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Predictability of skeletal sagittal and vertical jaw relationship with its correlation to cervical vertebral morphometry and cervical spine inclination

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Abstract

The cervical vertebra and its relation to maxilla and mandible is of particular interest to orthodontist due to their correlated developmental and anatomical relationship. The aim of the study is to evaluate and correlate the relationship between cervical vertebral morphology and cervical spine inclination with skeletal sagittal jaw relationship and growth pattern for an individual. Cephalogram of 30 subjects was divided in 3 groups based on ANB angle. All the craniofacial and craniocervical landmarks that are required to be analysed were recorded and it was concluded that class III patients had more posterior inclination of dens axis of CV2 but straighter spine inclination on subsequent arches. EVT/VER values indicated more enhanced curvature of vertical column in class II and class III patients. Morphological assessment of CV1SL & CV1HT revealed significantly less measurements in Class III that among class I and II subjects. CV2BL measurement in class II & III was significantly more than class. CV3SI was significantly more in class III and CV3BL was significantly less in class II.

Keywords: cervical vertebra, cervical spine inclination, sagittal jaw relationship, growth pattern

1. Introduction

The cervical vertebral column supports the head by seven vertebrae. The atlas & axis together form the sub-occipital segment that connects the cervical spine to the occiput ^[1]. The developmental association of cranial base to the vertebral column by notochord in early embryogenesis, and the attachments of cranial base to the jaw by ligaments, forms the developing link between cervical vertebral column and the jaws ^[2].

The stomatognathic apparatus consisting of head and cervical spine is believed to have musculo-neural connection between oral function and neck posture which is responsible for symptoms of disorders of masticatory system and cervical spine. According to study by Miralles in 2002 ^[3], reflex connections exist between the morphological structure of face and fusimotor muscle spindle of dorsal neck muscles. Any alteration in the anatomical elements, neural apparatus or their interconnections may influence the development of different structures and malocclusion resulting in postural changes.

Posture alignment starts its development from early period of life with development of spine and its curvature. At birth the spine has one 'c' shaped curve (primary curve) with one convexity and one concavity. With attainment of further growth and raising head from prone lying position sitting back and walking, the development of secondary curves (cervical curve and lumbar curve) takes place.

The correlation between cervical spine and posture was explained by Soft tissue stretching hypothesis (Solow and Kreiborg, 1977) ^[4] which stated that the soft tissue layer of facial skin and muscles are passively stretched when the head is extended in relation to the cervical column, which increases the forces on skeletal structures. These forces restrict the forward growth of maxilla and mandible and redirect it caudally.

It has been demonstrated earlier that in extended cranio-cervical posture; increased anterior facial height, reduced sagittal jaw dimensions and steeper inclination of mandible is observed,

Whereas, in flexed head position; in relation to cervical column, there is shortened anterior facial height, larger sagittal jaw dimension and less steep inclination of mandible (Solow and Tallgren, 1976) [4]. It has also been demonstrated that growth changes in cervicocranial posture are related to corresponding changes in growth pattern of facial skeleton (Solow and Siersback Nielson, 1986) [5]. In individuals with large or small craniocervical angle, the subsequent facial development can be predicted to some extent.

In view of these associations the relation between craniocervical inclinations and occurrence of malocclusion is of particular interest, but little information is available. So the present study was conducted with aim to determine the association between cervical spine inclination and cervical morphometry in patients with different sagittal and vertical skeletal jaw patterns.

2. Material and Methods

Patients reporting to the Out Patient Department of Orthodontics and Dentofacial Orthopaedics in age group of 18-30 years were selected for study and were divided in 3 groups based on ANB angle. Lateral cephalometric radiographs were taken with teeth in occlusion and standardized head posture. The posture was standardised by keeping forehead clamp and ear rods as external reference points. The radiographs were taken at Department of Oral Medicine and Radiology with focus-median plane distance of 180 cm and the film median plane distance of 10 cm as standard reference. They were grouped as: Group I–skeletal class I sagittal relation based on ANB angle (ANB angle of $2^{\circ} \pm 2^{\circ}$.) Group II–skeletal class II sagittal relation based on ANB angle (ANB angle of greater than 4° .) Group III–skeletal class III sagittal relation based on ANB angle (ANB angle) of less than 0° . Patients in all the 3 groups were sub-grouped in male and female patients.

Patients in age group of 18-30 years with presence of all permanent of first molars with good gingival & periodontal status, no history of previous orthodontic treatment, no congenitally missing teeth with no supernumerary teeth were included in the study. Patient with history of craniofacial syndromes or systemic muscle or joint disorder, history of orthodontic treatment and/or extraction and/or trauma to teeth or jaw were excluded from the study. Other exclusion criteria

parameters were presence or history of symptoms like backache or postural problems for prolonged period, non-availability of a profile radiograph with first six cervical vertebrae visible, cleft lip and/or palate and history of hormonal disturbances.

