with normal head posture. Upper and lower incisal proclination was also found to be significantly more in patients with extended head posture as compared to that in patients with normal head posture.

Material and Method

SAMPLE COLLECTION

The present study was conducted on 170 untreated subjects in the Department of Orthodontics and Dentofacial Orthopaedics. Subjects who had plans to undergo orthodontic treatment were included. Further screening of subjects for inclusion was done after a detailed case history and clinical examination. Written informed consent was obtained from each participant or his or her parents, and ethical clearance was obtained from the institutional ethics committee.

CRITERIA FOR CASE SELECTION INCLUSION CRITERIA

- Skeletal Class II by ANB angle (>4°) and Wits analysis (3mm-8mm) evaluated on lateral cephalogram taken in natural head position (NHP)

- Age group of 18 to 25 years
- No prior orthodontic treatment.
- No craniofacial anomalies or systemic muscle or joint disorders;
- All permanent teeth including second molars erupted.
- Accessibility of a profile radiograph before orthodontic treatment with the first five cervical vertebral units visible.

EXCLUSION CRITERIA

- TMJ or cervical spine disorders
- Upper respiratory disorders
- Neuromuscular disorders

MATERIALS AND INSTRUMENTS REQUIRED

1. Sample size of 170 untreated skeletal class II subjects which were divided according to different malocclusion traits
2. CS 8100 SC Carestream Digital Panoramic and Cephalomaetric system (Figure 1)
3. Digital printer (FUJI FILM DRY PIX SMART) (Figure 2)
4. Study models (Figure 3)
5. Lateral Cephalometric Radiographs (Figure 4)
6. Nemoceph software (Figure 6)
7. Geometric box (for model analysis)

Lateral Cephalometric Radiographs

Lateral skull radiographs were taken using CS 8100 SC Carestream Digital Panoramic and Cephalomaetric system. The x-ray source had a focus of 0.6 mm, and the exposure data were 72 kV and 32 mA for 1.2 seconds. The equipment had a fixed film to focus plane distance of 190 cm and a fixed film to midsagittal plane distance of 10 cm with a final enlargement of 10%. For all subjects, 24 X 30 cm films were used. All lateral skull radiographs were taken by the same operator with the subjects standing in orthoposition with the head in the natural head position (self-balanced position) as described by Sahin Sag˘lam and Uydas[15]. The lateral radiographs had to include the first four cervical verebrae

Study Models

All 170 selected subjects were divided into different malocclusion trait groups based on subjects study models as determined by model analysis.

Total sample size = 170 (Male - 90, female - 80)

↓

Divided into subgroups

MALOCCLUSAL TRAIT	SAMPLE SIZE
Crowding more than 2 mm (includes both upper and lower incisors	35
Overjet more than 3 mm	35
Overbite more than 3 mm	35
Crossbite (ranging from anterior more than one tooth involvement to bilateral full posterior	25
Proclination (as determined by upper incisor to NSL line angle and IMPA angle for upper and lower incisor proclination respectively)	40

METHOD OF MEASUREMENT

The reference points and lines used in analysis were plotted, all lateral cephalometric tracings were scanned and output images were directly convered into a portable JPEG format to the input. Seven reference points and seventeen variables were marked digitally on lateral cephalogram and measurements were done using NEMOCEPH Software, version 6.0 Nemotec SRL (Spain)

Figure 5 shows the reference points and lines used in analysis.

Reference points of the cephalograms:

1. **S**- Sella turcica (The midpoint of sella turcica)
2. **N**- Nasion (The intersection of the internasal suture with nasofrontal suture in the mid saggital plane)
3. **ANS**- Anterior nasal spine (Tip of the anterior nasal spine seen on the x ray from the normal lateralis)
4. **PNS**- Posterior nasal spine (Tip of the posterior spine of the palatine bone in the hard palate)
5. **Cv2tg-** Tangent point of OPT line on the odontoid process of the second cervical verebra
6. **Cv2ip-** The most inferior posterior point on the corpus of the second cervical verebra
7. **Cv4ip-** The most inferior posterior point on the corpus of the fourth cervical verebra

Reference lines of the cephalograms:

1. **VER**- True vertical line (true vertical line projected on the film)
2. **HOR**- True horizontal line (true horizontal line projected on the film)

3. **NSL-** Cranial base (line extending between sella and nasion)
4. **NL**- Palatal plane (line extending between ANS and PNS)
5. **FOP** – Functional occlusal plane
6. **CVT-** Cervical verebra tangent (posterior tangent to the odontoid process through Cv4ip)
7. **OPT**- Odontoid process tangent (posterior tangent to the odontoid process through Cv2ip)
8. **ML -** Tangent to the lower border of the mandible
9. Line through long axis of upper and lower incisor

List of variables

Craniofacial posture (craniovertical angles)

1. **NSL/VER-** Anterior cranial base inclination (downward opening angle between NSL line and VER line)

2. **NL/VER**- Palatal line inclination (downward opening angle between NL line and VER line)

3. **FOP/VER-** Occlusal plane inclination (downward opening angle between FOP and VER line)

4. **ML/VER**- Mandibular plane inclination (downward opening angle between ML line and VER line)

Craniocervical angulations

1. **NSL/OPT -** Craniocervical posture (downward opening angle between NSL line and OPT line)

2. **NSL/ CVT-** Craniocervical posture (downward opening angle between NSL line and CVT line)

3. **NL/OPT-** Maxillary base inclination upon cervical column (downward opening angle between NL line and OPT line)

4. **NL/CVT-** Maxillary base inclination upon cervical column (downward opening angle between NL line and CVT line)

5. **FOP/OPT-** functional occlusal plane inclination upon cervical column (downward opening angle between FOP line and OPT line)

6. **FOP/CVT-** functional occlusal plane inclination upon cervical column (downward opening angle between FOP line and CVT line)

7. **ML/OPT-** mandibular plane inclination upon cervical column (downward opening angle between ML line and OPT line)

8. **ML/CVT-** mandibular plane inclination upon cervical column (downward opening angle between ML line and CVT line)

Cervical posture

1. **CVT/HOR**- Craniohorizontal angle (upward opening angle between HOR line and CVT line)

2. **OPT/HOR**- Craniohorizontal angle (upward opening angle between HOR line and OPT line)

Cervical curvature

1. **OPT/CVT** – cervical curvature angle

Maxillary incisor inclination

1. Angle between NSL plane and long axis of maxillary incisor

Mandibular incisor inclination

1. **IMPA** - Incisor mandibular plane angle (upward opening angle between mandibular plane and long axis of mandibular incisor)

COLOUR PLATE I

Fig. 1: CS 8100 SC Carestream Digital Panoramic and Cephalomaetric system

Fig. 2: Digital Printer (Fujifilm Dry Pix Smart)

COLOUR PLATE II

Figure 3: Study Models

Figure 4: Soft Copy of Lateral Cephalogram

COLOUR PLATE III

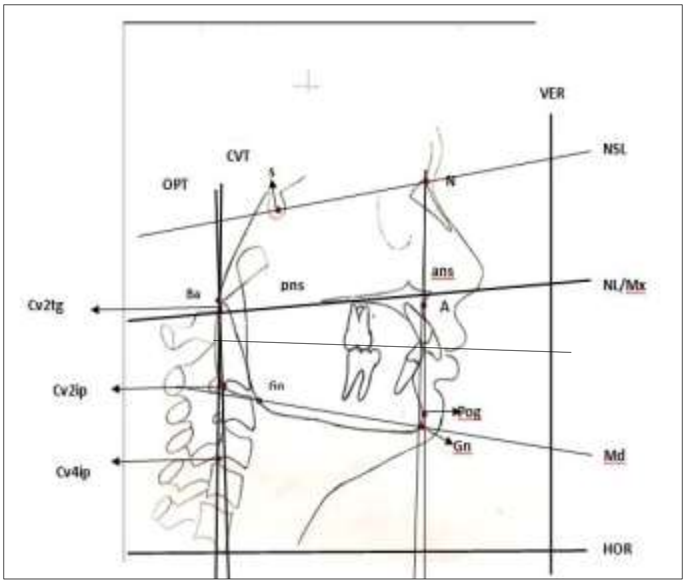

Fig. 5: Reference Points and Lines used in the Cephalometric Analysis

Figure 6: Nemoceph Software, Version 6.0 Nemotec Srl (Spain)

COLOUR PLATE IV

Figure 7: Caliberation on Nemoceph Software

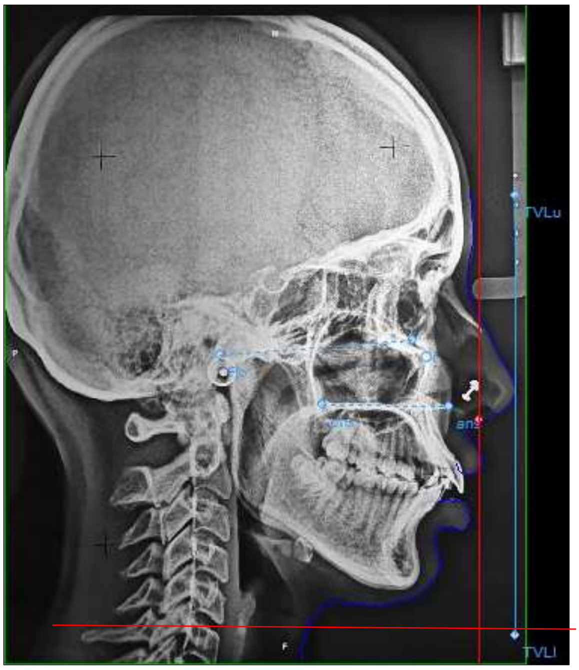

Figure 8: Marked VER and HOR on Nemoceph Software

COLOUR PLATE V

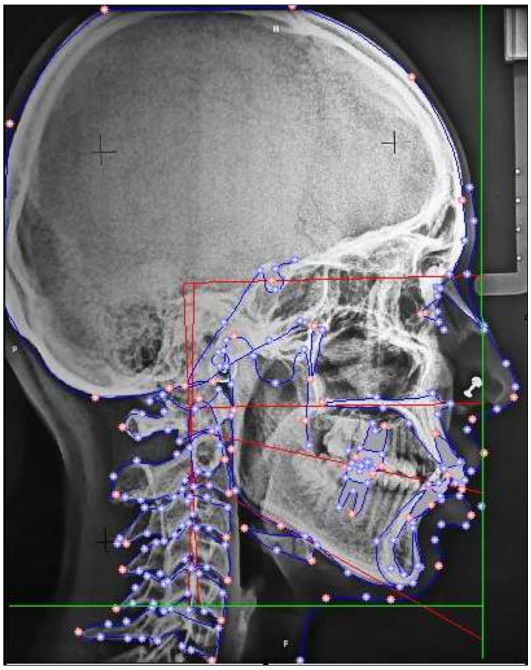

Figure 9: Traced Landmarks on Nemoceph Software

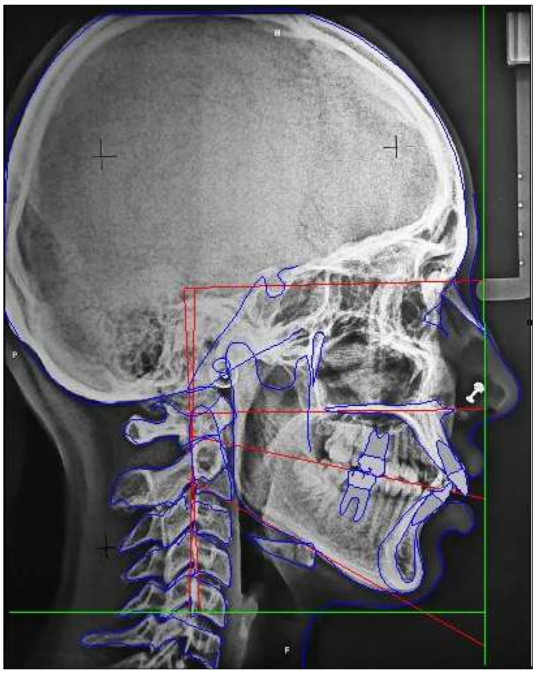

Figure 10: Completed Tracing on Nemoceph Software

Results

Results

The descriptive statistics displaying the mean values along with standard deviations of postural variables were calculated amongst the groups with following malocclusion traits:

- Crowding
- Increased overjet
- Increased overbite
- Crossbite
- Proclination

The statistical analysis was done using the Statistical Package for the Social Science (SPSS version 22, Armonk, NY: IBM Corp). The recorded values were statistically evaluated using the one-way analysis of variance test (ANOVA), followed by Tukey post hoc test for multiple comparisons. The one-way analysis of variance (ANOVA) is used to determine whether there are any significant differences between the means of two or more independent (unrelated) groups. The independent samples t-test was done to find if any statistically significant difference existed for the postural variables amongst males and females. The relationship between postural variables and malocclusion traits was determined using Spearman's correlation coefficient. The relationship between inclination of upper and lower incisors, interincisal angle with postural variables amongst the proclination group was evaluated using Pearson's correlation coefficient. The "p" values were considered significant at or below 0.05.

Some of the statistics computed to test the hypothesis are as below:

Arithmetic Mean

The arithmetic means or mean is the most commonly used and readily understood measure of central tendency in a data set. In statistics, the term average refers to any of the measures of central tendency. The arithmetic mean of a set of observed data is defined as being equal to the sum of the numerical values of each and every observation divided by the total number of observations. Symbolically, if we have a data set consisting of the values, then the arithmetic mean is defined by the formula:

$$A = \frac{1}{n}\sum_{i=1}^{n} a_i = \frac{a_1 + a_2 + \cdots + a_n}{n}$$

Standard Deviation:

The standard deviation is a statistic that measures the dispersion of a dataset relative to its mean and is calculated as the square root of the variance. It is calculated as the square root of variance by determining the variation between each data point relative to the mean.

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n-1}}$$

where:

xi=Value of the *ith* point in the data set

x=The mean value of the data set

n=The number of data points in the data set.

Independent Samples t-Test:

The Independent Samples t-Test compares the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. The Independent Samples t-Test is a parametric test. When the two independent samples are assumed to be drawn from populations with identical population variances (i.e., $\sigma 1^2 = \sigma 2^2$), the test statistic t is computed as:

With

$$t = \frac{\overline{x}_1 - \overline{x}_2}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where,

$$s_p = \sqrt{\frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2}}$$

x¯1 = Mean of first sample

x¯2 = Mean of second sample

n1 = Sample size (i.e., number of observations) of first sample

n2 = Sample size (i.e., number of observations) of second sample

s1 = Standard deviation of first sample

s2 = Standard deviation of second sample

sp = Pooled standard deviation

The calculated t value is then compared to the critical t value from the t distribution table with degrees of freedom df = n1 + n2 - 2 and chosen confidence level. If the calculated t value is greater than the critical t value, then we reject the null hypothesis. Note that this form of the independent samples T test statistic assumes equal variances.

One-Way ANOVA:

One-Way ANOVA ("analysis of variance") compares the means of two or more independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. One-Way ANOVA is a parametric test. Numerically, one-way ANOVA is a generalisation of the two-sample t test. The F statistic compares the variability between the groups to the variability within the groups:

$$F = \frac{MST}{MSE}$$

$$MST = \frac{\sum_{i=1}^{k}(T_i^2/n_i) - G^2/n}{k-1}$$

$$MSE = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n_i} Y_{ij}^2 - \sum_{i=1}^{k}(T_i^2/n_i)}{n-k}$$

where F is the variance ratio for the overall test, MST is the mean square due to treatments/groups (between groups), MSE is the mean square due to error (within groups, residual mean square), Yij is an observation, Ti is a group total, G is the grand total of all observations, ni is the number in group i and n is the total number of observations.

Tukey's Post-hoc test:

After performing ANOVA, if alternative hypothesis H1 is accepted, then the subsequent interest is to determine the pair wise significance of difference in the means of study groups. This could be carried using Tukey's post-hoc test. The difference between the means of all groups are determined and compared with this critical difference called the honest significant difference (HSD). It is given by:

$$HSD = q\sqrt{\frac{MS_{within}}{n}}$$

where, q is the standardized range statistic derived from the tables, n is the sample size and the mean square value are from the ANOVA analysis. If the critical difference exceeds the absolute difference between any two-sample means, then the correspondingmeans differ significantly.

