



YEDITEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF ORAL DIAGNOSIS AND ORAL RADIOLOGY

**ASSESSMENT OF THE CORRELATION BETWEEN SPHENO-
OCCIPITAL SYNCHONDROSIS, CERVICAL VERTEBRA, AND
HYOID BONE MATURATION STAGES AND MEASUREMENTS ON
CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN REGARDS TO
AGE AND SEX: A RETROSPECTIVE STUDY**

DOCTOR OF PHILOSOPHY THESIS

EMAN. A. B. AGUORI

B.D.S, M.S.c

ISTANBUL-2022



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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated.....and numbered

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

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LIST OF SYMBOLS AND ABBREVIATIONS

AVBH	Anterior Vertebral Body Height
BSL	Basion to Sella Length
C	Cervical Vertebra
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
CVBW	Cervical Vertebral Body Width
CVM	Cervical Vertebral Maturation
CVMS	Cervical Vertebral Maturation Stage
DVR	Direct Volume Rendering
FOV	Field Of View
HMS	Hyoid Maturation Stage
HBD	Hyoid Body Depth
HBH	Hyoid Body Height
GBT	Hyoid Body Thickness
HWM	Hand-Wrist Method
ICC	Intraclass Correlation Coefficient
ICRP	International Committee On Radiation Protection
IVBT	Inferior Vertebral Body Thickness

IVR	Indirect Volume Rendering
KVp	Kilovoltage peak
Ma	Milliamper
Max HBW	Maximal Hyoid Body Width
MIP	Maximum Intensity Projection
Min HBW	Minimal Hyoid Body Width
Mm	Millimeter
MPR	Multiplanar Reformatting
PVBH	Posterior Vertebral Body Height
SD	Standard Deviation
SOSS	Spheno-Occipital Synchondrosis Stage
SPSS	Statistical Package for Social Sciences
SVBT	Superior Vertebral Body Thickness
TMJ	Temporomandibular Joint
USA	United States of America
VBCD	Vertebral Body Concavity Depth
2D	2 Dimension
3D	3 Dimension

ABSTRACT

Eman Aguori (2022), Assessment of The Correlation Between Spheno-Occipital Synchondrosis, Cervical Vertebra, and Hyoid Bone Maturation Stages and Measurements on Cone Beam Computed Tomography (CBCT) in Regards to Age and Sex: A Retrospective Study. Yeditepe University, Institute of Health Sciences, Department of Department of Oral Diagnosis and Oral Radiology, PhD Thesis, Istanbul

This study aims to analyze the correlation between metric and fusion stages of the cervical vertebrae, the hyoid bone, and the spheno-occipital synchondrosis on Cone Beam Computed Tomography (CBCT) regarding the age and the sex. A total of 129 CBCT images from patients aged between 8-48 years, were subjected to inclusion and exclusion criteria. The general anatomical parameters evaluated on CBCT images for the second, the third and the forth cervical vertebrae, hyoid bone, and spheno-occipital bone were as follows: Cervical Vertebral Maturation Stages (**CVMS**), Anterior Vertebral Body Height (**AVBH**), Posterior Vertebral Body Height (**PVBH**), Vertebral Body Width (**VBW**), Superior Vertebral Body Thickness (**SVBT**), Inferior Vertebral Body Thickness (**IVBT**), Vertebral Body Concavity Depth (**VBCD**), Hyoid Maturation Stages (**HMS**), maximal Hyoid Body Width (**maxHBW**), minimal Hyoid Body Width (**minHBW**), Hyoid Body Thickness (**HBT**), Hyoid Body Depth (**HBD**), Hyoid Body Height (**HBH**), Spheno-Occipital Synchondrosis Stages (**SOSS**), and Basion to Sella length (**BSL**). Significance was evaluated at the $p < 0.05$ level. There were no significant differences between the mean age of sexes at different stages of CVMS, HBMS, and SOSS ($P > 0.05$). There was a significant difference between the sexes regarding the distribution of CVMS ($P < 0.05$). There were significant differences between age groups of females regarding all parameters ($P < 0.05$) except for AVBH2, VBW2, VBW3, VBCD3, VBCD4, BSL, HBT, and HBH ($p > 0.05$). Also, there were significant differences between age groups of males regarding AVBH2, PVBH2, VBCD2, AVBH3, PVBH3, VBCD3, AVBH4, PVBH4, VBCD4, maxHBW, minHBW, and HBD ($P < 0.05$). There were significant differences between sexes regarding all parameters ($p < 0.05$), except for VBCD2, AVBH3, VBCD3, AVBH4, VBCD4, SOSS, and HMS ($p > 0.05$). At **CVMS1**, there were significant differences between sexes regarding AVBH2, PVBH2, SVBT2, VBW3, and VBW4 ($p < 0.05$). At **CVMS4**, there were significant differences between sexes regarding SVBT2, PVBH3, IVBT3, PVBH4, SVBT4, and HBH ($p < 0.05$). At **CVMS5** and **CVMS6**, there were significant differences between sexes