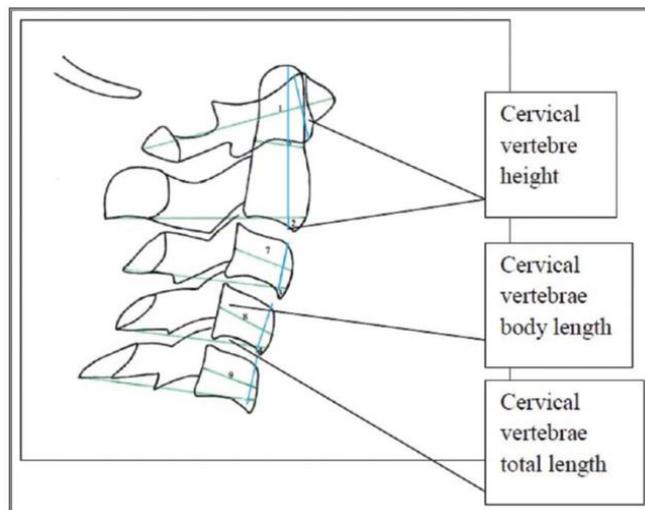


Fig 1: Cervical measurements

3. Results

Data was entered into Microsoft Excel spreadsheet and was analysed using Statistical Package for Social Sciences (SPSS) version 21. All the variables were continuous variables, which were summarized as mean and standard deviation. Normality of the data was checked by Shapiro Wilk test. Data was found to be normal. Keeping in view the nature (continuous) & distribution (normal) of data, inferential statistics were performed using parametric tests of significance.

Inferential statistics were performed using One way Analysis of Variance (ANOVA) Test & Independent Student’s t test. ANOVA test was used to compare variables according to Angle’s classes of molar relationship. Post hoc pairwise comparisons were done by post hoc Tukey’s test. Independent Student’s t test was used to compare variables according to growth pattern. The level of statistical significance was set at 0.05.

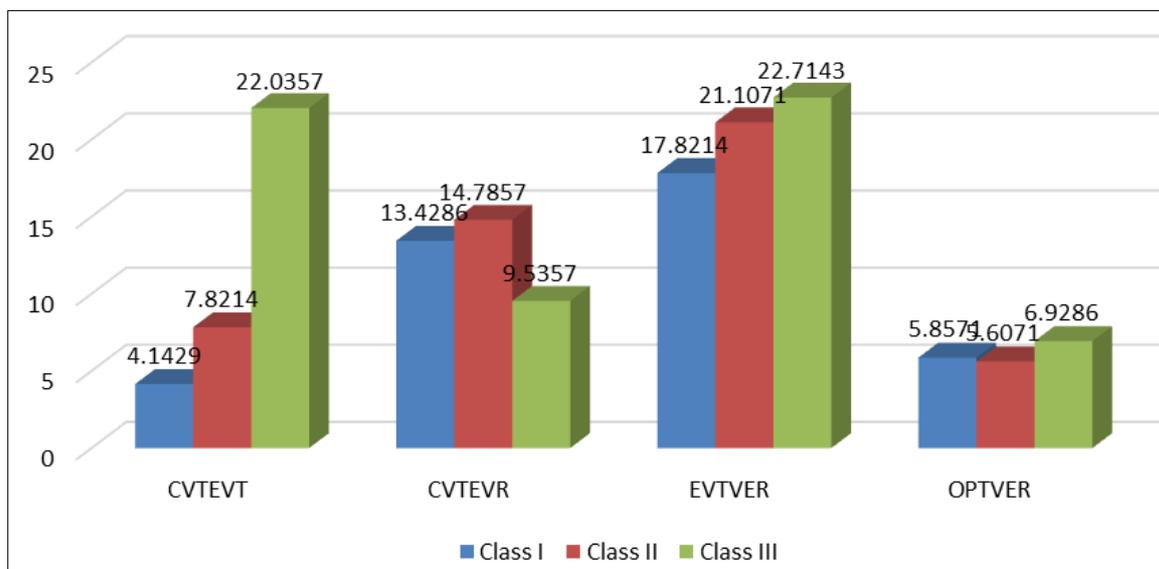


Fig 1: Intergroup comparison of mean CVT/EVT, CVT/VER, EVT/VER, OPT/VER

Table 1: Mean CVT/EVT, CVT/VER, EVT/VER, OPT/VER compared among subjects

	Growth pattern	N	Mean	Std. deviation	P value
CVTEVT	Horizontal	32	12.0938	8.99232	0.557, NS
	Vertical	52	10.8654	9.44547	
CVTVER	Horizontal	32	12.5000	4.06400	0.908, NS
	Vertical	52	12.6346	5.71900	
EVTVER	Horizontal	32	19.3438	4.56218	0.107, NS
	Vertical	52	21.2885	5.71663	
OPTVER	Horizontal	32	7.0938	2.37404	0.005, S
	Vertical	52	5.5385	2.41289	

4. Discussion

The Maxillo-mandibular relationship determining the facial profile of a patient is integral to orthodontic diagnosis and treatment planning. The close proximity and related origin of maxilla – mandible and cervical vertebrae indicate the presence of a biological mechanism coordinating change in posture and lower facial development. This correlation was assessed by Solow and Kreiberg in 1977.