Results of the present study :

Comparison of postural variables amongst males and females

The mean values of all postural variables were almost equal amongst males and females. There did not exist any statistically difference between males and females with respect to any of the postural variables. (Table 1)

Comparison of postural variables amongst different malocclusion groups

The comparison of postural variables amongst different malocclusion traits have been explained as below: (Table 2 & 3)

Cranio-vertical angulations

- NSL/VER (Anterior cranial base inclination): There existed a highly statistically significant (p = 0.001) difference amongst all the malocclusion groups with respect to anterior cranial base inclination. The mean values were greater in patients with crowding, 96.9 ± 2.6 and crossbite, 96.8 ± 3.5, followed by least values for patients with increased overjet, 93.7 ± 5.0. Upon subject to post hoc analysis, it was seen that there existed a statistically significant difference between crowding and increased overjet (p=0.005), crowding and increased overbite (p = 0.03), crossbite and increased overjet (p =0.02). (Fig. 1)

- NL/VER (Palatal line inclination): The mean values of palatal line inclination were seen in patients with increased overbite, 91.2 ± 2.8 followed by crossbite, 90.3 ± 3.5 crowding, 89.3 ± 3.0, proclination 89.7 ± 3.0, whereas it was least in patients with increased overjet 88.5 ± 3.5. This difference was highly statistically significant ($p = 0.008$). On subject to post hoc analysis, it was seen that a statistically significant difference existed between increased overjet and increased overbite ($p = 0.004$). (Fig. 2)

- FOP/VER (Occlusal plane inclination): The mean values of occlusal plane inclination were greater in patients with crossbite 94.3 ± 4.2, followed by increased overbite 86.9 ± 4.8, increased overjet 84.4 ± 6.5, crowding 84.2 ± 11.5, whereas the values were least in patients with proclination 83.5 ± 8.3. This difference was highly statistically significant ($p = 0.001$). On subject to post hoc Tukey's test, it was seen that a statistically significant difference existed between crowding and crossbite ($p = 0.0001$), increased overjet and crossbite ($p = 0.0001$), increased overbite and crossbite ($p = 0.003$), proclination and crossbite ($p = 0.0001$). (Fig. 3)

- MP/VER (Mandibular plane inclination): The mean values of mandibular plane inclination were greater in patients with crossbite 88.3 ± 3.1, followed by increased overbite 83.4±6.1, increased overjet 68.5 ± 6.1, proclination 64.6 ± 6.2 and these values were less in patients with crowding 63.3 ± 6.3. This difference was highly statistically significant ($p = 0.001$). The post hoc analysis revealed that a statistically significant difference existed between all the groups of malocclusion except for the pair of crowding and proclination ($p =0.87$). (Fig. 4)

Cranio-cervical angulations

- NSL/OPT (Cranio-cervical posture): The downward opening angle between NSL line and OPT line was greater in patients with crowding 108.7 ± 6.6, followed by crossbite 101.6 ± 6.3, increased overbite 95.7 ± 7.2, proclination 94.5 ± 10.2, and less in patients with increased overjet 93.0 ± 8.4. This difference was found to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was revealed that a statistically significant difference was found between crowding and increased overjet ($p = 0.001$), crowding and increased overbite ($p = 0.001$), crowding and crossbite ($p = 0.001$), crowding and proclination ($p = 0.001$), increased overjet and crossbite ($p = 0.001$), increased overbite and crossbite ($p = 0.04$), proclination and crossbite ($p = 0.006$). (Fig. 5)

- NSL/CVT (Craniocervical posture): The downward opening angle between NSL line and CVT line was seen to be greater in patients with crowding 112.9 ± 6.7, followed by crossbite 104.3 ± 5.7, proclination 99.0 ± 10.2, increased overbite 98.6 ± 7.2 and less in patients with increased overjet 96.0 ± 7.1. This difference was found to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was observed that a statistically significant difference existed between crowding and increased overjet ($p = 0.001$), crowding and increased overbite ($p = 0.001$), crowding and crossbite ($p = 0.001$), crowding and proclination ($p = 0.001$), increased overjet and crossbite ($p = 0.001$), increased overbite and crossbite ($p = 0.04$). (Fig. 6)

- NL/OPT Maxillary base inclination upon cervical column: The downward opening angle between NL line and OPT line was seen to be greater in patients with crowding 97.2 ± 5.2, followed by crossbite 93.7 ± 8.1, increased overbite 91.6 ± 5.8, proclination 90.1 ± 9.0, and less in patients with increased overjet 89.8 ± 8.0. This difference was found to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overjet ($p = 0.001$), crowding and increased overbite ($p = 0.01$), crowding and proclination ($p = 0.001$). (Fig. 7)

- NL/CVT- Maxillary base inclination upon cervical column: The downward opening angle between NL line and CVT line was observed to be greater in patients with crowding 101.9 ± 6.3, followed by crossbite 96.4±8.0, proclination 94.1 ± 8.7, increased overbite 92.7 ± 7.8 and less in patients with increased overjet 91.1 ± 7.0. This difference was seen to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overjet ($p = 0.001$), crowding and increased overbite ($p = 0.001$), crowding and crossbite ($p = 0.04$), crowding and proclination ($p = 0.001$). (Fig. 8)

- FOP/OPT- functional occlusal plane inclination upon cervical column: The downward opening angle between FOP line and OPT line was seen to be greater in patients with crowding 87.9 ± 5.5, followed by crossbite 84.8±4.7, increased overbite 83.9 ± 5.9, proclination 81.3 ± 8.6, and less in patients with increased overjet 80.6 ± 7.1. This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overjet (p = 0.001), crowding and proclination (p = 0.001). (Fig. 9)

- FOP/CVT- functional occlusal plane inclination upon cervical column: The downward opening angle between FOP line and CVT line was observed to be greater in patients with crowding 92.2 ± 5.5, followed by crossbite 88.6 ± 5.0, increased overbite 86.7 ± 6.3, proclination 85.8 ± 8.1 and were less in patients with increased overjet 84.4 ± 7.2. This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overjet (p = 0.001), crowding and increased overbite (p = 0.001), crowding and proclination (p = 0.0001). (Fig. 10)

- ML/OPT- mandibular plane inclination upon cervical column: The downward opening angle between ML line and OPT line was seen to be greater in patients with increased overbite 91.1 ± 9.3, followed by crowding 72.2 ± 5.1, increased overjet 69.0 ± 9.1. These values were less in patients with proclination and crossbite 65.8 ± 8.0, 65.4 ± 5.6 respectively. This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overbite (p = 0.0001), crowding and proclination (p=0.004), increased overjet and increased overbite (p = 0.001), increased overbite and proclination (p = 0.001), increased overbite and crossbite (p = 0.001). (Fig. 11)

- ML/CVT- mandibular plane inclination upon cervical column: The downward opening angle between ML line and CVT line was seen to be greater in patients with increased overbite 93.7 ± 9.7, followed by crowding 76.5 ± 5.1, increased overjet 72.5 ± 9.3, proclination 70.3 ± 7.3 and were less in patients with crossbite 69.2 ± 6.3. This difference was seen to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overbite ($p = 0.001$), crowding and crossbite ($p = 0.004$), crowding and proclination ($p = 0.007$), increased overjet and increased overbite ($p = 0.001$). (Fig. 12)

Cervical posture

- OPT/HOR- Craniohorizontal angle: The upward opening angle between Hor line and OPT line was greater in patients with increased overjet and overbite, 90.1 ± 6.7 and 90.0 ± 5.7 respectively followed by proclination and crossbite 89.7 ± 8.5 and 89.4 ± 4.8 respectively. These values were minimum in patients with crowding 82.5 ± 3.0. This difference was seen to be highly statistically significant ($p = 0.001$). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and other malocclusion traits ($p = 0.001$), whereas no significant difference was observed amongst the pair-wise combinations of increased overjet, increased overbite, crossbite and proclination. (Fig. 13)

- CVT/HOR- Craniohorizontal angle: The upward opening angle between Hor line and CVT line was greater in patients with increased overjet and overbite, 86.5 ± 5.8 and 86.6 ± 5.6 respectively followed by crossbite and proclination, 85.6 ± 4.1 and 85.3 ± 8.4 respectively. These values were least in patients with crowding 78.7 ± 4.2. This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and other malocclusion traits (p = 0.001), whereas no significant difference was observed amongst the pair-wise combinations of increased overjet, increased overbite, crossbite and proclination. (Fig. 14)

Cervical curvature

- OPT/CVT – The cervical curvature angle was greater in patients with proclination 4.5 ± 1.8, followed by crowding 4.2 ± 1.2, crossbite 3.8 ± 1.8 and increased overjet 3.6 ± 1.9. These values were least in patients with increased overbite 2.8 ± 1.9. This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overbite (p = 0.01), increased overbite and proclination (p = 0.001). (Fig. 15)

Relationship between postural variables and malocclusion traits

The relationship between postural variables and different malocclusion traits was determined using Spearman’s correlation coefficient. (Table 4)

Crowding

This malocclusion trait had moderate significant correlation with NSL/OPT (r = 0.41), NSL/CVT (r = 0.40), NL/OPT (r = 0.41), and a weak significant correlation with NL/CVT (r = 0.39) and CVT/HOR (r = 0.39).

Increased overjet

On estimating the correlation between increased overjet and postural variables, it was observed that a moderate significant correlation existed with NSL/VER, anterior cranial base inclination (r = 0.43), NL/VER (r = 0.41) and a weak significant correlation with OPT/CVT (r = 0.39).

Increased overbite

On evaluating the correlation between increased overbite and postural variables, it was observed that a moderate significant correlation existed with NL/OPT Maxillary base inclination upon cervical column (r = 0.40), OPT/HOR, craniohorizontal angle (r = 0.43), whereas a negative weak but significant correlation existed with NSL/VER, anterior cranial base inclination (r = -0.39), NSL/OPT, cranio-cervical posture (r = -0.39), NSL/CVT (r = -0.35), and positive weak significant correlation existed with NL/CVT (r = 0.39), CVT/HOR (r = 0.39).

Crossbite

On estimating the relationship between crossbite and postural variables, it was observed that this malocclusion trait did not bear any significant correlation with postural variables.

Proclination

This malocclusion trait had a moderate significant correlation with NSL/VER (r = 0.43), NSL/OPT (r = 0.40), NL/CVT (r = 0.42), MP/OPT (r = 0.43), MP/CVT (r = 0.44) and a weak significant correlation with NSL/CVT (r = 0.39), NL/OPT (0.39).

Relationship between inclination of upper and lower incisors with postural variables

The relationship between inclination of upper and lower incisors, interincisal angle with postural variables was evaluated using Pearson's correlation coefficient. (Table 5)

Upper incisors: The upper incisor inclination was observed to have negative weak but significant correlation with palatal line inclination (r = -0.39) and negative moderate significant correlation with anterior cranial base inclination (r = -0.41). It did not have significant correlation with other postural variables

Lower incisors: The lower incisor inclination had negative moderate significant correlation with mandibular plane inclination (r = -0.48), craniocervical posture, NSL/OPT (r = -0.43) and NSL/CVT (r = -0.47).

Interincisal angle: The interincisal angle had a weak significant correlation with palatal line inclination (r = 0.39) and mandibular plane upon cervical column (r = 0.33).

Discussion

A renewed interest between form and function in the craniofacial region has been witnessed recently. The possible relationship between the craniofacial development and the postural relations of the head and the cervical column has received particular attention.

ANGLE understands occlusion as the relationship of the jaws at rest i.e. when they are locked. In this position, the muscles of mastication are somewhat contracted. If all the muscles are entirely relaxed and the jaws are at rest, the teeth are separate even if the lips are closed. According to Schwarz[13], the position of the jaws at rest is dependent upon the position of the head. In dorsiflexion of the head, the teeth are comparatively far apart. The mandible at the same time is posterior as in a Class II case. In ventroflexion just the contrary takes place; the teeth touch but not in normal occlusion, for the mandible is anterior as in a Class III case.

If we bend the head forward, all the soft tissues in front of the spine are compressed. The opposite occurs if we bend the head backwards.

Variations in natural head position have been observed, ranging between extension and flexion. These postural features studied by Solow and Tallgren (1976)[12], showed statistical associations with both craniofacial and dentoalveolar morphology. large anterior and small posterior facial height, a small anteroposterior craniofacial dimension, a larger inclination of the mandible to the anterior cranial base, facial retrognathism, a larger cranial base angle, and a small nasopharyngeal space. Such a restraint might be provided by the soft-tissue layer covering the face and continuing into the investing fascia of the neck. Conversely, a release of tension in this soft-tissue layer might potentially allow for a more sagittal craniofacial development[20]. The suggestion that head posture may affect facial morphology does not imply that facial morphology does not influence head posture. One important function of head posture is to maintain adequate naso-oro-pharyngeal airways (BOSMA 1963, TALMANT 1976)[63,64]. It may be assumed that subjects with morphologic deviations which affect the adequacy of the airways will react by extending the head in relation to the cervical column. This would initiate or increase a soft-tissue stretching with a subsequent retrusive force on facial morphology.

In a study conducted by Schwartz (1928)[13] on the effect of upper airway obstruction in children, he concluded that a relationship exists between the inability to breathe properly and the development of malocclusion. This hypothesis was based on the fact that a forward head posture, i.e., a forward cervical inclination combined with an extended position of the head (extended craniocervical angle), could be found in subjects with airway obstruction. Schwartz concluded that posture may be linked to the development of certain types of malocclusion, especially Class II malocclusion. The same finding was reported by Gresham and Smithels

(1954)[65] who concluded in their study that a larger prevalence of Class II malocclusions and an increase in vertical development of the face were present in subjects with poor neck posture compared to subjects with good neck posture. An association between class II and forward head posture, which can be defined as a forward cervical inclination combines with an a extended craniocevical angle, was described by Rocabado et al. (1982)[66] as the strongest evidence they had been able to observe in the relationship between head posture and malocclusion. Woodside, et al. (1991)[67] also proposed a relationship between upper airway obstruction and the development of malocclusion. In their study, they found that subjects with impaired nose breathing due to nasal mucosal swelling had a higher prevalence of lower anterior crowding of the dental arch compared to normal breathers.

In a study conducted by Solow and Sonnesen (1998)[36] in which subjects with severe malocclusal problems and no airway subjects were examined, a pattern of association between posture of the head and neck and malocclusion was observed. They concluded that in those individuals with severe malocclusion, a more extended cervical inclination or forward postured neck was present. When investigating which malocclusal problem (crowding, overbite, overjet, spacing, different classes of malocclusion, etc.) was more commonly present in conjunction with the variables of posture, it was found that crowding was the most common malocclusal trait that was associated with a large craniocervical angle. On the other hand, Alkofide et al. can be concluded that certain malocclusal problems are more strongly associated with head posture than others, and that crowding does not seem to play a major role in this association in Saudi subjects.

Pachi et al. (2009)[14] was a clear pattern of association between extended head posture and lower arch dental crowding. Torill A and L. Sonnesen (2011)[38] concluded association between cervical column morphology, craniofacial morphology, and head posture in preorthodontic children with horizontal maxillary overjet.

In view of these associations, the relationship between craniocervical angulations and occurrence of malocclusion is of particular interest. Hence, there was a need to study their relationship as very less content is available on effects of extended head posture on occlusion as compared to the causes of extended head posture, especially, in Indian subjects.

In the present study, the relationship between head posture and malocclusion traits in skeletal class II patients was assessed and determined which malocclusion trait was more strongly associated with the postural angles. Also the relationship between maxillary and mandibular incisor inclination and head posture.

COMPARISON OF POSTURAL VARIABLES AMONGST MALES AND FEMALES

The mean values of all postural variables were almost equal amongst males and females. There did not exist any statistically significant difference between males and females with respect to any of the postural variables in present population i.e. the natural head posture was not different among genders in untreated skeletal class II patients. These observations were in agreement with the studies carried out by Sahin Sanglam (2006)[15], who found that there were no sex variations in head position. Although, when comparing the postural variables of the current study with that of Sahin Sanglam (2006)[15] study, a difference could be found between them. The means of the craniovertical, Cervical posture angles in the present sample were higher than those reported for the Turkish sample. The craniocervical anglulation and cervical curvature, on the other hand, showed lower means. The possible reason for difference in the means might be due to dissimilarities in the composition of the samples.

