The determining of the proper moment to interfere is a constant pursuit in orthodontic treatment. Orthodontists modulate patient’s jaw growth which depends on various factors such as genetics, nutrition, systemic factors, and remaining growth at that point of time. Treatment options are dependent on their physiological maturity and clinical findings. Determination of skeletal age is an essential part of the orthodontic treatment planning.

The standard method - skeletal maturity evaluation was assessing the hand-wrist radiograph. However, Lamparski concluded that the cervical vertebrae seen on lateral cephalograms, were as statistically and clinically reliable in assessing the skeletal age as the hand-wrist technique. He found that the cervical vertebrae indicators were same for females and males, but the females showed the changes earlier. He also published an atlas that simulated the morphological changes in cervical vertebrae bodies in puberty and used these changes to evaluate skeletal maturation. In recent years, cervical spine, as visualized on the lateral cephalogram, has been used as an essential tool as a skeletal maturity indicator and as an alternative to hand-wrist radiograph. Since assessing them in lateral cephalogram is only - two-dimensional (2D), 3D computed tomography (CT) is advised.

The aim of the study is to assess, visualize, and evaluate the cervical vertebral morphology (bone density) of orthodontic patients of age group 9, 16, and 27 years.

Materials and Methods

The study consisted of randomly selected 24 subjects of three groups of age 9, 16, and 27 years (four subjects of both genders). Bone density assessment for evaluation of gender differences in cervical vertebral maturation: A computed tomography study. J Pharm Bioall Sci 2016;8:S65-70.
in each) who reported to the Department of Orthodontics and Dentofacial Orthopaedics, Tamil Nadu Government Dental College and Hospital. The subjects had no potential health influence on cervical vertebrae such as genetic abnormalities or hormonal disorders.

The CT of cervical vertebrae C1, C2, and C3 was taken in subjects using multi-slice spiral CT scanner (Toshiba Asteion TSX-021B 4 slice CT Scanner, 2007, Japan). The CT images were formatted into standard DICOM (Digital Imaging and Communications in Medicine, 2007, Japan) and reconstructed into continuous slices of 0.6 mm thickness. The images were transferred to a workstation and reconstructed using software (Version 2.1.2., 2006, Merge Health Care, and Milwaukee, USA), which is a standard software for DICOM image viewing and analysis. The coronal, sagittal, and axial slices of the DICOM images where then viewed and measured using reconstruction software (Mimics co., Materialise, Belgium).

The following morphological variations (bone density) with respect to cervical vertebrae were studied [Figures 1-7].

i. The middle component of C1 that gets relatively thinner with age

ii. The superior surface of the anterior arch of C2 that becomes more prominent with increasing age

iii. The inferior surface of the anterior tubercle of C3 that becomes more prominent with increasing age.

Results

The results were tabulated and statistically analyzed [Table 1]. The data obtained was analyzed statistically using SPSS software 2005. Analysis of variance (ANOVA) [Tables 2 and 3]. Student’s t-test was used for independent sample to identify the gender difference or comparison between males and females in the above said age groups [Tables 4-6]. Results were considered statistically significant at a \( P < 0.001 \).

ANOVA done for this study showed that the middle component of C1 that gets relatively thinner with age; the superior surface of the anterior arch of C2 that becomes more prominent with increasing age and the inferior surface of the anterior tubercle of C3 that becomes more prominent with increasing age, are highly statistically significant in both males and females.

Student’s t-test showed that cervical vertebra C1 is denser in males than females at 9 years, whereas it is denser in females than males at 16 years and it is denser in males than females at 27 years. The cervical vertebrae C2 and C3 are denser in females than males at 9 years and 16 years, whereas it is denser in males than females in 27 years. These results indicate
the early maturation in females when males still have some growth left.

**Discussion**

The use of cervical vertebrae to determine skeletal maturity is not new. Lamparski concluded that cervical vertebral
### Table 1: Observed computed tomography values

| Years | Sex  | Cervical vertebra | Coronal Axial | Transverse Area value (mm²) | CT value (Hounsfield) |
|-------|------|-------------------|---------------|-----------------------------|----------------------|
| 27    | Female | 41.16 | 33.23 | 77.43 | 50.61 | 510.23 |
| 27    | Female | 52.68 | 54.15 | 105.96 | 70.93 | 382.42 |
| 27    | Female | 52.68 | 52.10 | 126.34 | 77.04 | 407.15 |
| 27    | Female | 41.16 | 33.23 | 77.43 | 50.61 | 510.23 |
| 27    | Female | 52.68 | 54.15 | 105.96 | 70.93 | 382.42 |
| 27    | Female | 52.68 | 54.15 | 105.96 | 70.93 | 382.42 |
| 27    | Female | 52.68 | 52.10 | 126.34 | 77.04 | 407.15 |