Our study showed that mean Saddle angle among Class II subjects was more than that of class III subjects. This angle is formed between anterior cranial base & posterior cranial base and is influenced by the sagittal growth centre (the sphenoccipital synchondrosis) which is enclosed within the posterior cranial base. Growth at the spheno-occipital synchondrosis carries the maxilla upward and forward relative to mandible resulting in flattening of saddle angle in class II patients (wik *et al.*)^[71]. This inference though not statistically significant suggests about posteriorly placed glenoid fossa in class II patients which is in accordance to studies by Sicher and Krasa 1920, Bacon *et al.* 1992^[6] who reported posterior placed temporomandibular joint in class II patients.

The results of our study reveal that mean facial axis value and Jaraback ratio was maximum for class III subjects, followed by class I and class II in decreasing order. This is suggestive of more common class III horizontal growers. The positive association of posteriorly placed condyle of mandible in Class III subjects with increased incidence in horizontal growers is indicative of higher musculoskeletal development and stronger masticatory apparatus. This is explained by Wolf's Law (Dibbets *et al.* 1992) which states that internal structure and shape of bone is closely related to muscle function. Studies on EMG and bite force studies by Moller 1966, Ringquist 1973, Sassouni 1969, Ingervall 1976 also suggest that broad face individuals have stronger muscles and predominantly horizontal growth pattern as they have more pull effect of ligaments which connect the face with cervical vertebrae^[6].

Along with the muscles, the atlanto-occipital and atlanto axial joints are supported by ligaments namely, membrane tectoria, the cruciate ligament, the apical ligament of dens and alar. These ligaments and muscles work in unison to bring about flexion, extension, lateral bending and rotation of head, in addition to maintaining the integrity and stability of normal physiologic functions^[1]. Their role in influencing the head posture has been explained in an FEM model study by M. Motoyoshi *et al.* to study the biomechanical influence of head posture. The authors postulated that alteration in head posture influences mastication, respiration, deglutition, sight balance and hearing (VIg *et al.*, 1980). They suggested that head posture is maintained by neuromuscular system with afferent pathways from proprioceptors in muscles, tendons, joints, vestibular and visual receptors & information from cortical and subcortical motor areas (verrario *et al.* 1996)^[8].

On analysis it was found that the craniovertebral variables

angular measurements, it was observed that CVT/EVT in class III was more than class II followed by class I subjects. It is indicative of posterior inclination of dens axis of CV2 in class III patients as compared to class II and class I patients. The Dens axis or odontoid process is a characteristic projection on the axis, which gives an attachment to the apical odontoid ligament superiorly and alar ligament inferiorly. These ligaments connect the process to the occipital bone. As the apex dentis starts the growth by 2 years and completes its growth by age of 12 year, the inclination shift is possibly related to the caudal displacement of the anterior arch of axis. This was also observed in results of Rasterstereographic study by Segatto *et al.* in 2014^[9] where medium to strong correlation between body posture, axis (second cervical vertebra) morphology and craniofacial parameters. Based on his inferences he also suggested that the morphological features and inclinations of dens could be valuable predictive markers for assessing malocclusion in orthodontics.

When the mean OPT/VER was compared to subjects having horizontal and vertical growth pattern, it was found higher in patients with horizontal which is suggestive of stronger stomatognathic musculature and higher pull effect of the ligaments which connect the face with cervical vertebrae. The second vertebra is the location where apical ligament of dens and alar ligaments attach. According to study by Kylamarkula and Huggare (1985)^[10]. These muscular attachments determine the extension or flexion of the neck and hence the distance between the skull and posterior arch of atlas. Hence it can be inferred that patients with horizontal growth pattern have a relatively straighter spine inclination and hyper extended neck posture.