HEAD POSTURE IN DIFFERENT MALOCCLUSION TRAITS IN UNTREATED SKELETAL CLASS II PATIENTS

1. CROWDING

The present study shows a clear pattern of association between crowding more than 2 mm (includes both upper and lower incisors) and extended craniocervical posture expressed by an increase of NSL/ CVT [*P* _ .001], NSL/OPT [*P* _ .001], NL/CVT [*P* _ .008], and NL/OPT [*P* _ .002], FOP/CVT [P = 0.001], FOP/OPT [P = 0.001], ML/CVT [P = 0.001], ML/OPT [P = 0.001] . This is in accordance with the results of a study conducted by Solow and Sonnesen's[36].

Also, Subjects (more than 2 mm dental crowding) had mean craniocervical angles (NSL/CVT, NSL/OPT, NL/CVT, NL/OPT) that were 6 to 7 degree larger than other malooclusion traits and the mean craniohorizontal angles (CVT/HOR, OPT/HOR) were 5 degree smaller than other malocclusion traits. On subject to post hoc analysis, it showed a statistically significant difference existed between crowding and other malooclusion traits in relation to craniocervical and craniohorizontal angles. This was similar to results obtained by Francesco Pach**i** [14] who noted Subjects with more than 2 mm dental crowding had mean craniocervical angles (NSL/CVT, NSL/OPT, NL/CVT, NL/OPT) that were 5 to 6 degree larger than the subjects with the space conditions smaller than 2 mm (*P* = .01). In addition, the mean craniohorizontal angles (CVT/HOR, OPT/HOR) in the subjects with lower dental crowding were 4 degree smaller than subjects without dental crowding (*P* =.05). Also, Alkofide[61] reported that in upper arch crowding the means of the craniocervical (NSL/OPT, NL/OPT) and cervicohorizontal (OPT/HOR) variables showed an average 3-5 degree difference when compared with the non crowding subjects, but this was not statistically significant. An explanation for these associations has been described previously as the –soft tissue stretching hypothesis (Solow and Kreiborg 1977)[20]

In the present study, when relationship between postural variables and different malocclusion traits was determined using Spearman‘s correlation coefficient, crowding malocclusion trait had moderately significant correlation with NSL/OPT (r = 0.41), NSL/CVT (r = 0.40), NL/OPT (r = 0.41), and a weak significant correlation with NL/CVT (r = 0.39) and CVT/HOR (r = 0.39). According to B. Solow and

L. Sonnesen36, crowding had moderate significant correlation with NSL/OPT (0.28) NSL/CVT (0.031), NL/OPT (0.25), NL/CVT (0.27) with no effect of gender or age. In contrast to B.Solow and L. Sonnesen contention, Alkofide et al.61 found that this malocclusion trait did not bear any significant correlation with postural variables.

2. INCREASED OVERJET

In present study the mean of all craniocervical angulations (NSL/CVT, NSL/OPT, NL/CVT, NL/OPT, FOP/CVT, FOP/OPT, ML/CVT, ML/OPT) are leSS as compared to other malocclusion traits. Also, the mean of all craniohorizontal angulations i.e cervical posture (OPT/HOR, CVT/HOR) are greater as compared to other malocclusion traits. On subject to post hoc analysis, it was seen that a no statistically significant difference existed between increased overjet and other malocclusion traits. All this findings are suggestive of retroclination of cervical spine in increased overjet group as compared to other malocclusion traits in untreated skeletal class II subjects. On the other hand, Huggare and Harkness (1993)[62], from a study of head posture in 13 class II and 17 class I children concluded that distal occlusion and increased overjet were associated with a flexed head posture and a backward bend of spine.

On estimating the correlation between increased overjet and postural variables in present study, it was observed that a moderate significant correlation existed with NSL/VER, anterior cranial base inclination (r = 0.43), NL/VER (r = 0.41) and a weak significant correlation with OPT/CVT (r = 0.39). According to B. Solow and L. Sonnesen[36], crowding had weak significant correlation with OPT/CVT (P = 0.23) due to effect of gender and age. In contrast, Alkofide et al.[61] found that this malocclusion trait bear weak significant correlation with NSL/VER (P = 0.17) with no significant effect of gender and age.

3. INCREASED OVERBITE

Least (Mean ± SD = 2.8 ±1.9) value for cervical curvature can be seen with increased overbite as compared to other malooclusion traits. On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overbite (p=0.01), increased overbite and proclination (p = 0.001). Also, there is increased craniohorizontal angles i.e. OPT/HOR (90.0 ± 5.7) and CVT/HOR (86.6 ± 5.6) along with increased mandibular plane inclination upon cervical column i.e. MP/OPT (91.1 ± 9.3) and MP/CVT (93.7 ± 9.7). On subject to post hoc analysis, it was seen that a statistically significant difference existed between crowding and increased overbite (p = 0.0001), increased overjet and increased overbite (p=0.001), increased overbite and proclination (p = 0.001), increased overbite and crossbite (p = 0.001) in relation to MP/OPT. Also, statistically significant difference existed between crowding and increased overbite (p = 0.001), increased overjet and increased overbite (p = 0.001) on post hoc test in relation to MP/CVT. No statistically significant difference existed between overbite and other malocclusion traits in relation to craniohorizontal angles i.e. cervical posture.

Correlating all these finding, suggestive of straighter spine without any forward and backward inclination of spine among other malocclusion traits.

On evaluating the correlation between increased overbite and postural variables, it was observed that a moderate significant negative correlation existed with NL/OPT, Maxillary base inclination upon cervical column (r = 0.40), and moderate significant positive correlation existed with OPT/HOR, craniohorizontal angle (r =

0.43), whereas a weak but significant negative correlation existed with NSL/VER, anterior cranial base inclination (r = 0.39), NSL/OPT, cranio-cervical posture (r = 0.39), NSL/CVT (r=0.35), NL/CVT (r = 0.39), and moderate significant positive correlation existed with CVT/HOR (r = 0.39) which is in accordance with B. Solow and L. Sonnesen[36] and Alkofide et al.[61] results.

4. CROSSBITE

The mean values of occlusal plane inclination and mandibular plane inclination were greater in patients with crossbite 94.3±4.2 and 88.3±3.1, respectively. One may suggest that when crossbite is present in an individual, a shift in position of the head, and hence, the cervical column relationship may be altered due to the faulty bite.

On subject to post hoc Tukey's test, it was seen that a statistically significant difference existed between crowding and crossbite (p=0.0001), increased overjet and crossbite (p = 0.0001), increased overbite and crossbite (p=0.003), proclination and crossbite (p = 0.0001) in relation to occlusal plane inclination. Similar results found in relation to mandibular plane inclination between crossbite and all the groups of malocclusion, on subject to post hoc Tukey's test.

Mandibulal plane inclination on cervical column i.e. ML/OPT and ML/CVT were seen least in crossbite, 65.4 ± 5.6 and 69.2 ± 6.3 respectively. On subject to post hoc analysis, it was seen that a statistically significant difference existed between

- increased overbite and crossbite (p=0.001) in relation to ML/OPT
- crowding and crossbite (p=0.004) in relation to ML/CVT

On estimating the relationship between crossbite and postural variables, Alkofide et al.[61] found significant correlation with craniocervical angles i.e NSL/OPT (P = 0.26), NSL/CVT (P = 0.26), NL/OPT (P = 0.28) AND NL/CVT (P = 0.32) with no significant effect of age and gender but in present study, it was observed that this malocclusion trait did not bear any significant correlation with postural variables may be because of limited sample size (n = 25) for this malocclusion trait.

5. PROCLINATION

The mean values of occlusal plane inclination (FOP/VER) were least in patients with proclination 83.5±8.3. On subject to post hoc Tukey's test, it was seen that a statistically significant difference existed between proclination and crossbite (p=0.0001) only.

OPT/CVT i.e. the cervical curvature angle was greater in patients with proclination 4.5 ± 1.8, This difference was seen to be highly statistically significant (p = 0.001). On subject to post hoc analysis, it was seen that a statistically significant difference existed between increased overbite and proclination (p = 0.001) only.

This malocclusion trait had a moderate significant correlation with NSL/VER (r = 0.43), NSL/OPT (r = 0.40), NL/CVT (r=0.42), MP/OPT (r=0.43), MP/CVT (r=0.44) and a weak significant correlation with NSL/CVT (r = 0.39), NL/OPT (0.39).

However, no study has been conducted in relation to proclination and its effect on head posture it was concluded that significant association between proclination (malocclusion trait) and head posture variables.

RELATIONSHIP BETWEEN INCLINATION OF UPPER AND LOWER INCISORS WITH POSTURAL VARIABLES

Upper incisors: The upper incisor inclination was observed to have weak significant correlation with palatal line inclination (r = 0.39) and negative moderate significant correlation with anterior cranial base inclination (r=-0.41). It did not have significant correlation with other postural variables. The possible explanation for these association in our study could be an experimental study by Hellsing and L'Estrange (1987)[18], who showed that a 5-degree extension and flexion of the head resulted in a corresponding increase and decrease in the force exerted by the lips on the facial surfaces of the maxillary incisors.

Lower incisors: The lower incisor inclination had positive moderate significant correlation with mandibular plane inclination (r = 0.48) and negative moderate significant correlation with craniocervical posture, NSL/OPT (r = -0.43) and NSL/CVT (r = -0.47). Similarly, Solow and Tallgren[12] noted an increase in lower incisor retroclination with extended head position. They have also observed a positive correlation between mandibular retrusion and head extension. These findings have been supported in both adult and child samples

Interincisal angle: The interincisal angle had a weak significant correlation with palatal line inclination (r = 0.39) and mandibular plane upon cervical column (r = 0.33).

Thus, in present study varied results were found when compared to other studies. This was due to the limitation of our inclusion criteria based solely on the skeletal class II pattern whereas few parameters which are included in our study are influenced by growth pattern. So, to conclude within limitations, extended head posture was seen in skeletal class II pattern. The cranial base angle showed statistically significant difference in patients with five different malocclusion traits in untreated skeletal class II subjects. Similarly, the cervical column morphology deviations were also significant statistically in five different malocclusion traits in untreated skeletal class II subjects.

The present study would have clinical implications for the management of space problems in the dental arches and, in particular, for the decision to extract teeth in orthodontic treatment. However the hypothetical explanations which are given in the literature with respect to the change in head posture, cervical column morphology with different malocclusions need to be substantiated with further research and if they can be confirmed, it would be beneficial to establish borderline conditions for clinical decisions and to find out the possible etiological factors.

Limitations

1. In the present study the subjects were included on the basis of skeletal class II pattern. However, the growth pattern in vertical direction should also be taken into consideration.

2. The study did not evaluate the possible effect of age on average postural differences between subjects with each category of malocclusion traits in skeletal class II pattern and further studies can be done for the same.

3. Since our sample size was limited with malocclusion restricted to dentoalveolar discrepancies, further studies with a larger sample and skeletal jaw discrepancies can be carried out.

Summary and Conclusion

The present study was done to assess the relationship between head posture and different malocclusion traits in untreated skeletal class II patients. 170 lateral cephalograms were taken which were divided into five groups according to the different malocclusion traits and all the cephalometric angular measurements were done using Nemoceph digital software.

From the present study it can be concluded that,

- The head posture variables were significantly increased in all malocclusion traits in untreated skeletal class II patients. Therefore an extended head posture is seen in untreated skeletal class II patients in present population.

- There was not any significant difference existed in present population between males and females with respect to head postural variables.

- Proclination of upper and lower incisors is strongly associated with the head posture followed by increased overjet and crowding in untreated skeletal class II patients.

- Lower incisors proclination affects head posture more than upper incisors proclination in untreated skeletal class II patients.

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Tables and Graphs

Table 1: Comparison of postural variables amongst males and females

Gender	N	Postural variables														
		Cranio-vertical angu-lations Mean ± SD				Cranio-cervical angu-lations Mean ± SD								Cervical posture Mean ± SD		Cervical curva-ture Mean ± SD
		NSL/ VER	NL/ VER	FOP/ VER	MP/ VER	NSL/ OPT	NSL/ CVT	NL/ OPT	NL/ CVT	FOP/ OPT	FOP/ CVT	MP/ OPT	MP/ CVT	OPT/ HOR	CVT/ HOR	OPT/ CVT
Males	90	95.6±5.8	90.1±4.3	87.1±10.1	72.6±9.1	97.2±12.2	101.3±5.8	91.5±12.7	93.8±9.8	83.8±17.1	87.6±9.2	73.1±8.4	76.9±11.2	89.5±9.5	85.4±12.1	4.2±3.0
Females	80	95.2±4.7	89.5±4.5	85.2±8.2	72.6±8.3	99.8±10.2	103.1±9.2	93.5±9.1	96.4±6.7	83.8±12.2	87.4±8.5	73.1±9.5	76.4±5.8	87.3±10.2	83.6±10.1	3.4±2.1
p-value		0.57	0.98	0.78	0.12	0.84	0.67	0.30	0.07	0.89	0.14	0.72	0.83	0.08	0.45	0.75

Table 2: Comparison of postural variables amongst different malocclusion traits

Malocclusion traits	N	Postural variables														
		Cranio-vertical angulations Mean ± SD				Cranio-cervical angulations Mean ± SD								Cervical posture Mean ± SD		Cervical curvature Mean ± SD
		NSL/ VER	NL/ VER	FOP/ VER	MP/ VER	NSL/ OPT	NSL/ CVT	NL/ OPT	NL/ CVT	FOP/ OPT	FOP/ CVT	MP/ OPT	MP/ CVT	OPT/ HOR	CVT/ HOR	OPT/ CVT
Crowding	35	96.9±2.6	89.3±3.0	84.2±11.5	63.3±6.3	108.7±6.6	112.9±6.7	97.2±5.2	101.9±6.3	87.9±5.5	92.2±5.5	72.2±5.1	76.5±5.1	82.5±3.0	78.7±4.2	4.2±1.2
Increased overjet	35	93.7±5.0	88.5±3.5	84.4±6.5	68.5±6.1	93.0±8.4	96.0±7.1	89.8±8.0	91.1±7.0	80.6±7.1	84.4±7.2	69.0±9.1	72.5±9.3	90.1±6.7	86.5±5.8	3.6±1.9
Increased overbite	35	94.3±3.3	91.2±2.8	86.9±4.8	83.4±6.1	95.7±7.2	98.6±7.2	91.6±5.8	92.7±7.8	83.9±5.9	86.7±6.3	91.1±9.3	93.7±9.7	90.0±5.7	86.6±5.6	2.8±1.9
Crossbite	25	96.8±3.5	90.3±3.5	94.3±4.2	88.3±3.1	101.6±6.3	104.3±5.7	93.7±8.1	96.4±8.0	84.8±4.7	88.6±5.0	65.4±5.6	69.2±6.3	89.4±4.8	85.6±4.1	3.8±1.8
Proclination	40	95.7±4.4	89.7±3.0	83.5±8.3	64.6±6.2	94.5±10.2	99.0±10.2	90.1±9.0	94.1±8.7	81.3±8.6	85.8±8.1	65.8±8.0	70.3±7.3	89.7±8.5	85.3±8.4	4.5±1.8
p-value		0.001*	0.008*	0.0001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*

*$p \leq 0.001$ highly statistically significant using ANOVA

Table 3a: Pair-wise comparison of Cranio-vertical angulation amongst the malocclusion traits by post hoc test

Dependent variable	Malocclusion groups			
Cranio-vertical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
NSL/VER	Crowding	Increased overjet Increased overbite Crossbite Proclination	3.28 2.68 0.21 1.27	0.005* 0.03* 1.0 0.6
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-3.28 -0.6 -3.07 -2.0	0.005* 0.9 0.02* 0.17
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-2.68 0.6 -2.47 -1.41	0.03* 0.9 0.11 0.51
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-0.21 3.1 2.47 1.0	1.0 0.02* 0.11 0.82
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-1.27 2.0 1.41 -1.0	0.60 0.17 0.51 0.82
NL/VER	Crowding	Increased overjet Increased overbite Crossbite Proclination	0.8 -1.9 -1.02 -0.39	0.80 0.09 0.73 0.98
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-0.80 -2.71 -1.82 -1.19	0.83 0.004* 0.19 0.48
	Increased overbite	Crowding Increased overjet Crossbite Proclination	1.91 2.71 0.89 1.52	0.09 0.004* 0.82 0.24