regarding AVBH2, PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, and VBCD4 ($p<0.05$). At **HMS1**, there were significant differences between sexes regarding all hyoid bone parameters ($p<0.05$). At **HMS2**, there were significant differences between sexes regarding all hyoid bone parameters ($p<0.05$) except for HBT ($p>0.05$). At **SOSS1** and **SOSS4**, there were significant differences between sexes regarding BSL ($p<0.05$). There were significant correlations between all parameters ($p<0.05$) except the correlation between: **Age** with VBW3 and HBH, **CVMS** with SVBT2, IVBT2, VBW2, SVBT3, IVBT3, VBW3, SVBT4, IVBT4, VBW4, HBT, and HBH, **SVBT2** with VBW2, VBCD3, VBCD4, and HMS, **BSL** with VBCD2, VBCD3, and VBCD4, **HBH** with VBW2, VBCD3, and HBT, **HMS** with IVBT2, VBW2, VBCD2, VBW4, HBH, and VBW3, **SOSS** with VBW2, IVBT2, VBW3, VBW4, BSL, and HBT, **HBT** with VBCD2 and VBCD3 ($p>0.05$). There were significant differences regarding the distribution of SOSS and HMS at each CVMS ($p<0.05$). There was a significant correlation between CVM, HMS, SOSS, and age ($p<0.05$). Due to the correlation between cervical vertebrae, spheno-occipital and hyoid bone parameters and maturation stages, then the maturation of growing subjects can be estimated by evaluating the spheno-occipital or the hyoid bone instead of the cervical vertebrae.

Keywords: CBCT, Cervical Vertebra, Hyoid bone, and Spheno-Occipital Synchondrosis.

ABSTRACT (TURKISH)

Eman Aguori (2022), Konik Işınli Bilgisayarli Tomografide (KIBT) Sfenooksipital Sinkondrozis, Servikal Vertebra ve Hyoid Kemik Olgunlaşma Aşamalarının Belirlenmesi ve Ölçümlerinin Yapılması İle Aralarındaki Korelasyonun Yaş ve Cinsiyete Göre Değerlendirilmesi: Retrospektif Çalışma. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Ağız, Diş ve Çene Radyolojisi Anabilim Dalı, Doktora Tezi, İstanbul

