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ORIGINAL ARTICLE

VARIATION IN THE MORPHOLOGY OF ATLAS VERTEBRAE IN DIFFERENT SKELETAL PATTERNS: A THREE – DIMENSIONAL COMPUTED TOMOGRAPHY EVALUATION

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ABSTRACT: OBJECTIVE: The morphology of the atlas vertebrae seems to be affected by the head posture, age, congenital anomalies and the skeletal growth pattern. The present study was carried out to assess the variation in the morphology of atlas vertebrae in different vertical skeletal patterns **MATERIAL AND METHOD:** Cone-beam computed tomography images of 45 adult subjects aged 18 to 35 years were evaluated. Subjects constituted three groups: group 1; average growth pattern; group 2; vertical growth pattern (Skeletal open bite) and group 3; horizontal growth pattern (Skeletal deep bite). Nine linear measurements were used to assess the vertebral morphology. The One way Anova and Tukey Hsd multiple comparison test were used for statistical analysis. **RESULTS:** The mean inner anteroposterior diameter of the atlas (C1) was significantly greater in the skeletal open bite and the skeletal deep bite group. The height of the atlas dorsal arch was lower in the skeletal open bite subjects. The mean height of the atlas dorsal arch was increased in skeletal deep bite group. The mean outer anteroposterior diameter was significantly greater in the skeletal open bite and skeletal deep bite group. The mean inner anteroposterior diameter of the axis was significantly higher in both skeletal open bite group and the skeletal deep bite group. The mean outer transverse diameter was significantly smaller in skeletal deep bite subjects. **CONCLUSION:** There exists an association between the morphology of the atlas vertebrae and the skeletal growth pattern.
KEYWORDS: Atlas vertebrae, skeletal deep bite, skeletal open bite.

INTRODUCTION: The knowledge of cervical vertebrae (CV) has led to the understanding of its association with the growth changes occurring in the dentofacial complex. Dimensions of cervical vertebrae as well as the head and neck posture has been associated with factors such as craniofacial morphology, including the dimensions of the cranial base, upper airway space, occlusion and temporomandibular disorders.[1]

The morphology of the atlas vertebrae has been associated with the head posture by many researchers in the literature. In subjects with extended head posture, increased anterior facial height and a steeper inclination of the mandible were generally observed. When the head was bent in relation to the atlas column, a shorter anterior facial height and a less steep inclination of the mandible were observed. This may be because the altered head orientation alters the dimension, orientation, and functions of the craniomaxillary musculature which will indirectly alter the growth and orientation of both maxilla and mandible.[2,3,4]

It can be hypothesized that the variation in the morphology of the atlas vertebrae and the presence of atlas vertebrae anomalies may have an association with the growth pattern of the craniofacial skeleton.

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For the evaluation of the atlas vertebrae most often we use lateral cephalograms which provide a two dimensional image of the three dimensional objects. Many times the image of the atlas vertebrae may be distorted or obscured in the lateral cephalogram which may at times give an illusionary image. There may also be some magnification error and the clarity may be affected due to enlargement and superimposition of structures.

With the advances in the radiographic imaging technology and introduction of three dimensional imaging the cone beam computed tomography (CBCT) has proved remarkably accurate in the studies for measurements within the maxillofacial complex.

In most of the researches done so far the atlas vertebrae were studied on profile radiographs. Very few studies in the literature have used 3D imaging for the evaluation of the atlas vertebrae and its variations. Therefore the present study was planned to investigate the variations in the morphology of the atlas vertebrae in subjects with different growth patterns (Average, horizontal and vertical) using three dimensional imaging techniques (CBCT).

MATERIAL AND METHODS: A total sample of 45 subjects was selected from the patients attending the outpatient Department of Sharad Pawar Dental College & Hospital, (DMIMS DU), Sawangi, Wardha. The sample was divided into the 3 groups; 15 individuals with skeletal deep bite; 15 individuals with skeletal open bite and 15 individuals with average growth pattern (Control group).

Inclusion criteria for selected Individuals:

1. Age range between 18 to 35 years.
2. No history of orthodontic treatment till completion of growth.
3. At least 24 permanent teeth present.
4. No systemic muscle or joint disorders
5. Non-syndromic patients.

Individuals for the study were assessed clinically and selected after analyzing the lateral cephalometric radiographs. Cases selected had the cephalometric parameters as described in Table 1.The purpose and methodology of the study was explained and written consent was obtained from the subjects. All the selected individuals were scanned using CBCT unit in the department of Oral Medicine and Radiology at Government Dental College Nagpur. Ethical clearance to carry out the present study was obtained from the Ethical Committee of Datta Meghe Institute of Medical Sciences, Deemed University.