Dependent variable	Malocclusion groups			
Cranio-vertical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
	Crossbite	Crowding Increased overjet Increased overbite Proclination	1.02 1.82 -0.89 0.63	0.73 0.19 0.82 0.93
	Proclination	Crowding Increased overjet Increased overbite Crossbite	0.39 1.19 -1.52 -0.63	0.98 0.48 0.24 0.93
FOP/VER	Crowding	Increased overjet Increased overbite Crossbite Proclination	-0.14 -2.65 -10.10 0.68	1.0 0.60 0.001* 0.99
	Increased overjet	Crowding Increased overbite Crossbite Proclination	0.14 -2.51 -9.96 0.82	1.00 0.65 0.001* 0.99
	Increased overbite	Crowding Increased overjet Crossbite Proclination	2.65 2.51 -7.44 3.33	0.60 0.65 0.001* 0.34
	Crossbite	Crowding Increased overjet Increased overbite Proclination	10.10 9.96 7.44 10.78	0.001* 0.001* 0.003* 0.34
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-0.68 -0.82 -3.33 -10.78	0.99 0.99 0.34 0.001*
MP/VER	Crowding	Increased overjet Increased overbite Crossbite Proclination	-5.22 -20.11 -25.01 -1.28	0.002* 0.001* 0.001* 0.87
	Increased overjet	Crowding Increased overbite	5.22 -14.88 -19.78	0.002* 0.001* 0.001*

Dependent variable	**Malocclusion groups**			
Cranio-vertical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
		Crossbite Proclination	3.94	0.033*
	Increased overbite	Crowding Increased overjet Crossbite Proclination	20.11 14.88 -4.90 18.83	0.001* 0.001* 0.01* 0.001*
	Crossbite	Crowding Increased overjet Increased overbite Proclination	25.01 19.78 4.90 23.73	0.001* 0.001* 0.01* 0.001*
	Proclination	Crowding Increased overjet Increased overbite Crossbite	1.28 -3.94 -18.83 -23.73	0.87 0.03* 0.001* 0.001*

*The mean difference is significant at the 0.05 level

Table 3b: Pair-wise comparison of Cranio-cervical angulation amongst the malocclusion traits by post hoc test

Dependent variable	**Malocclusion groups**			
Cranio-cervical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
NSL/OPT	Crowding	Increased overjet Increased overbite Crossbite Proclination	15.68 12.94 7.07 14.18	0.001* 0.001* 0.01* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-15.68 -2.74 -8.61 -1.49	0.001* 0.61 0.001* 0.93
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-12.90 2.74 -5.86 1.24	0.001* 0.61 0.04* 0.96
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-7.07 8.61 5.86 7.11	0.01* 0.001* 0.04* 0.01*
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-14.18 1.49 -1.24 -7.11	0.001* 0.93 0.96 0.01*
NSL/CVT	Crowding	Increased overjet Increased overbite Crossbite Proclination	16.85 14.28 8.59 13.83	0.001* 0.001* 0.001* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-16.85 -2.57 -8.26 -3.01	0.001* 0.63 0.001* 0.45
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-14.28 2.57 -5.69 -0.44	0.001* 0.63 0.04* 0.99
	Crossbite	Crowding Increased overjet	-8.59 8.26	0.001* 0.001*

Dependent variable	**Malocclusion groups**			
Cranio-cervical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
		Increased overbite Proclination	5.69 5.24	0.04* 0.06
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-13.83 3.01 0.44 -5.24	0.001* 0.45 0.99 0.06
NL/OPT	Crowding	Increased overjet Increased overbite Crossbite Proclination	7.34 5.54 3.44 7.12	0.001* 0.01* 0.39 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-7.34 -1.80 -3.90 -0.21	0.001* 0.84 0.26 1.00
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-5.54 1.80 -2.10 1.58	0.01* 0.84 0.81 0.88
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-3.44 3.90 2.10 3.68	0.39 0.26 0.81 0.29
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-7.12 0.21 -1.58 -3.68	0.001* 1.00 0.88 0.29
NL/CVT	Crowding	Increased overjet Increased overbite Crossbite Proclination	10.80 9.20 5.54 7.86	0.001* 0.001* 0.04* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-10.80 -1.60 -5.25 -2.93	0.001* 0.90 0.05* 0.45

Dependent variable	**Malocclusion groups**			
Cranio-cervical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-9.20 1.60 -3.65 -1.33	0.001* 0.90 0.35 0.94
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-5.54 5.25 3.65 2.32	0.04* 0.06 0.35 0.75
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-7.86 2.93 1.33 -2.32	0.001* 0.45 0.94 0.75
FOP/OPT	Crowding	Increased overjet Increased overbite Crossbite Proclination	7.31 4.05 3.17 6.67	0.001* 0.08 0.37 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-7.31 -3.25 -4.14 -0.64	0.001* 0.25 0.13 0.99
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-4.05 3.25 -0.88 2.61	0.08 0.25 0.98 0.44
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-3.17 4.14 0.88 3.50	0.37 0.13 0.98 0.24
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-6.67 0.64 -2.61 -3.50	0.001* 0.99 0.44 0.24
FOP/CVT	Crowding	Increased overjet Increased overbite Crossbite	7.82 5.48 3.65 6.43	0.001* 0.001* 0.23 0.001*

Dependent variable	Malocclusion groups			
Cranio-cervical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
		Proclination		
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-7.82 -2.34 -4.17 -1.39	0.001* 0.58 0.12 0.89
	Increased overbite	Crowding Increased overjet Crossbite Proclination	-5.48 2.34 -1.82 0.94	0.001* 0.58 0.83 0.97
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-3.65 4.17 1.82 2.77	0.23 0.12 0.83 0.48
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-6.43 1.39 -0.94 -2.77	0.001* 0.89 0.97 0.48
MP/OPT	Crowding	Increased overjet Increased overbite Crossbite Proclination	3.20 -18.88 6.81 6.45	0.42 0.001* 0.001* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-3.20 -22.08 3.61 3.25	0.42 0.001* 0.39 0.37
	Increased overbite	Crowding Increased overjet Crossbite Proclination	18.88 22.08 25.70 25.34	0.001* 0.001* 0.001* 0.001*
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-6.81 -3.61 -25.70 -0.36	0.001* 0.39 0.001* 1.00
	Proclination	Crowding Increased overjet Increased	-6.45 -3.25 -25.34	0.001* 0.37 0.001*

Dependent variable	**Malocclusion groups**			
Cranio-cervical angulations	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
		overbite Crossbite	0.36	1.00
MP/CVT	Crowding	Increased overjet Increased overbite Crossbite Proclination	3.97 -17.17 7.30 6.19	0.21 0.001* 0.001* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	-3.97 -21.14 3.33 2.22	0.21 0.001* 0.48 0.73
	Increased overbite	Crowding Increased overjet Crossbite Proclination	17.17 21.14 24.47 23.36	0.001* 0.001* 0.001* 0.001*
	Crossbite	Crowding Increased overjet Increased overbite Proclination	-7.30 -3.33 -24.47 -1.11	0.001* 0.48 0.001* 0.98
	Proclination	Crowding Increased overjet Increased overbite Crossbite	-6.19 -2.22 -23.36 1.11	0.001* 0.73 0.001* 0.98

Table 3c: Pair-wise comparison of cervical-posture angulation amongst the malocclusion traits by post hoc test

Dependent variable	**Malocclusion groups**			
Cervical-posture	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
OPT/HOR	Crowding	Increased overjet Increased overbite Crossbite Proclination	-7.60 -7.45 -6.85 -7.20	0.001* 0.001* 0.001* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	7.60 0.14 0.74 0.39	0.001* 1.00 0.99 0.99
	Increased overbite	Crowding Increased overjet Crossbite Proclination	7.45 -0.14 0.60 0.25	0.001* 1.00 0.99 1.00
	Crossbite	Crowding Increased overjet Increased overbite Proclination	6.85 -0.74 -0.60 -0.35	0.001* 0.99 0.99 0.99
	Proclination	Crowding Increased overjet Increased overbite Crossbite	7.20 -0.39 -0.25 0.35	0.001* 0.99 1.00 0.99
CVT/HOR	Crowding	Increased overjet Increased overbite Crossbite Proclination	-7.82 -7.88 -6.88 -6.63	0.001* 0.001* 0.001* 0.001*
	Increased overjet	Crowding Increased overbite Crossbite Proclination	7.82 -0.05 0.94 1.19	0.001* 0.001* 0.97 0.91
	Increased	Crowding	7.88	0.001*

Dependent variable	**Malocclusion groups**			
Cervical-posture	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
	overbite	Increased overjet Crossbite Proclination	0.05 1.00 1.25	1.00 0.97 0.90
	Crossbite	Crowding Increased overjet Increased overbite Proclination	6.88 -0.94 -1.00 0.25	0.001* 0.97 0.97 1.00
	Proclination	Crowding Increased overjet Increased overbite Crossbite	6.63 -1.19 -1.25 -0.25	0.001* 0.91 0.90 1.00

*The mean difference is significant at the 0.05 level

Table 3d: Pair-wise comparison of cervical-curvature angulation amongst the malocclusion traits by post hoc test

Dependent variable	Malocclusion groups			
Cervical-curvature	**Group (I)**	**Group (J)**	**Mean difference (I-J)**	**p-value**
OPT/CVT	Crowding	Increased overjet	0.65	0.54
		Increased overbite	1.40	0.01*
		Crossbite	0.45	0.86
		Proclination	-0.29	0.95
	Increased overjet	Crowding	-0.65	0.54
		Increased overbite	0.74	0.41
		Crossbite	-0.20	0.99
		Proclination	-0.95	0.15
	Increased overbite	Crowding	-1.40	0.01*
		Increased overjet	-0.74	0.41
		Crossbite	-0.94	0.26
		Proclination	-1.69	0.001*
	Crossbite	Crowding	-0.45	0.86
		Increased overjet	0.20	0.99
		Increased overbite	0.94	0.26
		Proclination	-0.75	0.47
	Proclination	Crowding	0.29	0.95
		Increased overjet	0.95	0.15
		Increased overbite	1.69	0.001*
		Crossbite	0.75	0.47

*The mean difference is significant at the 0.05 level

Table 4: Correlation between postural variables and malocclusion traits

Malocclusion traits	**Postural variables**														
	Cranio-vertical angulations Mean ± SD				**Cranio-cervical angulations Mean ± SD**								**Cervical posture Mean ± SD**		**Cervical curvature Mean ± SD**
	NSL/ VER	**NL/ VER**	**FOP/ VER**	**MP/ VER**	**NSL/ OPT**	**NSL/ CVT**	**NL/ OPT**	**NL/ CVT**	**FOP/ OPT**	**FOP/ CVT**	**MP/ OPT**	**MP/ CVT**	**OPT/ HOR**	**CVT/ HOR**	**OPT/ CVT**
Crowding	0.05	0.08	0.02	0.21	0.41**	0.40*	0.41**	0.39*	0.19	0.12	0.09	0.14	0.23	0.39*	0.21
Increased overjet	0.43**	0.41**	0.08	0.17	0.23	0.15	0.18	0.19	0.21	0.23	0.17	0.22	0.12	0.20	0.39*
Increased overbite	-0.39*	0.22	0.11	0.03	-0.39*	-0.35*	0.40*	0.39*	0.07	0.16	0.26	0.03	0.43**	0.39*	0.03
Crossbite	0.11	0.09	0.24	0.01	0.05	0.19	0.12	0.17	0.20	0.05	0.15	0.17	0.16	0.18	0.04
Proclination	0.43**	0.22	0.03	0.14	0.40*	0.39*	0.39*	0.42**	0.03	0.10	0.43**	0.44**	0.02	0.11	0.10

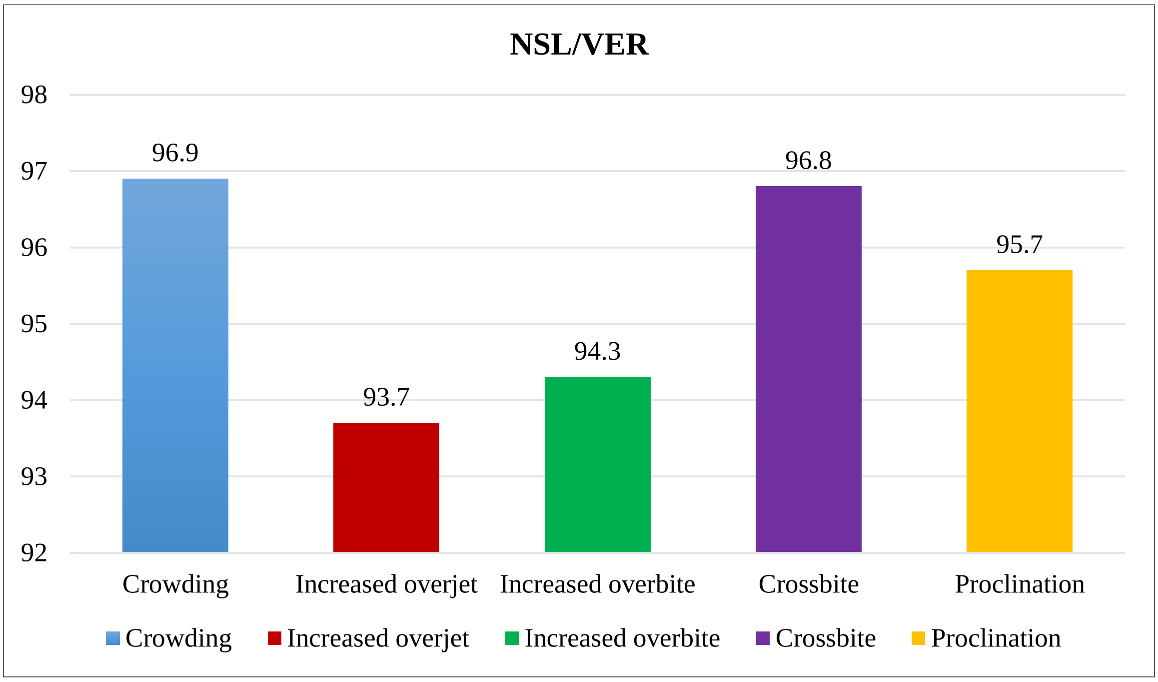
**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level

Table 5: Correlation between inclination of upper and lower incisors with postural variables in patients with proclination