Bu çalışmanın amacı, konik ışınli bilgisayarlı tomografi (KIBT) çekilen büyüme çağındaki ve genç erişkin bireylerde, metrik analizler ile sfeno-oksipital sinkondrozis kapanma evreleri, hyoid kemik ve servikal vertebra evreleri arasındaki ilişkiyi belirlemektir. 8-48 yaş arası hastalardan alınan toplam 129 KIBT görüntüsü çalışmaya dahil edilme ve edilmeme kriterlerine göre değerlendirilmiştir. İkinci, üçüncü ve dördüncü servikal vertebra, hyoid kemik ve sfeno-oksipital kemik için KIBT görüntülerinde değerlendirilen genel anatomik parametreler; Servikal Vertebra Olgunlaşma Aşamaları (SVOA), Ön Vertebral Gövde Yüksekliği (ÖVGY), Arka Vertebral Gövde Yüksekliği (AVGY), Vertebral Gövde Genişliği (VGG), Üstün Vertebral Gövde Kalınlığı (ÜVGK), Alt Vertebral Gövde Kalınlığı (AVGK), Vertebral Gövde Konkavite Derinliği (VGKD), Hyoid Olgunlaşma Aşamaları (HOA), Maksimal Hyoid Gövde Genişliği (MakHGG), Minimal Hyoid Gövde Genişliği (MinHGG), Hyoid Gövde Kalınlığı (HGK), Hyoid Gövde Derinliği (HGD), Hyoid Gövde Yüksekliği (HGY), Sfen-Oksipital Sinkondrozis Aşamaları (SOSA), ve Bazyon- Sella arası Uzunluk (BSU). SVOA, HOA ve SOSA' nın farklı evrelerinde cinsiyetlerin yaş ortalamaları arasında anlamlı bir fark bulunmadı ($P>0.05$). Cinsiyetler arasında SVOA dağılımında anlamlı farklılık bulundu ($P<0.05$). ÖVGY2, VGG2, VGG3, VGKD3, VGKD4, HGK, BSU ve HGY dışındaki tüm parametrelerde kadınlarda yaş grupları arasında anlamlı farklılıklar saptandı ($P<0.05$). Erkeklerde yaş grupları arasında ÖVGY2, AVGY2, VGKD2, ÖVGY3, AVGY3, VGKD3, ÖVGY4, AVGY4, VGKD4, MakHGG, MinHGG ve HGD açısından anlamlı farklılıklar bulundu ($P<0.05$). Cinsiyetler arasında VGKD2, ÖVGY3, VGKD3, ÖVGY4, VGKD4, SOSA ve HOA dışındaki tüm parametrelerde ($p<0.05$) anlamlı farklılıklar bulundu ($p>0.05$). SVOA1'de ÖVGY2, AVGY2, ÜVGK2, VGG3 ve VGG4 açısından cinsiyetler arasında anlamlı farklılıklar bulundu ($p<0.05$). SVOA4' te ÜVGK2, AVGY3, AVGK3, AVGY4, ÜVGK4 ve HGY açısından cinsiyetler arasında anlamlı farklılıklar bulundu ($p<0.05$). SVOA5 ve SVOA6'da ÖVGY2, AVGY2, ÜVGK2, AVGK2, ÖVGY3, AVGY3, ÜVGK3, AVGK3,

VGG3, ÖVGY4, AVGY4, ÜVGK4, AVGK4, VGG4 ve VGKD4 açısından cinsiyetler arasında anlamlı farklılıklar bulundu ($p<0.05$). **HOA1** 'de tüm hyoid kemik parametreleri açısından cinsiyetler arasında önemli farklılıklar belirlendi ($p<0.05$). **HOA2**'de, HGK dışında tüm hyoid kemik parametrelerinde ($p<0.05$) cinsiyetler arasında anlamlı farklılıklar saptandı ($p>0.05$). **SOSA1** ve **SOSA4**'te BSU açısından cinsiyetler arasında anlamlı farklılıklar bulundu ($p<0.05$). VGG3 ve HGY ile **yaş**, ÜVGK2, AVGK2, VGG2, ÜVGK3, AVGK3, VGG3, ÜVGK4, AVGK4, VGG4, HGK, ve HGY ile **SVOA**, VGG2, VGKD3, VGKD4, ve HOA ile **ÜVGK2**, VGKD2, VGKD3, ve VGKD4, ile **BSU**, VGG2, VGKD3, ve HGK ile **HGY**, AVGK2, VGG2, VGKD2, VGG4, HGY, ve VGG3 ile **HOA**, VGG2, AVGK2, VGG3, VGG4, BSU ve HGK, ile **SOSA**, VGKD2 ve VGKD3 ile **HGK** ($p>0.05$) arasındaki korelasyon dışında tüm parametreler ($p<0.05$) arasında anlamlı korelasyonlar bulundu. **SVOA**'nin her aşamasında SOSA ve **HOA**'nin dağılımı ile ilgili olarak anlamlı farklılıklar bulundu ($p<0.05$). **SVOA**, **HOA**, **SOSA** ve yaş arasında anlamlı bir korelasyon bulundu ($p<0.05$). Servikal vertebra, sfeno-oksipital ve hyoid kemik parametreleri ve olgunlaşma aşamaları arasındaki korelasyon nedeniyle, servikal vertebra yerine sfeno-oksipital veya hyoid kemiği değerlendirilerek kişinin yaşı ve cinsiyeti tahmin edilebilir.

Anahtar Kelimeler: KIBT, Servikal Vertebra, Hyoid Kemik, Sfeno-Oksipital Sinkondrozis.

1. INTRODUCTION

Identification is important in living and dead persons, mutilated bodies, disintegrated bodies, and skeletal remains. Sex, age, and stature are three importance features for the identification of a person (1)(2)(3).

The identification of a person by visual examination becomes impossible in cases of explosions, fires, advanced decomposition, mutilation, earthquakes, aircraft accidents, mass disasters, and other terrorist activities (1), because the dead body decomposes with loss of soft tissues, leading to the inability for facial recognition in a putrefied body. However, the assessment of age and sex from human skeletal remains are the most essential characteristics in establishing the identity of unknown skeletal remains (3).