Also CVT/VER was the least in class III as compared to class II & I which is indicative of straighter spine inclination of class III subjects as compared to class II and class I. This was also observed in study by Tauheed *et al.* 2019^[11] who assessed cervical curvature and inclination on 63 subjects that were grouped in skeletal class I, class II and class III. Class III patients presented with extended craniocervical head posture presented with increased sagittal jaw dimension & less steeper inclination of mandible. This is in accordance with Soft Tissue Stretching hypothesis of Solow and Tallgren (1976)^[5]. Mean EVT/VER among class II and class III was significantly more than that among class I which indicates more enhanced curvature of vertical column in Class II and Class III patients. This can be attributed to the altered inclination of dens of CV2 that can both be a cause or effect of malocclusion.

The Study by Carvalho *et al.* is also in agreement to our results in class II subjects. It also revealed a predominance of anteriorized head posture in class II individuals as compared to class III individuals. They also suggested that according to theory of Mafosky, occipital extension of atlas is accompanied by sliding of maxilla following which the mandible positions itself behind maxilla.

Morphological assessment of first cervical vertebra (CV1SL & CV1HT) revealed significantly less measurements in class III than that among class I and II subjects. This is owing to the presence of deep attachments of the broad ligaments of cervical spine, namely Anterior and Posterior longitudinal ligaments, Ligamentum Flavum, Interspinous ligament, Nuchal ligament, transverse ligament of the atlas that run from foramen caecum to the subsequent vertebrae^[12].

It was also observed that CV2BL measurement in class II & III was significantly more than class I but mean CV2BL among class II & III did not show any significant difference. This was suggestive of increased body length due to altered muscle attachment in patients of skeletal Class II and Class III malocclusion. Mean CV2HT was significantly more in class I as compared to class III. This is owing to normal growth in height and normal inclination of the CV2 odontoid in Class I in absence of any musculoskeletal hindrances. In cases of class II and class III, the soft tissue stretching mechanism causes reduced height and altered inclination of dens. When these findings are correlated with vertical and horizontal growers, it can be assumed based on Houstons study that the vertical increase in the cervical spine deviates the cranium with respect to the shoulder girdle (clavicle, sternum, scapula)^[12]. The growth and stretch of muscles fascia passing between cranium, mandible, hyoid bone and shoulder girdle cause descent of symphysis of mandible and hyoid relative to cranial base, which causes downward head posture.

Morphological parameters of 3rd cervical vertebral CV3SL was significantly more in class III and CV3BL was significantly less in class II. These readings are indicative of higher muscular forces in class III as compared to class II subjects.

With respect to 4th cervical vertebral CV4BL & CV4HT was significantly more in class I than class III and the 5th & 6th cervical vertebrae measurements (CV5SL, CV6SL, CV5HT, CV6HT) had significant values in class II subjects as compared to class III subjects. However, there is lack of research and any supporting literature related to these parameters. It can be assumed that altered muscular forces and posture changes in different malocclusions might be the reason for these inferences.

The skeletal sagittal relations of maxilla and mandible have been proposed as a valuable factor for diagnosis and treatment planning in orthodontics. In our study, the cephalometric analysis of cervical vertebral column inclination, morphometry and its relation to sagittal jaw relation, has also provided a guiding light to predict the craniofacial and craniovertebral association in different skeletal jaw relation. However, a greater sample size and further research is needed to establish concrete inferences and to rule out errors if any.

5. Conclusion

- The results of our study concluded that a significantly positive correlation of craniofacial variable with cervical inclination and morphology.
- Facial axis value and Jaraback ratio was maximum for class III subjects, followed by class I and class II in decreasing order. This is suggestive of more common class III horizontal growers
- CVT/EVT in class III was more than class II followed by class I subjects. It is indicative of posterior inclination of dens axis of CV2 in class III patients as compared to class II and class I patients
- OPT/VER was compared to subjects having horizontal and vertical growth pattern, it was found higher in

horizontal growers which is suggestive of stronger stomatognathic musculature and higher pull effect of the ligaments which connect the face with cervical vertebrae.

- Also CVT/VER was the least in class III as compared to class II & I which is indicative of straighter spine inclination of class III subjects as compared to class II and class I.
- EVT/VER among class II and class III was significantly more than that among class I which indicates more enhanced curvature of vertical column in class II and class III patients
- Morphological assessment of first cervical vertebra (CV1SL & CV1HT) revealed significantly less measurements in class iii that among class I and II subjects
- CV2BL measurement in class ii & iii was significantly more than class I but mean CV2BL among class II & III did not show any significant difference. this was suggestive of increased body length due to altered muscle attachment in patients of skeletal class II and class III malocclusion
- Parameters of 3rd cervical vertebral CV3SL was significantly more in class III and CV3BL was significantly less in class II.
- With respect to 4th cervical vertebral CV4BL & CV4HT was significantly more in class I than class III while CV4BL in class II subjects showed no significant difference.
- The 5th & 6th cervical vertebrae measurements (CV5SL, CV6SL, CV5HT, CV6HT) had significant values in class ii subjects as compared to class iii subjects

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