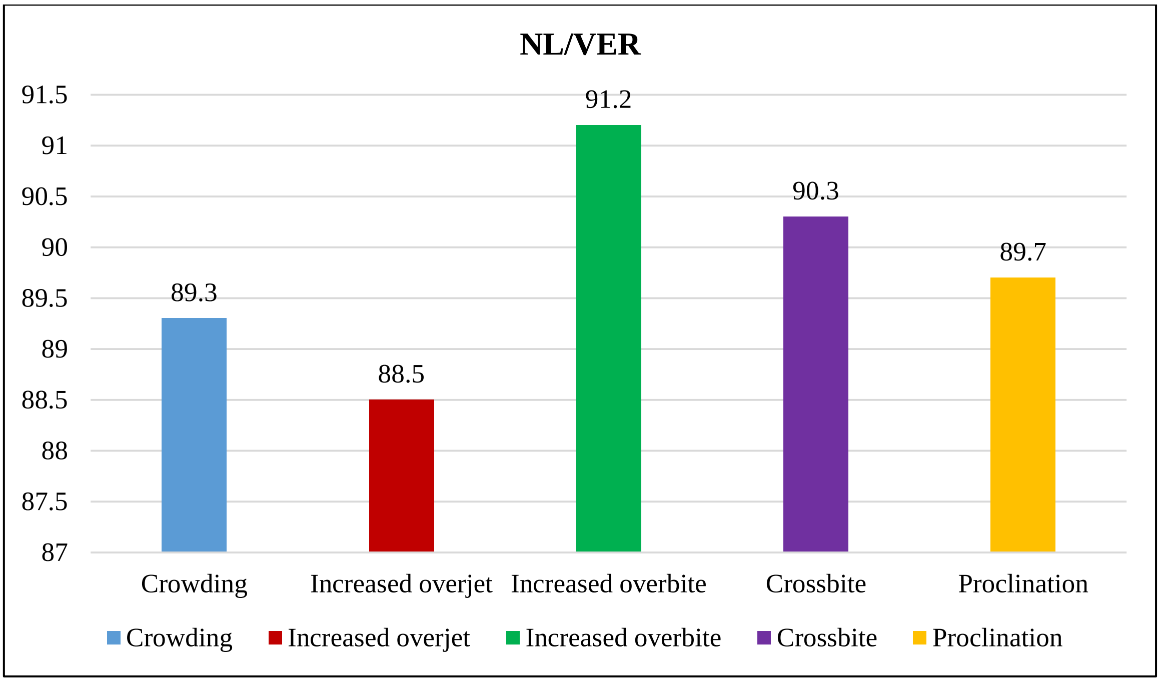
	Postural variables														
	Cranio-vertical angulations				Cranio-cervical angulations								Cervical posture		Cervical curvature
	NSL/ VER	NL/ VER	FOP/ VER	MP/ VER	NSL/ OPT	NSL/ CVT	NL/ OPT	NL/ CVT	FOP/ OPT	FOP/ CVT	MP/ OPT	MP/ CVT	OPT/ HOR	CVT/ HOR	OPT/ CVT
Upper incision	-0.41**	-0.39*	0.001	0.14	-0.16	-0.15	-0.27	-0.28	-0.19	-0.20	-0.21	-0.21	0.20	0.17	0.05
Lower incisors	-0.03	0.18	-0.04	-0.48**	-0.43**	-0.47**	-0.15	-0.29	0.11	-0.10	0.17	0.21	-0.08	-0.13	0.09
Interincisal angle	-0.04	0.39*	-0.05	0.12	0.18	0.14	0.14	0.12	0.10	0.06	0.33*	0.30	-0.05	-0.001	-0.23

**Correlation is significant at 0.01 level; *Correlation is significant at 0.05 level

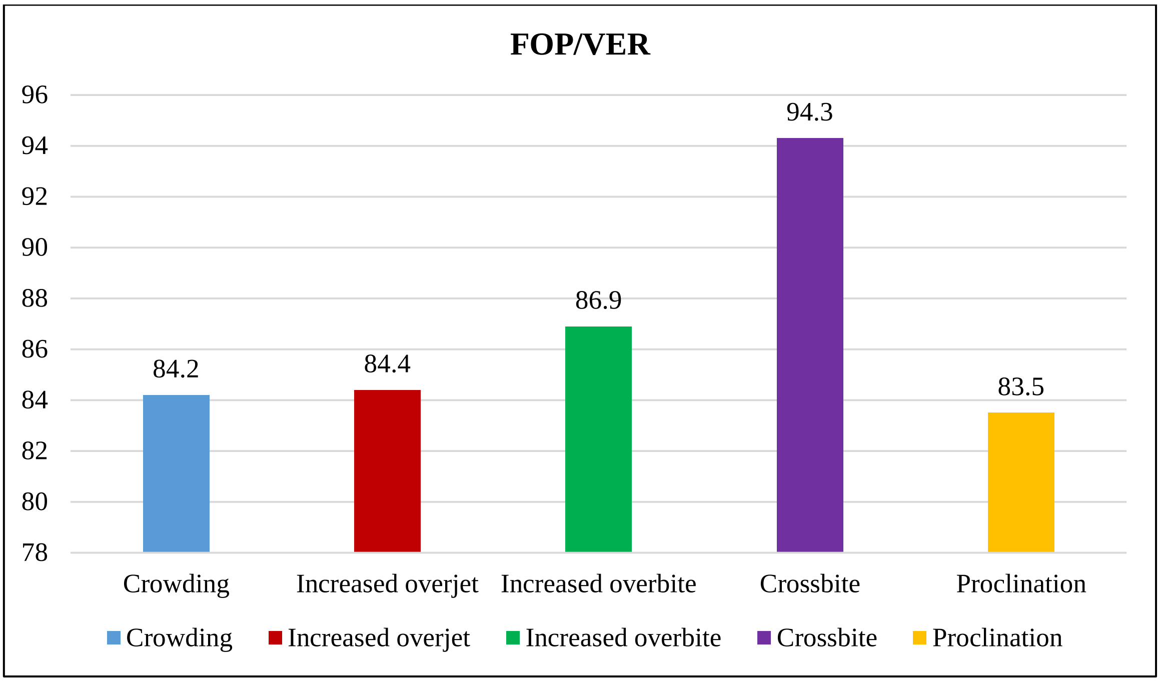
Graphs



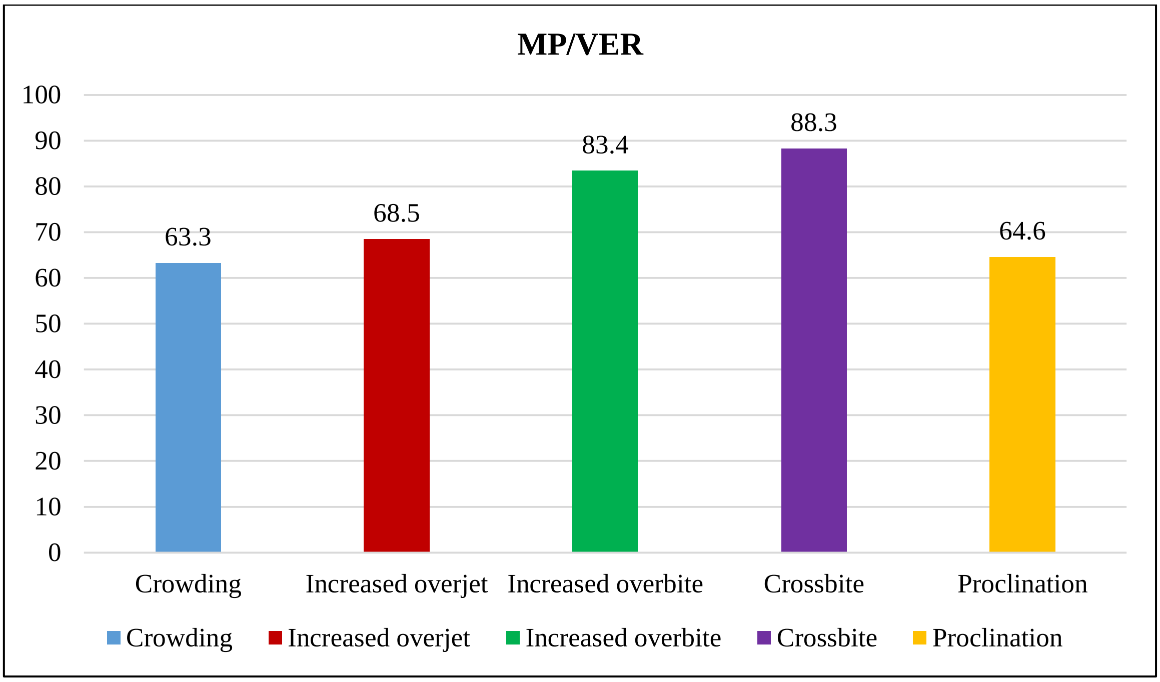
Graph 1: Comparison of the mean values of NSL/VER amongst the malocclusion traits



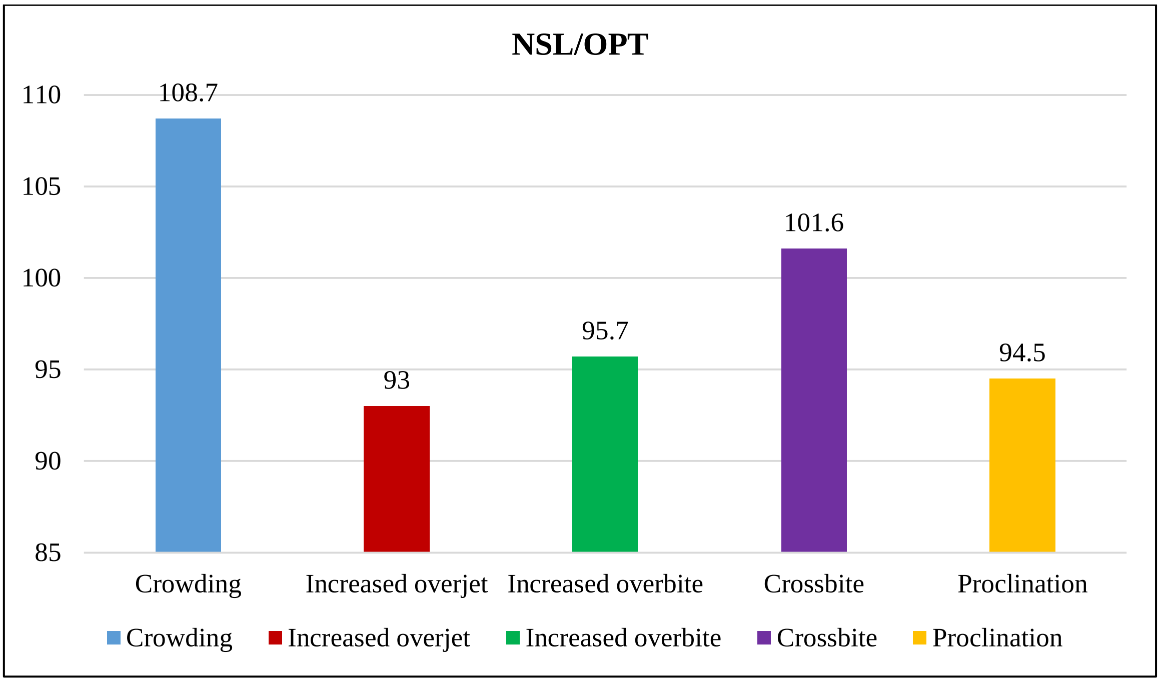
Graph 2: Comparison of the mean values of NL/VER amongst the malocclusion traits



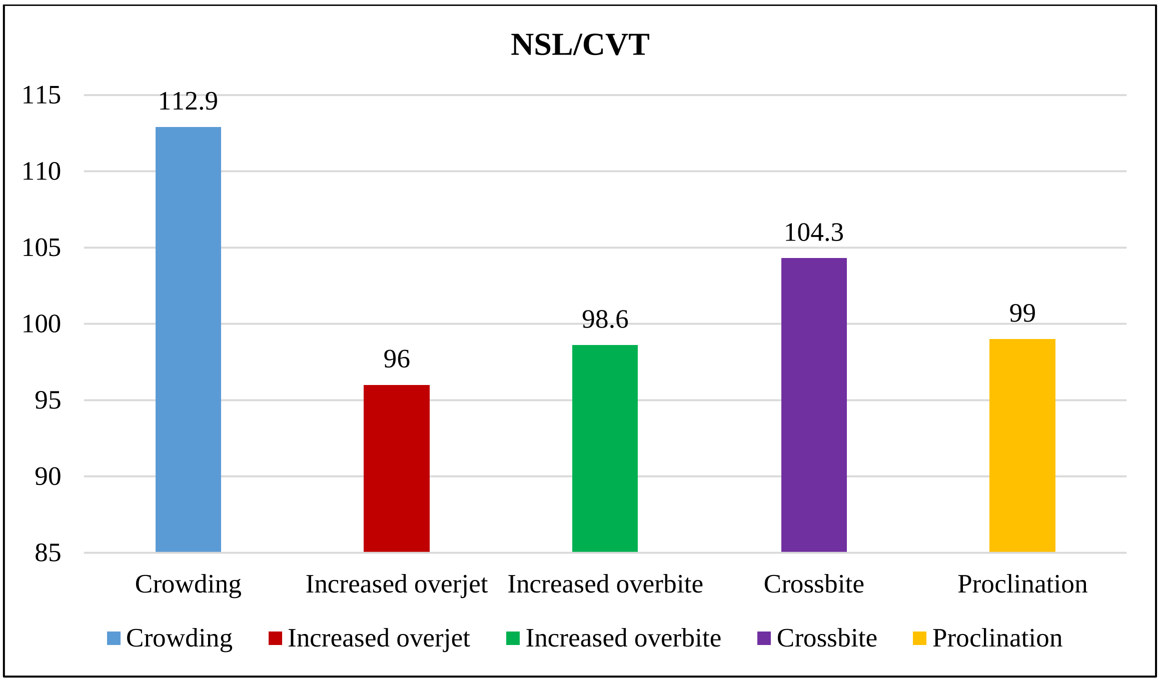
Graph 3: Comparison of the mean values of FOP/VER amongst the malocclusion traits



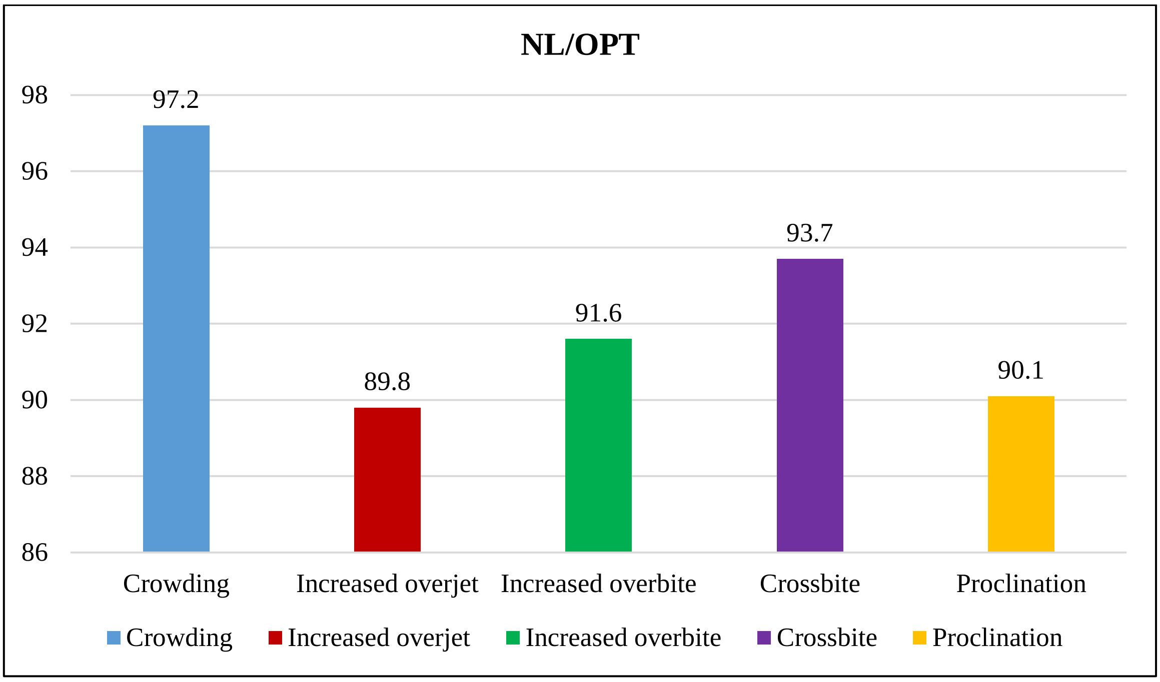
Graph 4: Comparison of the mean values of MP/VER amongst the malocclusion traits