The sex is the first important feature for the identification. The estimation of sex from the human skeletal remains is considered as a basic stage in Forensic Medicine and Archeology for identifying an individual. Sex variances have been evaluated in several ways in Osteoarcheology and Anthropology either by assessing the morphology or metric dimensions of the human bone. Experts can estimate the sex from a bone or a small set of bones (3)(4)(5)(6)(7)(8)(9). In Archeology, sex estimation is based on the integrity of the skeletal elements; as accuracy rate for the sex estimation from an entire skeleton is higher than the accuracy rate from an individual bone. So, gathering as much information as possible from every bone available is very significant (10)(11). The estimation of sex from the scapula, the femur, the sternum, the radius, the ulna, the clavicle and other bones has been done by many studies. However, estimation of sex from the hip bones is considered as the most accurate way (1)(3)(12).

The age is the second important feature for the identification, and its evaluation is considered significance. There are three main causes for age evaluation, and these are due to the rising in the number of unidentified human remains, the rising in the number of living individuals who have no legal proof of their date of birth, and importance of age for the determination of determent the optimal time in orthodontic treatment planning and treatment (13)(14)(15).

During the life of a person, the bone continuously changes following a chronological pattern (1)(16). These changes are responsible for developing, growth and maturity in the bone, which start from a primary ossification center to the stage of completely developing of bone. Knowing the changes in all the body, including the bones will help in the estimation of the age and the sex (17).

1.1 The growth and the age assessment methods:

During humans development, the bones undergo accelerated and decelerated bone growths. There are many biologic indicators that can be used to assess the age (18). Chronological age can provide general information about the growth and the development of an individual (19). Some bone changes may occur between the age of 40-60 years, which are indicative of advancing age in an individual, these are as following:

1. The fusion between the greater horns and the body in the hyoid bone.
2. The fusion of the manubrium and xiphisternum with the body of the sternum.
3. The lipping of the vertebrae.
4. Fusion between exocranial and endocranial sutures of the skull bone.
5. Calcification changes of the cricoids and thyroid cartilages.
6. Gastofson's method for estimating age from teeth.
7. The closure of parietal ectocranial sutures and four maxillary sutures and their patterns of closure can be used as a reliable age estimator after the age of 40 years (1)(20)(21).

Nevertheless, the chronological age has been accepted to be a poor biologic indicator due to the significant individual growth variation, as the children of equal chronological age do not grow at the same rate.

There are other biologic indicators that can be used in the evaluation of age, like general development, dental eruption and occlusion, age-related degenerative conditions, and skeletal age assessment (cortical bone histology and ossification of bones) (1)(16)(22)(23)(24)(25)(26)(27)(28).

1.1.1 General development:

A. In children:

The age of children can be estimated from maturation of chorionic villi, head and chest circumferences, scalp hairs, length and weight of the fetus, nails, position of testes, foot length, closure of anterior fontanelle, and ossification centers of the fetus (1).

B. In childhood:

The age of childhood can be estimated from closure of anterior fontanelle, anthropometry, ossification centers, and dentition (1)(29).

C. Secondary sexual characters:

The sexual changes in both genders, including; mustache, axillary, and pubic hair can be used for age estimation (30)(31).

The sexual changes in males including; position of testes are useful for age assessment. Whereas, the sexual changes in females, including; menstruation, breasts changes, and external genitalia changes are useful for age estimation (1).

However, these changes have been accepted to be unpractical in orthodontic clinics as the sexual development changes can be often seen at the end of the pubertal growth spurt. Also, they cannot be used to expect the time of maximum growth, due to their retrospective nature (22)(32)(33).

1.1.2 Dental eruption and occlusion:

Dental eruption and occlusion method bases on the degree of eruption for both the deciduous and permanent teeth (34). Clinically, it can be used until the age of 15 years. Nevertheless, the third permanent molar erupts after 15 years of age and if it does not erupt, this method can be unreliable for determining age. Several studies have approved that the dental age is unreliable, because of the inter individual variations among patients. It is hard to assess the accurate age after eruption of the full permanent teeth and fusion of all centers of ossification of bones. Occlusal wear is another biological indicator of age, but it is highly inaccurate (1)(32)(33).