Obtaining CBCT Images: All the selected individuals were scanned using the Planmeca Promax 3d mid CBCT unit in the department of Oral Medicine and Radiology at Government Dental College Nagpur. The scanning conditions were 90 kVp, 12 mA, F-mode 512 slices/scan (Slice width of 377 mm), and 9.0 seconds. For CBCT imaging, patients were positioned in centric occlusion (Maximum dental intercuspation), and their heads were positioned such that the Frankfort and mid sagittal planes were perpendicular to the floor. This position was controlled by a guideline directed from the front and sides. Data obtained was analyzed using the Romexis software.

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Measurements: All the CBCT scans were used for a three dimensional evaluation of the atlas vertebrae. For each sample a total of four linear measurements were used to assess the vertebral morphology. Table 2. Illustrates the measurements used in the study.

Statistical Analysis: For all the measurements in each group the mean and standard deviation were calculated and the results were obtained using the One Way ANOVA and the Tukey Hsd multiple comparison tests. P values less than 0.05 were considered statistically significant.

RESULTS: Table 3. Details the mean values of dimensions of atlas vertebrae (C1) in control, skeletal open bite & skeletal deep bite group. Table 4. Details the comparison of the mean values of dimensions of atlas vertebrae (C1) between control, skeletal open bite & skeletal deep bite group.

There was a statistically significant variation in the inner anteroposterior diameter (IAPD)(Figure 3.) of atlas vertebrae (C1).The mean diameter was significantly greater in both skeletal open bite group and the skeletal deep bite group as compared to the control group. The mean values were slightly higher in the skeletal open bite group as compared to the skeletal deep bite group but the difference was not statistically significant.

There was a significant variation in the height of the atlas dorsal arch (PAH) (Figure 4.) Of atlas (C1). The posterior arch height was significantly greater in the skeletal deep bite group as compared to skeletal open bite and the control group. And the posterior arch height was significantly smaller in the skeletal open bite group as compared to the control group.

There was no statistically significant difference in the mean outer transverse diameter (OTD) (Figure 1.), outer anteroposterior diameter (OAPD) (Figure 2.) of atlas (C1) between the control skeletal open bite and skeletal deep bite subjects.

DISCUSSION: The morphology of the atlas vertebrae seems to be affected by the following factors: head posture, age, congenital anomalies and the skeletal growth pattern.[5] The present study was planned to investigate the variations in the atlas vertebrae morphology in different growth patterns using CBCT imaging technique. In this study significant differences were noted in the morphology of the atlas vertebrae in subjects with different vertical skeletal jaw relationships.

The atlas vertebrae were evaluated for four linear measurements. The mean outer anteroposterior diameter of the atlas was not significantly different between the three groups. This is contradictory to the study done by Huggare ET al. in 1991 who observed an increase in the anteroposterior length of the atlas associated with the horizontal rotation of the mandible. The divergence might be due to the different method used (3 dimensional radiological examination in our study compared to dried skulls used in Huggare's) and also due to differences in ethnic background of the subjects under study.

The mean inner anteroposterior diameter of the atlas (C1) was observed to be significantly increased in the skeletal open bite and the skeletal deep bite group as compared to the control group. The lumen length was greatest in the Class II subjects in the skeletal deep bite group. This is in agreement with the study done by Baydas et al.[6] in 2004 who observed that the atlas lumen length was larger in subjects with skeletal class II malocclusion.

The results of the present study suggest that probably there may exist a correlation between the lumen width of the atlas and vertical and anteroposterior skeletal changes in the craniofacial morphology. A probable explanation for this can be found in the anatomy of the atlanto-axial joint.

The atlas holds the globe of the skull and its primary function is to provide support to the head. There is a pivot joint between the odontoid process of the axis and the ring formed by the anterior arch and the transverse ligament of the atlas. The atlanto-axial joint allows free rotation of the atlas on the odontoid process of the axis and provides for a stable configuration in flexion, extension and lateral bending. Hence the lumen length of the atlas may probably affect the atlanto-axial joint which influences the head posture.[7] and thus the growth pattern of the jaws.

An explanation for the association between the morphologic deviations in the atlas vertebral column and the craniofacial morphology could be found in the early embryogenesis. Because the notochord determines the development not only of the body of the atlas vertebra, but also of the basilar part of the occipital bone, which is the posterior part of the cranial base angle, it is possible that the cranial base angle is associated with deviations in the atlas vertebrae. Since the cranial base is connected to the atlas vertebral column by the notochord in early embryogenesis, and the jaws are attached to the cranial base, the cranial base could be the developing link between the atlas vertebrae and the jaws.[8]

The jaws, including the condylar cartilage, develop from ectomesenchymal tissue derived from the neural crest. In the first branchial arch the neural crest cells migrate towards the mandible, followed by their migration to the maxilla and lastly to the nasofrontal region. Therefore, it is understandable that a deviation in the amount or timing of migrating maxillary and mandibular cells may influence the craniofacial development. The precise signaling from the notochord to the neural crest followed by bilateral cell migration to the craniofacial area is still unknown. Signaling during early embryogenesis between the notochord, para-axial mesoderm, the neural tube, and the neural crest may explain the association between the atlas vertebral column, cranial base, and craniofacial development.