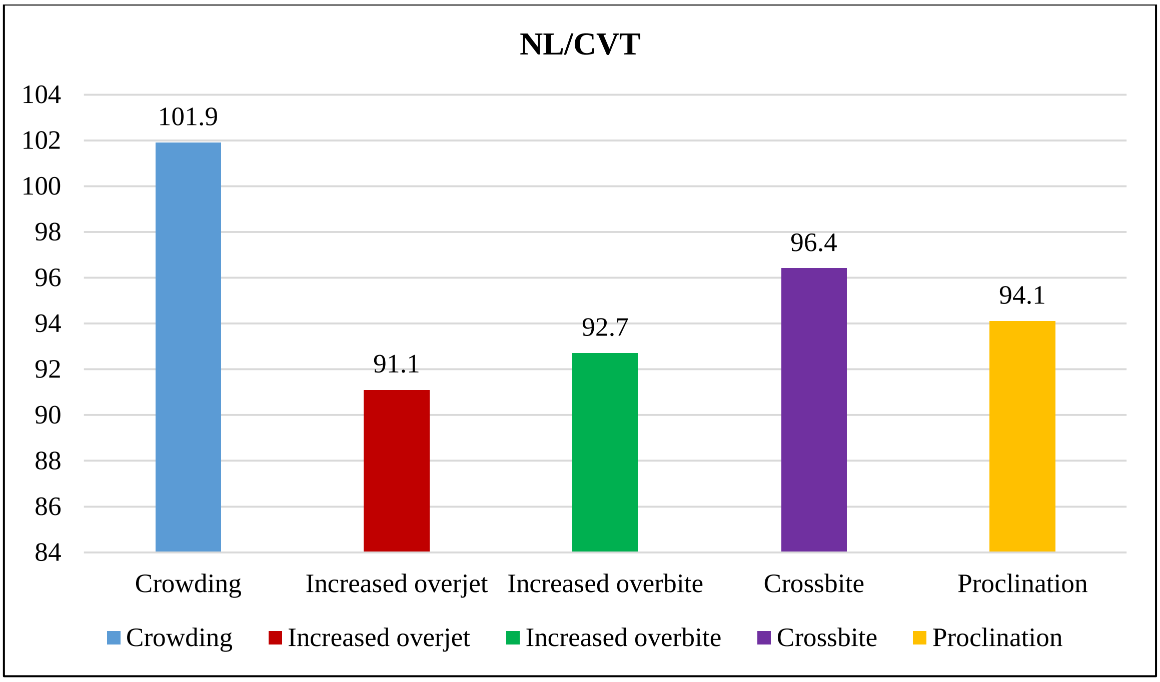
Graph 5: Comparison of the mean values of NSL/OPT amongst the malocclusion traits



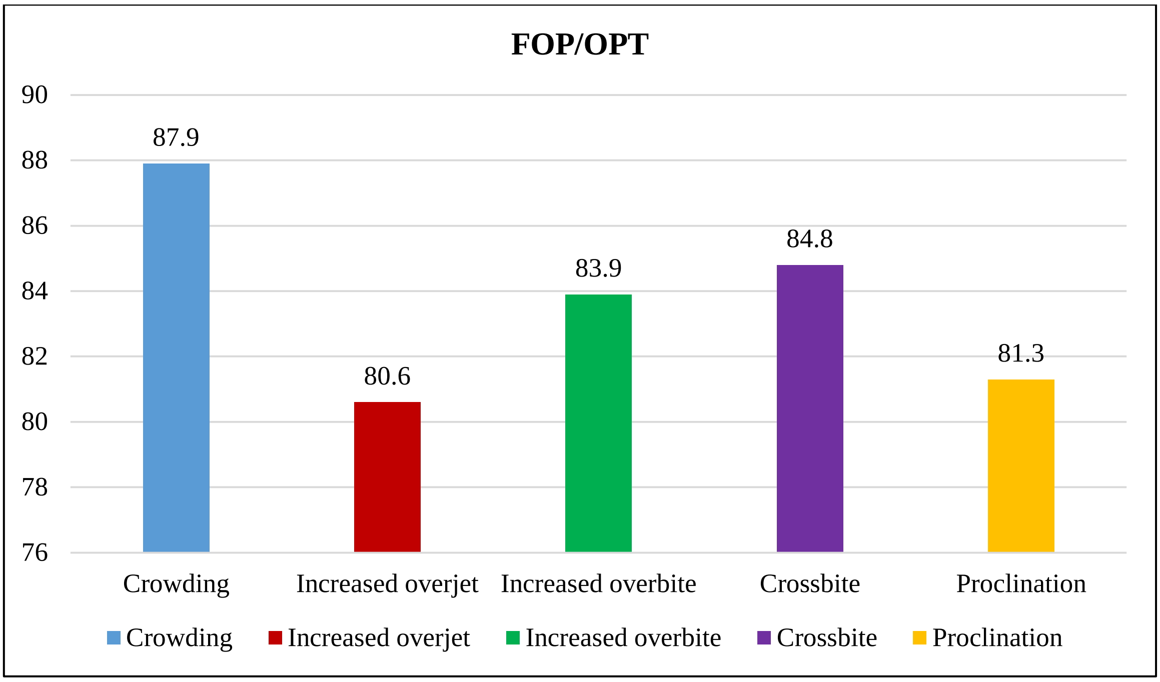
Graph 6: Comparison of the mean values of NSL/CVT amongst the malocclusion traits



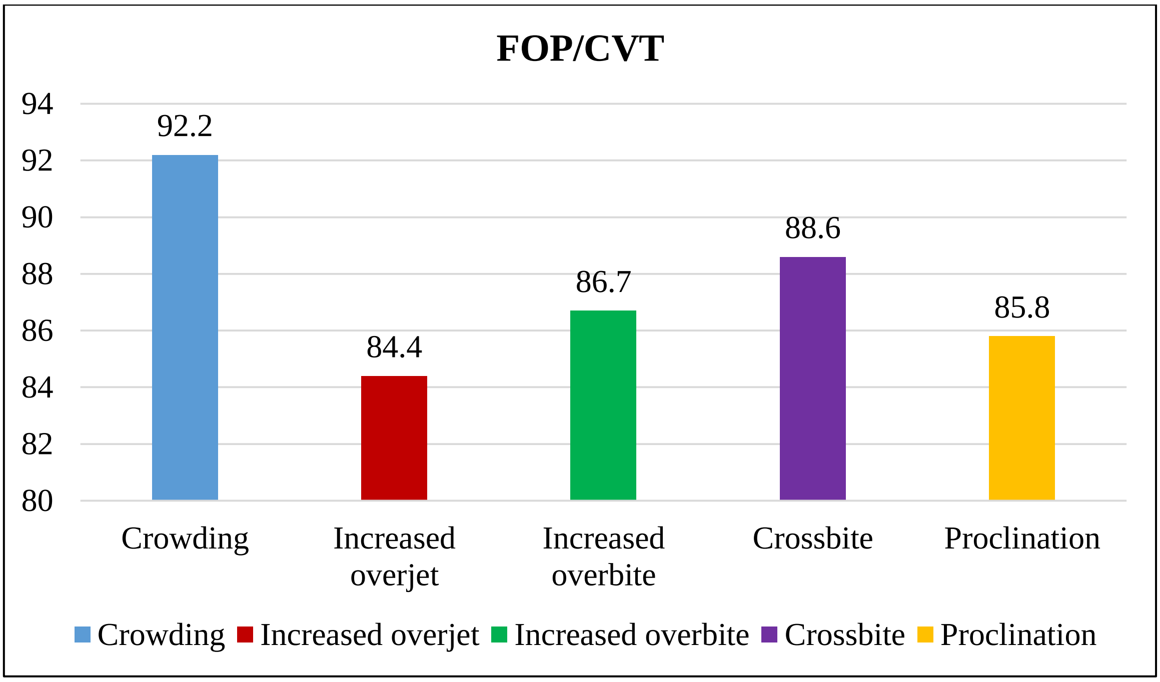
Graph 7: Comparison of the mean values of NL/OPT amongst the malocclusion traits



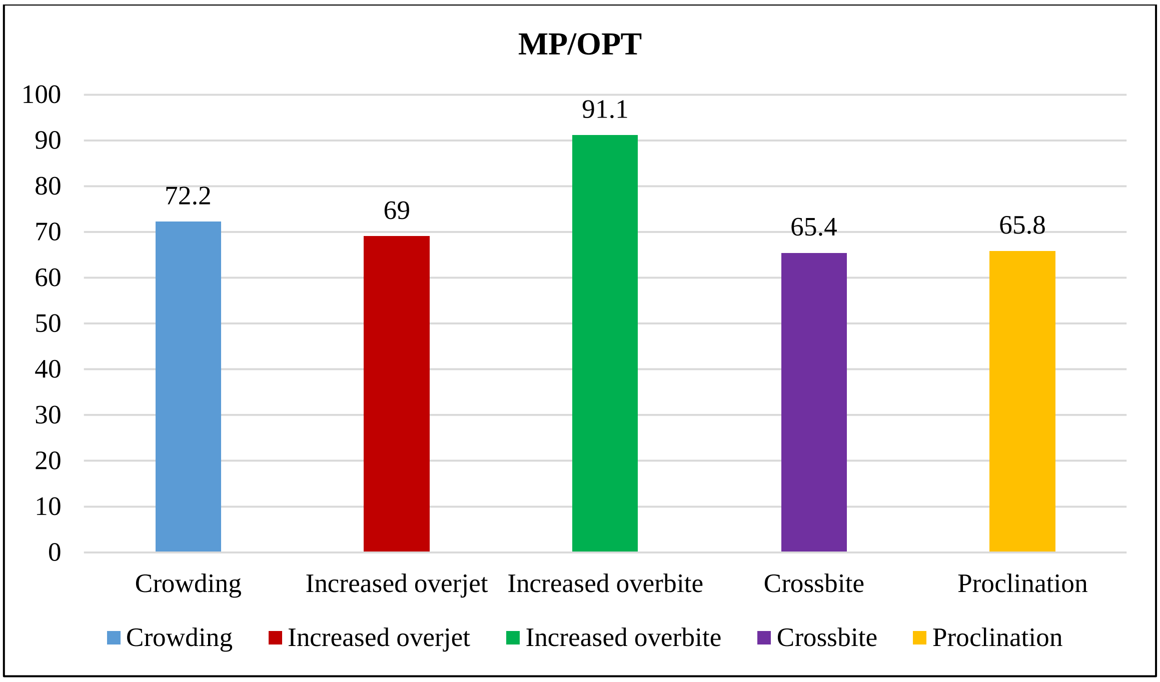
Graph 8: Comparison of the mean values of NL/CVT amongst the malocclusion traits



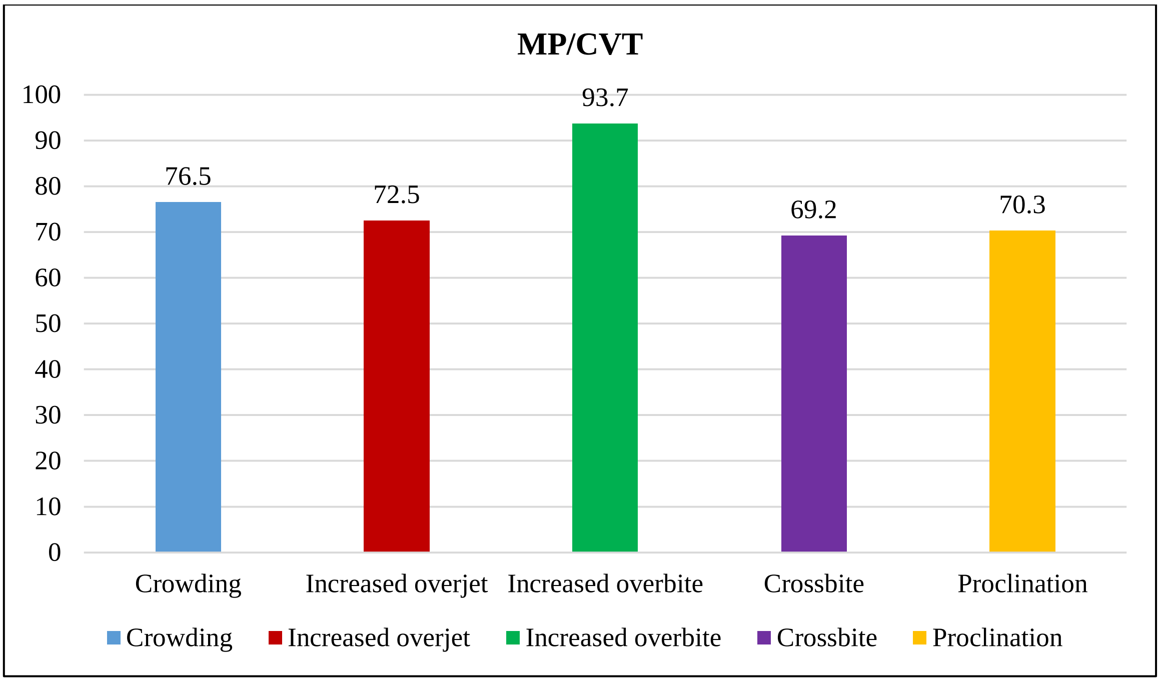
Graph 9: Comparison of the mean values of FOP/OPT amongst the malocclusion traits



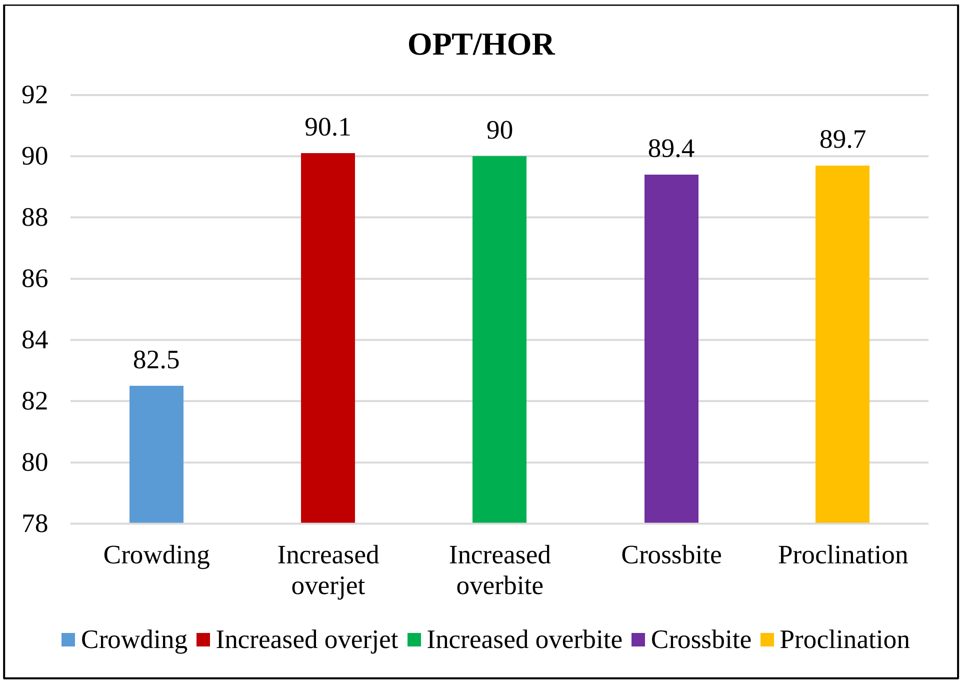
Graph 10: Comparison of the mean values of FOP/CVT amongst the malocclusion traits



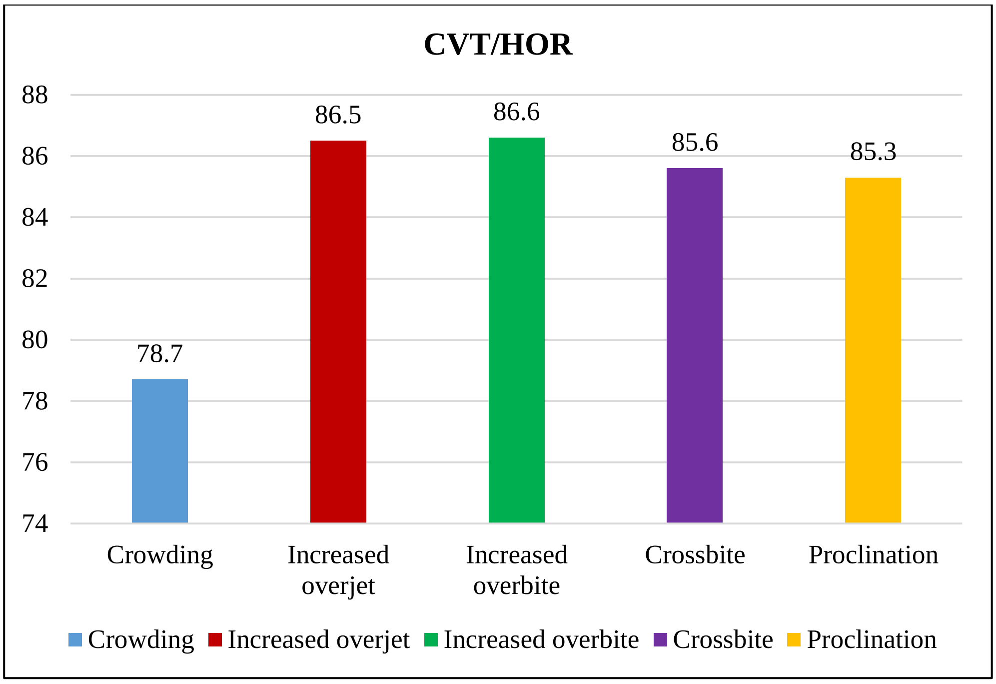
Graph 11: Comparison of the mean values of MP/OPT amongst the malocclusion traits