1.1.3 Degenerative conditions:

Degenerative conditions are those conditions related to age as osteophytic growths on the surface of the vertebral body (1).

1.1.4 Skeletal age assessment:

The bones of the human skeleton develop from hyaline cartilage which gradually changes into hard osseous tissue by osteogenesis and ossification; replacing processes of the cartilage to the bone, which begin from the middle portion of the cartilage then it extends laterally until the whole cartilage ossify (35). The centers of ossification mostly appear early in the embryonic life. Other centers of ossification appear latter during prenatal life and after birth. At the eleventh prenatal week, there are 806 ossification centers for development and growth of bone. In addition, during the birth, there are about 450 ossification centers. During the adult period, there are 600 ossification centers that fuse to form 206 bones (1)(36).

Some bones have a single center of ossification, like Tarsal and Carpal bones. Others have several separate centers of ossification at the middle of the bone, which progressively ossifies towards the bone ends. At birth, most of the bones have cartilaginous ends, which are ossified by separate or multiple centers called as secondary centers. The appearance of the ossification centers has sequent and time periods, which can be used for age estimation. However, it is reliant on the race, the sex and geological distribution. It is also reliant on other factors for example: nutritional status, food, physical and metabolic activity, socioeconomic status, exercise, and exposure to sunlight and hormonal balance (1)(37).

Histologically, as the age progress, the number and the size of osteons increase. However, the number of circumferential lamellar bones and the non-haversian canals decrease, which disappear completely after 50 years of age (1).

Bone maturation is routinely evaluated to indicate the level of body maturation and to determine the remaining growth potential in children. Bone maturation can be assessed by evaluating the degree of ossification of certain bony markers located within the skeletal system (25)(38).

The estimation of the age from the degree of bone maturation has been accepted by many studies to be the most reliable way to predict individual growth status, as it relates with physiological body maturation and general biology (22)(32).

There are many stages for the bone maturation, which can be evaluated on the radiographic images, can be predicted the time and the velocity of pubertal growth, and can be estimated the percentage of the remaining growth (22)(32)(39). Clinically, the assessment of individual bone age is considered an essential part in Orthodontic Departments to define the suitable time for growth modification therapy and orthognathic surgery (22).

1.2 Methods for skeletal age estimation:

1.2.1 Hand and wrist bones:

The estimation of age from hand-wrist radiograph is considered to be the most reliable method as they can predict the age of bone reliant on the maturation of the hand and wrist bones (32)(39). This method is based on:

- Evaluation of the shape and width of metaphyseal phalangeal cartilages and the radial bone and amount of the fusion between diaphyses and epiphyses.
- Evaluation of the secondary ossification centers that mineralize during maturation, leading to changes in bone shapes.
- Time and sequence of appearance of the carpal bones and certain ossification centers (19)(39)(40).

The indications for a hand-wrist radiograph to assess the bone age are as follows:

- Planing for expansion of palatine suture.
- Treatment of orthodontic-surgical cases.
- Assessment of the growth during orthodontic treatment.
- Assessment of residual growth during or after orthodontic treatment.
- Presence of variations between dental and chronological age (19).

Nevertheless, the estimation of age from hand-wrist radiograph has some disadvantages as follows:

- The time of ossification and maturation within the hand-wrist bone shows sexual variances, which can limit the use of this method in clinical prediction (22)(27)(39)(41).

- The maturation events in the hand and wrist bones can be used to expect the end and the peak of growth in the pubertal period, but they cannot expect the beginning of growth in the pubertal period (39)(42).
- According to the Guidelines of the British Orthodontic Society, the use of this method to evaluate the onset of the growth during pubertal period was impractical as they were concerned about extra radiation exposure. To overcome this disadvantage, the assessment of cervical vertebral maturation (CVM) on lateral cephalographs can be used as a substitute to the hand-wrist method (HWM), as it correlates with hand-wrist maturity (14)(17)(24)(25)(27)(43)(44)(45).

1.2.2 Cervical vertebrae of the spine:

1.2.2.1 Cervical vertebrae anatomy:

The spine has seven rings called cervical vertebrae (C1 to C7) that are positioned in the neck between the base of the skull and thoracic vertebrae. In spite that the cervical vertebrae are very thin bones, they have an important role in protecting the spinal cord, supporting the head, and helping mobility of the head and neck (46)(47).

C1 and C2 have the unique characteristics, comparing to the rest of the cervical spine; that is why they are called as the atypical vertebrae.