CT: Computed tomography

**Figure 7:** Cervical vertebra C3. (a) Coronal section, (b) axial section and (c and d) transverse sections

Contd...
Table 2: The bone density of C1, C2, and C3 in males of 9, 16, and 27 years, as measured by analysis of variance

| Cervical vertebra | 9 years (Hounsfield) | 16 years (Hounsfield) | 27 years (Hounsfield) | P     |
|-------------------|----------------------|-----------------------|-----------------------|-------|
| Mean              | SD                   | Mean                  | SD                    |       |
| C1                | 554.75               | 1.90                  | 538.52                | 1.38  | 522.49 | 1.27 | <0.001** |
| C2                | 277.81               | 1.41                  | 288.58                | 1.42  | 477.05 | 1.27 | <0.001** |
| C3                | 276.41               | 1.42                  | 331.79                | 1.33  | 538.39 | 1.07 | <0.001** |

P<0.001. **Significant at 1% level. SD: Standard deviation

Table 3: The bone density of C1, C2, and C3 in females of 9, 16, and 27 years, as measured by analysis of variance

| Cervical vertebra | 9 years (Hounsfield) | 16 years (Hounsfield) | 27 years (Hounsfield) | P     |
|-------------------|----------------------|-----------------------|-----------------------|-------|
| Mean              | SD                   | Mean                  | SD                    |       |
| C1                | 642.14               | 1.32                  | 633.79                | 1.34  | 511.76 | 1.27 | <0.001** |
| C2                | 294.80               | 2.53                  | 374.89                | 2.23  | 381.19 | 1.10 | <0.001** |
| C3                | 297.67               | 3.06                  | 401.80                | 1.30  | 406.35 | 1.32 | <0.001** |

P<0.001. **Significant at 1% level. SD: Standard deviation

Table 4: The comparison between bone densities of male and female patients of age group of 9 years using the student’s t-test

| Cervical vertebra | Males (Hounsfield) | Females (Hounsfield) | P     |
|-------------------|-------------------|----------------------|-------|
| Mean              | SD                | Mean                 | SD    |
| C1                | 554.75            | 1.90                 | 642.14 | 1.32 | <0.001** |
| C2                | 277.81            | 1.41                 | 294.80 | 2.53 | <0.001** |
| C3                | 276.41            | 1.42                 | 297.67 | 3.06 | <0.001** |

P<0.001. **Significant at 1% level. SD: Standard deviation

Table 5: The comparison between bone densities of male and female patients of age group of 16 years using the student’s t-test

| Cervical vertebra | Males (Hounsfield) | Females (Hounsfield) | P     |
|-------------------|-------------------|----------------------|-------|
| Mean              | SD                | Mean                 | SD    |
| C1                | 538.52            | 1.38                 | 633.79 | 1.34 | <0.001** |
| C2                | 288.58            | 1.42                 | 374.89 | 2.23 | <0.001** |
| C3                | 331.79            | 1.33                 | 401.80 | 1.30 | <0.001** |

P<0.001. **Significant at 1% level. SD: Standard deviation

Table 6: The comparison between bone densities of male and female patients of age group of 27 years using the Student’s t-test

| Cervical vertebra | Males (Hounsfield) | Females (Hounsfield) | P     |
|-------------------|-------------------|----------------------|-------|
| Mean              | SD                | Mean                 | SD    |
| C1                | 522.49            | 1.27                 | 511.76 | 1.27 | <0.001** |
| C2                | 477.05            | 1.27                 | 381.19 | 1.10 | <0.001** |
| C3                | 538.39            | 1.07                 | 406.35 | 1.32 | <0.001** |

P<0.001. **Significant at 1% level. SD: Standard deviation

cervical vertebrae.[1] The objective of this study was to assess and evaluate the gender differences in maturational differences. For this, 24 subjects with the age group of 9 years, 16 years, and 27 years were randomly selected from the patients who reported to the Department of Orthodontics and Dentofacial Orthopedics, Tamil Nadu Government Dental College, Chennai, and studied using 3D CT. Statistical analysis ANOVA, Tukey - honestly statistical significant difference test showed that:

a. The bone density of C2 tend to increase for both males and females as age advances (71.7% increase in the bone density of C1 tend to decrease for both males and females as age advances 5.8% decrease in females from 9 to 27 years and 20.3% decrease in males from 9 to 27 years)
b. Females from 9 to 27 years and 29.3% increase in males from 9 to 27 years
c. The bone density of C3 tend to increase for both males and females as age advances (94.7% increase in females from 9 to 27 years and 36.5% increase in males from 9 to 27 years).

According to the mean percentage changes mentioned above, it can be concluded that:

a. Among 9 years, males have lesser bone density when compared to females
b. Among 16 years, females have more bone density compared to males
c. Among 27 years, males have more bone density compared to females.

Conclusion

The result of this 3D study matched with the previous report in the literature concerning shape changes with skeletal age as judged in 2D sagittal views. The results of the study concluded that as age advances, morphological variations, or changes in the bone occurs, i.e. the bone density decreases in both females and males as age advances (71.7% increase in females and 5.8% decrease in males from 9 to 27 years). This study provides qualitative method of assessing gender differences of the patient by using images of cervical vertebrae by 3D approach. Hence, it can be useful for orthodontic diagnosis and treatment plan.

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Conflicts of interest

There are no conflicts of interest.

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