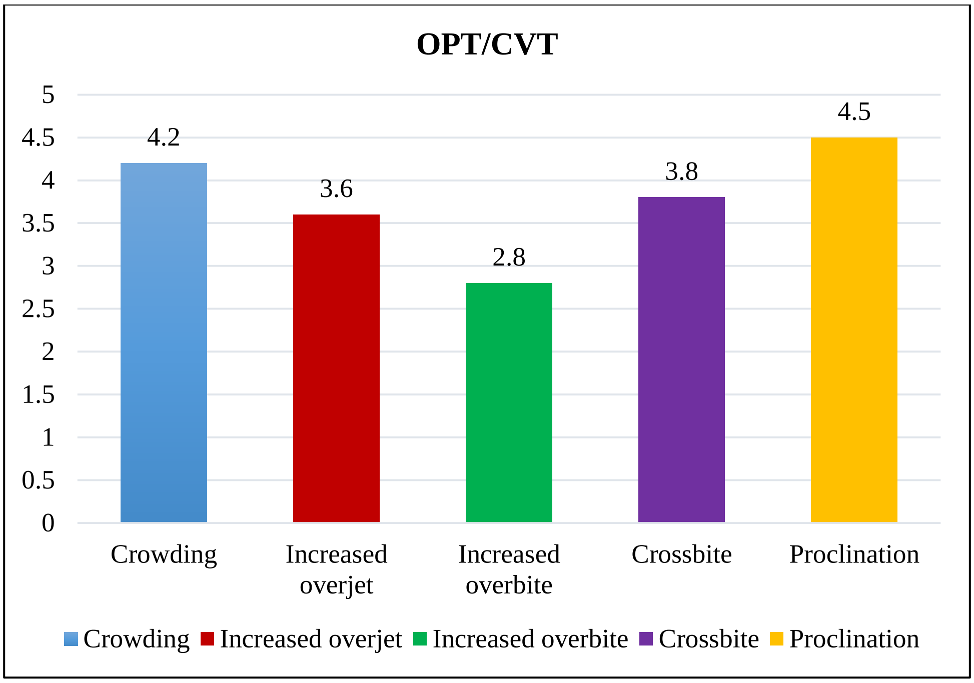
Graph 12: Comparison of the mean values of MP/CVT amongst the malocclusion traits



Graph 13: Comparison of the mean values of OPT/HOR amongst the malocclusion traits



Graph 14: Comparison of the mean values of CVT/HOR amongst the malocclusion traits



Graph 15: Comparison of the mean values of OPT/CVT amongst the malocclusion traits

ANNEXURE I

CASE RECORD FORM:

Name: Age/ Sex:

Address:

Contact number: OPD number:

Chief Complaint:

Past medical history:

Past dental history:

History of abnormal habit:

CLINICAL EXAMINATION:

- EXTRAORAL EXAMINATION:

  Facial profile:

  Facial symmetry:

  Lip competency:

  Nasolabial angle:

  Mentolabial sulcus:

TMJ examination:

- INTRAORAL EXAMINATION:

Teeth present:

Teeth in occlusion:

Molar relation:

Canine relation:

Overjet:

Overbite:

Other findings:

Probable diagnosis:

Investigations:

Date **Staff signature**

ANNEXURES III

(Confidential)

INFORMED CONSENT FORM

"EVALUATION OF RELATIONSHIP BETWEEN HEAD POSTURE AND MALOCCLUSION TRAITS IN UNTREATED SKELETAL CLASS II PATIENTS"

NAME: Mr./Master/Mrs./Miss.____

Resident of: ____

__________________________________aged _____ years, exercising my free will/choice, without any pressure/lure of incentive in any form, hereby give my consent for the project to be conducted by **Dr. ______________________________.**

I acknowledge the receipt of "patient's information sheet", and also the doctor has informed me about this research project suitably and sufficiently to my satisfaction.

I agree to let my X-rays, photographs, other investigations to be taken as required.

I agree to take part in this project and will not mix any other projects during the period of this trial. I shall report to the dental hospital or other place where called on given appointment dates and time.

I certify that I have read or had read to me the contents of this form.

Date

____

Patient /legally authorized representative signature

Master Charts

MEASUREMENTS (GROUP = MALE)

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	98	92	80	73	107	111	102	94	89	93	83	87	80	76	4
2	99	93	102	56	115	117	108	110	96	98	73	75	90	88	2
3	94	90	100	67	100	105	96	101	86	91	73	78	84	79	5
4	98	87	82	70	110	114	100	104	95	99	82	86	80	76	4
5	100	91	85	56	116	121	110	115	99	104	72	77	81	76	5
6	91	86	75	60	104	109	96	101	86	91	73	78	78	73	5
7	95	90	70	58	98	102	93	97	73	77	64	68	85	81	4
8	96	83	75	61	102	106	88	92	80	84	66	70	85	81	4
9	98	91	77	55	110	119	102	111	89	98	67	76	78	69	9
10	98	87	82	70	109	112	99	112	95	98	70	73	79	76	3
11	98	92	80	73	111	114	91	94	92	95	68	71	79	76	3
12	99	93	102	56	119	123	98	102	94	98	69	73	80	76	4
13	100	92	79	67	105	110	100	105	90	95	66	71	84	79	5
14	99	93	102	56	109	113	94	98	88	92	73	77	81	77	4
15	94	90	100	67	113	115	99	101	89	91	70	72	79	77	2
16	98	87	82	70	120	125	102	107	92	97	80	85	85	80	5
17	98	92	80	73	122	126	110	114	91	95	79	84	84	80	4
18	99	93	102	56	117	122	100	105	89	94	74	79	85	80	5
19	92	85	85	74	90	95	81	87	82	87	71	76	93	89	5
20	80	87	84	73	75	82	60	67	58	65	54	61	115	108	7
21	87	81	70	62	80	85	74	79	62	67	55	60	97	92	5
22	85	95	85	69	72	75	81	84	88	91	75	78	85	82	3
23	100	90	84	60	82	87	92	97	86	91	64	69	87	82	5
24	98	92	89	67	88	91	81	84	78	81	56	59	101	98	3

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
25	100	92	91	78	99	103	92	96	86	90	76	80	91	87	4
26	96	90	86	74	93	98	88	93	84	89	78	83	92	87	5
27	95	91	94	73	104	98	95	101	81	87	76	82	85	79	6
28	98	86	79	67	105	101	88	92	83	87	58	62	89	85	4
29	88	82	99	72	97	100	88	85	88	91	76	79	81	78	3
30	96	87	92	74	95	98	94	91	82	85	74	77	90	87	3
31	92	83	84	79	90	96	98	92	79	85	76	82	92	86	6
32	96	88	74	67	92	98	96	90	89	95	75	81	94	88	6
33	96	94	87	73	84	90	99	92	80	86	76	82	102	96	6
34	86	84	86	68	79	84	101	96	80	85	69	74	97	92	5
35	94	91	91	69	97	100	87	83	83	86	71	74	87	84	3
36	90	90	86	66	95	96	83	84	79	80	78	79	84	83	1
37	90	90	81	85	89	90	89	90	85	86	96	97	91	90	1
38	97	88	91	86	93	93	95	95	95	95	97	97	94	94	0
39	93	89	95	88	85	89	98	94	86	90	98	102	96	92	4
40	92	91	93	84	86	90	95	91	85	89	88	92	94	90	4
41	97	97	89	87	101	104	79	76	86	89	96	99	86	83	3
42	94	91	82	83	96	99	87	84	80	83	92	95	88	85	3
43	98	89	85	88	94	102	95	87	88	96	96	94	94	86	8
44	98	94	80	87	102	103	82	83	86	87	96	97	85	84	1
45	95	94	88	85	108	111	89	92	84	87	98	101	86	83	3
46	93	95	92	84	95	96	97	98	77	78	97	98	88	87	1
47	90	88	83	85	102	105	94	97	72	75	88	91	99	102	3
48	100	92	81	88	91	98	85	92	85	92	98	105	98	91	7
49	92	90	93	89	93	97	89	93	84	88	90	94	92	88	4
50	90	86	80	86	99	100	95	96	79	80	95	96	83	82	1
51	95	91	93	86	96	98	94	96	82	84	94	96	88	86	2

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
52	95	90	93	84	91	91	87	87	84	84	93	93	94	94	0
53	92	90	95	85	89	92	87	90	80	83	92	95	92	89	3
54	90	90	85	87	90	92	91	93	79	81	89	91	89	87	2
55	94	90	100	92	94	99	90	95	89	93	63	67	91	87	4
56	100	95	96	90	106	107	100	101	89	94	66	71	92	87	5
57	98	92	95	91	94	99	88	93	83	89	73	79	85	79	6
58	100	94	98	86	105	109	79	83	81	85	64	68	89	85	4
59	99	89	88	82	89	93	95	99	87	90	66	69	81	78	3
60	96	91	96	87	92	95	89	92	87	90	64	67	90	87	3
61	97	87	92	83	103	107	84	88	78	84	67	73	92	86	6
62	100	96	96	88	110	111	73	74	75	81	61	67	94	88	6
63	100	94	96	94	106	110	100	104	87	93	70	76	102	96	6
64	100	90	86	84	101	104	92	95	88	93	74	79	97	92	5
65	97	90	94	91	96	98	88	90	80	83	67	70	87	84	3
66	100	90	90	90	103	105	94	96	84	85	56	57	84	83	1
67	91	90	92	88	97	103	94	100	84	85	60	61	90	89	1
68	102	93	80	65	103	110	95	82	82	89	67	74	99	92	7
69	96	91	80	64	103	106	96	100	85	88	69	72	82	85	3
70	97	88	80	60	96	101	88	93	78	83	60	65	91	86	5
71	96	90	82	59	82	90	76	83	67	75	45	53	96	84	9
72	98	92	80	73	107	111	102	94	89	93	83	87	80	76	4
73	92	85	85	74	90	95	81	87	82	87	71	76	93	89	5
74	100	92	89	77	92	98	90	85	82	87	70	76	97	92	5
75	97	94	86	75	85	89	82	86	73	77	62	66	84	80	4
76	95	87	83	64	98	100	90	92	85	87	69	71	88	86	2
77	99	93	102	56	115	117	108	110	96	98	73	75	115	113	2
78	97	90	100	62	95	100	90	95	94	99	62	67	93	88	5

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
79	94	90	100	67	100	105	96	101	86	91	73	78	84	79	5
80	100	91	80	65	93	99	85	91	74	80	57	63	96	90	6
81	99	95	100	70	93	98	88	93	74	79	63	68	97	92	5
82	102	95	87	67	96	103	88	95	80	87	61	68	96	89	7
83	98	89	80	60	82	86	94	98	86	90	66	70	86	82	4
84	93	90	100	60	80	82	99	101	87	89	67	69	83	81	2
85	99	90	100	60	92	100	82	90	72	80	52	60	98	90	8
86	80	87	84	73	75	82	60	67	58	65	54	61	115	108	7
87	98	87	82	70	110	114	100	104	95	99	82	86	77	73	4
88	96	83	75	61	102	106	88	92	80	84	66	70	85	81	4
89	100	90	84	60	82	87	92	97	86	91	64	69	87	82	5
90	96	92	78	62	100	106	97	103	82	88	67	73	86	80	6

MEASUREMENTS (GROUP = FEMALE)

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	91	86	75	60	103	108	97	112	86	91	77	82	80	75	5
2	95	90	70	58	100	104	97	101	86	90	80	84	81	77	4
3	96	83	75	61	101	103	95	97	84	86	78	80	82	80	2
4	99	93	102	56	99	104	90	94	85	90	74	79	86	81	5
5	94	90	100	67	114	118	96	110	87	92	73	77	84	88	4
6	98	87	82	70	108	112	93	98	85	90	67	72	85	80	5
7	97	88	79	67	110	115	92	97	84	89	72	77	81	76	5
8	98	93	102	56	104	108	95	99	85	89	74	78	85	89	4
9	99	90	100	67	116	120	100	104	88	92	79	83	84	80	4
10	96	91	82	70	108	112	93	98	85	90	67	72	85	80	5
11	100	86	70	58	109	113	94	98	88	92	73	77	86	82	4
12	101	87	75	61	111	114	91	94	92	95	68	71	82	78	3
13	91	86	75	60	119	123	98	102	94	98	69	73	80	76	4
14	95	90	70	58	105	110	100	105	90	95	66	71	84	79	5
15	96	83	75	61	109	113	94	98	88	92	73	77	88	84	4
16	98	87	82	70	104	109	96	101	86	91	73	78	78	73	5
17	98	92	80	73	98	102	93	97	73	77	64	68	81	77	4
18	99	93	102	56	102	106	88	92	80	84	66	70	85	81	4
19	92	88	88	73	94	95	91	92	87	88	65	66	90	89	1
20	103	90	82	73	100	103	87	90	83	86	74	77	93	90	3
21	100	90	87	64	101	103	93	95	82	84	82	84	88	86	2
22	98	90	86	66	107	108	98	99	89	90	80	81	82	81	1
23	90	85	80	67	87	93	82	88	84	90	79	85	91	85	6
24	98	88	78	56	102	106	91	95	90	94	72	76	85	81	4
25	93	88	73	67	103	104	96	97	75	76	77	78	80	79	1
26	94	90	99	70	101	101	97	97	87	87	75	75	84	84	0
27	96	90	82	73	98	100	92	94	84	86	78	80	87	85	2
28	100	94	83	56	97	100	90	93	74	77	54	57	93	90	3
29	98	89	76	60	88	91	87	90	72	75	55	58	89	86	3

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
30	90	90	84	58	98	104	99	104	85	91	75	81	86	80	6
31	92	83	87	61	90	96	98	92	85	91	64	70	92	86	6
32	90	90	84	73	95	96	84	83	75	76	56	57	84	83	1
33	92	88	76	67	94	95	91	92	72	73	59	60	90	89	1
34	92	88	83	72	93	95	91	93	75	77	62	64	90	88	2
35	92	82	82	74	92	98	91	97	78	84	56	60	90	84	6
36	92	90	83	79	89	92	90	93	80	89	67	69	92	89	3
37	94	90	82	85	82	89	99	106	77	84	98	105	100	93	7
38	92	88	88	84	94	98	89	93	72	76	97	101	90	86	4
39	101	97	94	85	107	111	100	105	95	99	100	104	89	81	4
40	100	94	90	88	100	105	94	99	86	91	98	103	85	86	5
41	92	91	89	82	98	100	98	100	72	74	91	93	86	84	2
42	99	94	85	86	107	111	101	105	85	89	92	96	88	78	4
43	93	95	81	94	95	96	97	98	84	85	92	93	99	87	1
44	92	91	90	89	86	90	95	91	85	89	89	93	98	90	4
45	97	97	84	87	101	104	79	76	91	94	98	101	92	83	3
46	90	90	82	80	99	100	95	96	86	87	94	95	83	82	1
47	95	90	86	82	91	91	87	87	82	82	98	98	94	94	0
48	92	91	85	81	86	90	95	91	89	93	98	102	94	90	4
49	94	91	91	69	97	100	87	83	83	86	71	74	87	84	3
50	90	90	86	66	95	96	83	84	79	80	78	79	84	83	1
51	92	88	88	73	94	95	91	92	87	88	65	66	90	89	1
52	98	87	82	70	109	112	99	112	95	98	70	73	75	72	3
53	98	92	80	73	111	114	91	94	92	95	68	71	79	76	3
54	93	95	81	94	95	96	97	98	84	85	92	93	99	87	1
55	95	88	103	90	100	100	94	94	83	86	64	67	93	90	3
56	93	85	100	90	105	107	97	99	89	91	71	73	88	86	2
57	89	85	98	90	94	98	91	95	89	90	70	71	82	81	1
58	97	90	90	85	107	109	101	103	92	98	62	68	91	85	6
59	96	87	98	88	108	109	99	100	90	94	69	73	85	81	4
60	99	98	93	88	107	110	112	115	92	98	73	79	90	84	6