The vertebrae develop by endochondral ossification. The atlas is formed from three primary ossification centers - the body and two neural arches. The neural arches ossify approximately 3 years after birth but the body fuses at about 7 years. Thus the morphology of the atlas vertebrae is affected by the genetic and epigenetic factors. Once endochondral growth begins functional loads appear to have considerable influence on the final form of the bone.

In cases with severe skeletal malocclusions like skeletal deep bite and open bite there is alteration in the head posture. that may influence the musculature which may cause alterations in the biomechanical loading of the atlas vertebrae thus affecting their growth and development

Several 2D studies have evaluated the variations in the dimensions of atlas vertebrae and their association with skeletal malocclusions. In a study done by Huggare and Houghton.[9] on dried skulls of Thai and Polynesian populations a small dorsal arch of atlas (C1) was seen in conjunction with a small mandible.

The morphology of the CV also seems to be affected by the ethnic background of the individuals. Grave et al.[10] investigated and compared cervicovertebral dimensions in Australian aborigines and Caucasians. They reported that ethnic differences were evident in the vetebral morphology, especially in the upper segment of the vertebral column.

CONCLUSION: In the present study an association has been shown between morphological deviations of the atlas vertebrae and the skeletal malocclusions (Skeletal open bite and skeletal deep bite).This indicates that the morphological deviations of the upper atlas vertebrae are associated not

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only with malformation of the jaws but it may also have an association with the craniofacial morphology and occlusion. This study also gives us a new perspective about the anatomy of the atlas vertebrae in various malocclusions.

There was difference in ethnic background of the selected samples as compared to the previous studies. Several environmental factors also influence the morphology of the atlas vertebrae. The results obtained can be further substantiated by studies on a larger population. Further longitudinal studies are required to confirm the findings of our study.

FIGURE 1: Axial view of atlas vertebrae (c1) for measurement of OTD in control (a), skeletal open bite (b) and skeletal deep bite (c)

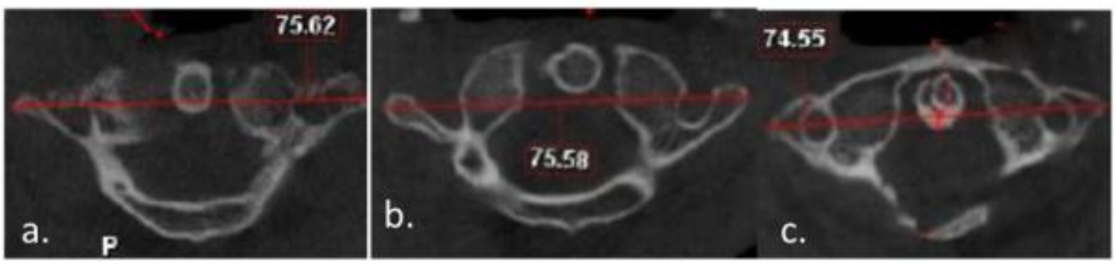

Fig. 1(a), 1(b), 1(c)

FIGURE 2: Sagittal view of atlas vertebrae (c1) for measurement of OAPD in control(a), skeletal open(b) bite and skeletal deep bite (c)

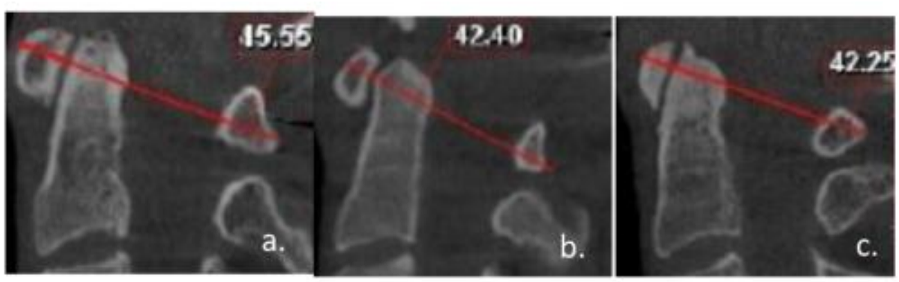

Fig. 2(a), 2(b), 2(c)

FIGURE 3: Sagittal view of atlas vertebrae (c1) for measurement of IAPD in control(a), skeletal open bite(b) and skeletal deep bite (c)

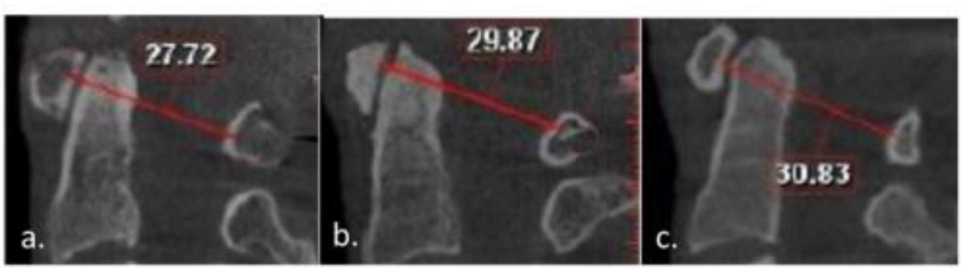

Fig. 3(a), 3(b), 3(c)

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FIGURE 4: Sagittal view of atlas vertebrae (c1) for measurement of PAH in control (a), skeletal open bite (b) and skeletal deep bite (c).

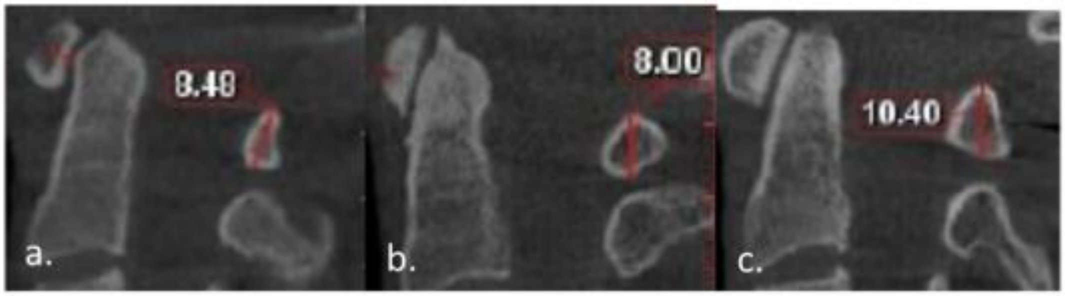

Fig. 4(a), 4(b), 4(c)

OUTER TRANSVERSE DIAMETER OF C1 (OTD)	The outer transverse diameter of the atlas was measured as the widest part of the vertebrae as viewed on the axial section.
OUTER ANTEROPOSTERIOR DIAMETER OF C1 (OAPD)	Measured on the sagittal section of the atlas vertebrae from the most anterior point on the anerior arch to the most posterior point on the posterior arch.
INNER ANTEROPOSTERIOR DIAMETER OF C1 (IAPD)	The maximum anteroposterior diameter of the vertebral canal was measured along the mid-sagittal plane as viewed on the sagittal section.
POSTERIOR ARCH HEIGHT OF C1(PAH)	The maximum height of the posterior arch measured as the distance between the superior most point to the inferior most point on the posterior arch in the mid-sagittal plane as viewed on the sagittal section.

Table 1: Measurements used in the study

Cephalometric Parameter	Average	Skeletal deep bite group	Skeletal open bite group
1) Gonial angle	121° – 135 °	< 121°	>135°
2) Mandibular plane angle(FMPA)	17° – 25°	< 17 °	>28°
3) Basal plane angle	17°– 25 °	<15°	>30°
4) Jaraback ratio	65% - 75 %	>75%	<65%
5) Lower anterior facial height	58mm – 72 mm	<58mm	>72mm

Table 2: Cephalometric Parameters of the Selected Cases

Atlas vertebrae	Control (n=10)	Skeletal open bite (n=10)	Skeletal deep bite(n=10)		P value
C1 OAPD	41.51(1.65)	41.37(2.22)	41.46(1.45)	NS	0.98
C1IAPD	28.20(1.80)	29.92(1.08)	30.72(1.54)	S	0.01
C1 OTD	75.19(2.83)	75.03(2.89)	73.18(3.81)	NS	0.21
C1 PAH	8.45(.43)	7.30(1.08)	9.23(1.26)	S	0.01

Table 3: Mean Values of Dimensions of Atlas Vertebrae (C1) in Control, Skeletal Open Bite & Skeletal Deep Bite Group

			P value
C1 IAPD	CONTROL VS SKELETAL OPEN BITE	S	0.04
	CONTROL VS SKELETAL DEEP BITE	S	0.01
	SKELETAL OPEN BITE VS SKELETAL DEEP BITE	NS	0.47
C1 PAH	CONTROL VS SKELETAL OPEN BITE	S	0.03
	CONTROL VS SKELETAL DEEP BITE	NS	0.21
	SKELETAL OPEN BITE VS SKELETAL DEEP BITE	S	0.01

Table 4. Comparison of the mean values of dimensions of atlas vertebrae (c1) between control, skeletal open bite & skeletal deep bite group

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