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
61	92	89	96	90	101	103	96	98	78	80	73	75	87	85	2
62	97	94	100	94	103	106	100	102	85	88	57	60	93	90	3
63	100	90	98	89	116	117	106	107	82	85	63	66	89	86	3
64	93	92	90	90	99	103	98	102	89	95	61	67	86	80	6
65	90	84	92	83	93	96	89	92	77	83	66	72	92	86	6
66	100	87	90	90	105	105	93	93	84	85	67	68	84	83	1
67	100	90	92	88	101	104	92	95	87	90	52	55	92	89	3
68	100	90	76	63	106	107	95	96	83	84	68	69	85	86	1
69	100	91	85	56	116	121	110	115	99	104	72	77	76	71	5
70	87	81	70	62	80	85	74	79	62	67	55	60	97	92	5
71	85	95	85	69	72	75	81	84	88	91	75	78	85	82	3
72	96	88	82	80	97	101	90	94	83	87	82	86	89	85	4
73	97	93	80	65	94	99	90	95	74	79	60	65	93	88	5
74	94	91	82	70	92	94	89	91	79	81	64	66	92	90	2
75	94	88	76	57	97	101	89	93	83	87	63	67	90	86	4
76	99	90	87	65	99	103	91	95	86	90	66	70	90	86	4
77	91	86	75	60	104	109	96	101	86	91	73	78	78	73	5
78	95	90	70	58	98	102	93	97	73	77	64	68	87	83	4
79	91	91	86	73	59	94	101	88	95	71	78	61	68	87	80
80	92	96	88	79	70	94	96	87	89	80	82	70	72	91	89

MEASUREMENTS (GROUP = CROWDING)

SR.NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	98	92	80	73	107	111	102	94	89	93	83	87	80	76	4
2	99	93	102	56	115	117	108	110	96	98	73	75	90	88	2
3	94	90	100	67	100	105	96	101	86	91	73	78	84	79	5
4	98	87	82	70	110	114	100	104	95	99	82	86	80	76	4
5	100	91	85	56	116	121	110	115	99	104	72	77	81	76	5
6	91	86	75	60	104	109	96	101	86	91	73	78	78	73	5
7	95	90	70	58	98	102	93	97	73	77	64	68	85	81	4
8	96	83	75	61	102	106	88	92	80	84	66	70	85	81	4
9	98	91	77	55	110	119	102	111	89	98	67	76	78	69	9
10	98	87	82	70	109	112	99	112	95	98	70	73	79	76	3
11	98	92	80	73	111	114	91	94	92	95	68	71	79	76	3
12	99	93	102	56	119	123	98	102	94	98	69	73	80	76	4
13	100	92	79	67	105	110	100	105	90	95	66	71	84	79	5
14	99	93	102	56	109	113	94	98	88	92	73	77	81	77	4
15	94	90	100	67	113	115	99	101	89	91	70	72	79	77	2
16	98	87	82	70	120	125	102	107	92	97	80	85	85	80	5
17	98	92	80	73	122	126	110	114	91	95	79	84	84	80	4
18	99	93	102	56	117	122	100	105	89	94	74	79	85	80	5
19	91	86	75	60	103	108	97	112	86	91	77	82	80	75	5
20	95	90	70	58	100	104	97	101	86	90	80	84	81	77	4

SR.NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
21	96	83	75	61	101	103	95	97	84	86	78	80	82	80	2
22	99	93	102	56	99	104	90	94	85	90	74	79	86	81	5
23	94	90	100	67	114	118	96	110	87	92	73	77	84	88	4
24	98	87	82	70	108	112	93	98	85	90	67	72	85	80	5
25	97	88	79	67	110	115	92	97	84	89	72	77	81	76	5
26	98	93	102	56	104	108	95	99	85	89	74	78	85	89	4
27	99	90	100	67	116	120	100	104	88	92	79	83	84	80	4
28	96	91	82	70	108	112	93	98	85	90	67	72	85	80	5
29	100	86	70	58	109	113	94	98	88	92	73	77	86	82	4
30	101	87	75	61	111	114	91	94	92	95	68	71	82	78	3
31	91	86	75	60	119	123	98	102	94	98	69	73	80	76	4
32	95	90	70	58	105	110	100	105	90	95	66	71	84	79	5
33	96	83	75	61	109	113	94	98	88	92	73	77	88	84	4
34	98	87	82	70	104	109	96	101	86	91	73	78	78	73	5
35	98	92	80	73	98	102	93	97	73	77	64	68	81	77	4

MEASUREMENTS (GROUP = INCREASED OVERJET)

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	92	85	85	74	90	95	81	87	82	87	71	76	93	89	5
2	80	87	84	73	75	82	60	67	58	65	54	61	115	108	7
3	87	81	70	62	80	85	74	79	62	67	55	60	97	92	5
4	85	95	85	69	72	75	81	84	88	91	75	78	85	82	3
5	100	90	84	60	82	87	92	97	86	91	64	69	87	82	5
6	98	92	89	67	88	91	81	84	78	81	56	59	101	98	3
7	100	92	91	78	99	103	92	96	86	90	76	80	91	87	4
8	96	90	86	74	93	98	88	93	84	89	78	83	92	87	5
9	95	91	94	73	104	98	95	101	81	87	76	82	85	79	6
10	98	86	79	67	105	101	88	92	83	87	58	62	89	85	4
11	88	82	99	72	97	100	88	85	88	91	76	79	81	78	3
12	96	87	92	74	95	98	94	91	82	85	74	77	90	87	3
13	92	83	84	79	90	96	98	92	79	85	76	82	92	86	6
14	96	88	74	67	92	98	96	90	89	95	75	81	94	88	6
15	96	94	87	73	84	90	99	92	80	86	76	82	102	96	6
16	86	84	86	68	79	84	101	96	80	85	69	74	97	92	5
17	94	91	91	69	97	100	87	83	83	86	71	74	87	84	3
18	90	90	86	66	95	96	83	84	79	80	78	79	84	83	1
19	92	88	88	73	94	95	91	92	87	88	65	66	90	89	1
20	103	90	82	73	100	103	87	90	83	86	74	77	93	90	3
21	100	90	87	64	101	103	93	95	82	84	82	84	88	86	2
22	98	90	86	66	107	108	98	99	89	90	80	81	82	81	1

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
23	90	85	80	67	87	93	82	88	84	90	79	85	91	85	6
24	98	88	78	56	102	106	91	95	90	94	72	76	85	81	4
25	93	88	73	67	103	104	96	97	75	76	77	78	80	79	1
26	94	90	99	70	101	101	97	97	87	87	75	75	84	84	0
27	96	90	82	73	98	100	92	94	84	86	78	80	87	85	2
28	100	94	83	56	97	100	90	93	74	77	54	57	93	90	3
29	98	89	76	60	88	91	87	90	72	75	55	58	89	86	3
30	90	90	84	58	98	104	99	104	85	91	75	81	86	80	6
31	92	83	87	61	90	96	98	92	85	91	64	70	92	86	6
32	90	90	84	73	95	96	84	83	75	76	56	57	84	83	1
33	92	88	76	67	94	95	91	92	72	73	59	60	90	89	1
34	92	88	83	72	93	95	91	93	75	77	62	64	90	88	2
35	92	82	82	74	92	98	91	97	78	84	56	60	90	84	6

MEASUREMENTS (GROUP = INCREASED OVERBITE)

SR.NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	90	90	81	85	89	90	89	90	85	86	96	97	91	90	1
2	97	88	91	86	93	93	95	95	95	95	97	97	94	94	0
3	93	89	95	88	85	89	98	94	86	90	98	102	96	92	4
4	92	91	93	84	86	90	95	91	85	89	88	92	94	90	4
5	97	97	89	87	101	104	79	76	86	89	96	99	86	83	3
6	94	91	82	83	96	99	87	84	80	83	92	95	88	85	3
7	98	89	85	88	94	102	95	87	88	96	96	94	94	86	8
8	98	94	80	87	102	103	82	83	86	87	96	97	85	84	1
9	95	94	88	85	108	111	89	92	84	87	98	101	86	83	3
10	93	95	92	84	95	96	97	98	77	78	97	98	88	87	1
11	90	88	83	85	102	105	94	97	72	75	88	91	99	102	3
12	100	92	81	88	91	98	85	92	85	92	98	105	98	91	7
13	92	90	93	89	93	97	89	93	84	88	90	94	92	88	4
14	90	86	80	86	99	100	95	96	79	80	95	96	83	82	1
15	95	91	93	86	96	98	94	96	82	84	94	96	88	86	2
16	95	90	93	84	91	91	87	87	84	84	93	93	94	94	0
17	92	90	95	85	89	92	87	90	80	83	92	95	92	89	3
18	90	90	85	87	90	92	91	93	79	81	89	91	89	87	2
19	94	90	82	85	82	89	99	106	77	84	98	105	100	93	7
20	92	88	88	84	94	98	89	93	72	76	97	101	90	86	4
21	101	97	94	85	107	111	100	105	95	99	100	104	89	81	4
22	100	94	90	88	100	105	94	99	86	91	98	103	85	86	5

SR.NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
23	92	91	89	82	98	100	98	100	72	74	91	93	86	84	2
24	99	94	85	86	107	111	101	105	85	89	92	96	88	78	4
25	93	95	81	94	95	96	97	98	84	85	92	93	99	87	1
26	92	91	90	89	86	90	95	91	85	89	89	93	98	90	4
27	97	97	84	87	101	104	79	76	91	94	98	101	92	83	3
28	90	90	82	80	99	100	95	96	86	87	94	95	83	82	1
29	95	90	86	82	91	91	87	87	82	82	98	98	94	94	0
30	92	91	85	81	86	90	95	91	89	93	98	102	94	90	4
31	94	91	91	69	97	100	87	83	83	86	71	74	87	84	3
32	90	90	86	66	95	96	83	84	79	80	78	79	84	83	1
33	92	88	88	73	94	95	91	92	87	88	65	66	90	89	1
34	98	87	82	70	109	112	99	112	95	98	70	73	75	72	3
35	98	92	80	73	111	114	91	94	92	95	68	71	79	76	3

MEASUREMENTS (GROUP = INCREASED CROSSBITE)

SR.NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT
1	94	90	100	92	94	99	90	95	89	93	63	67	91	87	4
2	100	95	96	90	106	107	100	101	89	94	66	71	92	87	5
3	98	92	95	91	94	99	88	93	83	89	73	79	85	79	6
4	100	94	98	86	105	109	79	83	81	85	64	68	89	85	4
5	99	89	88	82	89	93	95	99	87	90	66	69	81	78	3
6	96	91	96	87	92	95	89	92	87	90	64	67	90	87	3
7	97	87	92	83	103	107	84	88	78	84	67	73	92	86	6
8	100	96	96	88	110	111	73	74	75	81	61	67	94	88	6
9	100	94	96	94	106	110	100	104	87	93	70	76	102	96	6
10	100	90	86	84	101	104	92	95	88	93	74	79	97	92	5
11	97	90	94	91	96	98	88	90	80	83	67	70	87	84	3
12	100	90	90	90	103	105	94	96	84	85	56	57	84	83	1
13	91	90	92	88	97	103	94	100	84	85	60	61	90	89	1
14	95	88	103	90	100	100	94	94	83	86	64	67	93	90	3
15	93	85	100	90	105	107	97	99	89	91	71	73	88	86	2
16	89	85	98	90	94	98	91	95	89	90	70	71	82	81	1
17	97	90	90	85	107	109	101	103	92	98	62	68	91	85	6
18	96	87	98	88	108	109	99	100	90	94	69	73	85	81	4
19	99	98	93	88	107	110	112	115	92	98	73	79	90	84	6
20	92	89	96	90	101	103	96	98	78	80	73	75	87	85	2
21	97	94	100	94	103	106	100	102	85	88	57	60	93	90	3
22	100	90	98	89	116	117	106	107	82	85	63	66	89	86	3
23	93	92	90	90	99	103	98	102	89	95	61	67	86	80	6
24	90	84	92	83	93	96	89	92	77	83	66	72	92	86	6
25	100	87	90	90	105	105	93	93	84	85	67	68	84	83	1

MEASUREMENTS (GROUP = PROCLINATION)

SR. NO.	NSL/VER	NL/VER	FOP/VER	MP/VER	NSL/OPT	NSL/CVT	NL/OPT	NL/CVT	FOP/OPT	FOP/CVT	MP/OPT	MP/CVT	OPT/HOR	CVT/HOR	OPT/CVT	upper incisor	lower incisor	interincisal angle
1	102	93	80	65	103	110	95	82	82	89	67	74	99	92	7	112	111	110
2	96	91	80	64	103	106	96	100	85	88	69	72	82	85	3	102	96	100
3	97	88	80	60	96	101	88	93	78	83	60	65	91	86	5	111	109	101
4	96	90	82	59	82	90	76	83	67	75	45	53	96	84	9	120	107	96
5	98	92	80	73	107	111	102	94	89	93	83	87	80	76	4	107	111	117
6	92	85	85	74	90	95	81	87	82	87	71	76	93	89	5	124	110	106
7	100	92	89	77	92	98	90	85	82	87	70	76	97	92	5	120	111	107
8	97	94	86	75	85	89	82	86	73	77	62	66	84	80	4	98	112	121
9	95	87	83	64	98	100	90	92	85	87	69	71	88	86	2	115	111	105
10	99	93	102	56	115	117	108	110	96	98	73	75	115	113	2	101	90	125
11	97	90	100	62	95	100	90	95	94	99	62	67	93	88	5	110	92	121
12	94	90	100	67	100	105	96	101	86	91	73	78	84	79	5	106	104	123
13	100	91	80	65	93	99	85	91	74	80	57	63	96	90	6	122	98	104
14	99	95	100	70	93	98	88	93	74	79	63	68	97	92	5	117	110	103
15	102	95	87	67	96	103	88	95	80	87	61	68	96	89	7	125	98	100
16	98	89	80	60	82	86	94	98	86	90	66	70	86	82	4	110	103	110
17	93	90	100	60	80	82	99	101	87	89	67	69	83	81	2	118	99	110
18	99	90	100	60	92	100	82	90	72	80	52	60	98	90	8	107	96	103
19	80	87	84	73	75	82	60	67	58	65	54	61	115	108	7	122	95	117
20	98	87	82	70	110	114	100	104	95	99	82	86	77	73	4	118	102	111
21	100	90	76	63	106	107	95	96	83	84	68	69	85	86	1	122	90	114
22	100	91	85	56	116	121	110	115	99	104	72	77	76	71	5	111	92	115

23	87	81	70	62	80	85	74	79	62	67	55	60	97	92	5	120	97	118
24	85	95	85	69	72	75	81	84	88	91	75	78	85	82	3	114	110	98
25	96	88	82	80	97	101	90	94	83	87	82	86	89	85	4	90	113	140
26	97	93	80	65	94	99	90	95	74	79	60	65	93	88	5	113	99	114
27	94	91	82	70	92	94	89	91	79	81	64	66	92	90	2	123	104	99
28	94	88	76	57	97	101	89	93	83	87	63	67	90	86	4	112	102	110
29	99	90	87	65	99	103	91	95	86	90	66	70	90	86	4	112	96	118
30	91	86	75	60	104	109	96	101	86	91	73	78	78	73	5	120	101	108
31	95	90	70	58	98	102	93	97	73	77	64	68	87	83	4	100	98	123
32	96	83	75	61	102	106	88	92	80	84	66	70	85	81	4	91	89	144
33	100	90	84	60	82	87	92	97	86	91	64	69	87	82	5	84	91	123
34	96	92	78	62	100	106	97	103	82	88	67	73	86	80	6	109	105	112
35	91	86	73	59	94	101	88	95	71	78	61	68	87	80	7	108	103	115
36	96	88	79	70	94	96	87	89	80	82	70	72	91	89	2	115	103	117
37	90	88	80	70	94	97	93	96	83	86	74	77	85	82	3	118	100	121
38	98	91	77	55	110	119	102	111	89	98	67	76	78	69	9	110	104	103
39	98	92	89	67	88	91	81	84	78	81	56	59	101	98	3	118	107	105
40	97	88	80	60	96	101	88	93	78	83	60	65	91	86	5	111	109	101