C1 vertebrae (Atlas): The first cervical vertebra is the upper most vertebra named the Atlas. It is ring shape bone that does not have a vertebral body. Superiorly, the Atlas joins the occipital bone to form the atlanto-occipital joint which helps to support the base of the skull, and allows the backward and forward range motion of the head (46)(47)(48)(49).

The Atlas constitutes from a thin posterior arch, a thick anterior arch, pair of prominent lateral masses, and a pair of transverse foramen, which is enclosed by a pair of the transverse process through which the vertebral artery passes. Furthermore, the Atlas has two articular surfaces:

- The superior articular surface; concave, face upward, and inward to joint with the occipital condyles.
- The inferior articular surface; flat, face downward, and inward to joint with the superior surface of the axis (50).

- **C2 vertebrae (Axis):** The second cervical vertebra is named the Axis. It has a vertebral body containing a large bony protrusion called the odontoid process or dens, which articulates superiorly with the anterior arch of the atlas creating the atlanto-axial joint, where the atlas is able to rotate around the axis. In addition, the axis has laminae, pedicles, and transverse processes, which serve as attachment site for muscles (46)(47)(49)(50).

The cervical vertebrae from C3 to C6 have the same characters as the other vertebrae throughout the spine; that is why they are called as typical vertebrae. The typical cervical vertebrae have:

- **The vertebral body:** It is a cylindrical shaped bony structure. The anterior part is thicker than the posterior part. The cervical vertebrae set over each other with the cartilaginous disc between the vertebrae that helps in relieving the shocks and the cushioning between the bony vertebrae. The body of cervical vertebrae holds most of the load for a vertebra.
- **The vertebral arch:** It is bony arch structure surrounding the spinal cord. It is composed from pair of pedicles and laminae. The front surface of the pedicles connects with the vertebral body. Also, the laminae transition into the spinous process in the posterior surface of the vertebrae (46)(47)(48).

1.2.2.2 Development of the cervical vertebrae:

1.2.2.2.1 Development of the first cervical vertebrae:

The first cervical vertebra (Atlas) originates from three centers of primary ossification; one in the anterior arch and two in the posterior neural arches bilaterally. The primary ossification center in the anterior arch appears few months after birth. However, in rare cases, the ossification center in the anterior arch appears at birth and becomes completely ossified at the first year of age. The two ossification centers in the posterior neural arches appear in the seventh week of the fetus. So, they present at the time of birth. The bilateral posterior neural arches fuse with the anterior arch at seven years of age. The connection between the bilateral posterior neural arches and the anterior arch is known as the neurocentral synchondroses. The bilateral posterior neural arches fuse dorsally in the midline in the third year of age to form

the posterior synchondrosis. The fusion of the posterior synchondrosis is mostly followed by fusion of the neurocentral synchondrose (24)(51)(52)(53)(54)(55).

1.2.2.2.2 Development of the second cervical vertebrae:

The second cervical vertebra (Axis) originates from five primary ossification centers, Two in the posterior neural arches bilaterally, two in the odontoid process bilaterally, and one in the centrum (53)(56)(57). The bilateral ossification centers in the odontoid process fuse at birth. The junction between the odontoid process and the body of the second cervical vertebra is known as dentocentral synchondrosis. The junction between the two posterior arches and centrum is known as neurocentral synchondroses. During the ossification process, the bilateral neural arches fuse posteriorly, subsequent by the fusion between centrum-neural arch and odontoid process-centrum. After the fusion of the posterior and neurocentral synchondroses, the spinal canal reaches the final adult size. However, in some cases, the ossification of the dento-central synchondrosis never completes (24)(51).

Bilateral ossification centers of the odontoid process fuse at the midline in the seven month of the fetus. At the top of the odontoid process, the secondary ossification center can be seen between third and sixth years of age which fuse during the age of 12 years. The odontoid process fuses with the body of the second cervical vertebra between third and sixth years of age. The fusion line between these bones can be seen until the age of eleventh years and may be confused with a fracture. Between the second and third years of the age, the neural arches fuse posteriorly. Furthermore, between the third and six years of the age, the neural arches fuse with the body of the odontoid process (52)(58).

1.2.2.2.3 Development of the third to seventh cervical vertebrae:

The developmental processes of the third until the seventh cervical vertebrae are similar. They develop from three primary ossification centers; one in the anterior of centrum and pair in the posterior neural arches (57)(59)(60).

The connection between the centrum and the posterior neural arches is known as neurocentral synchondrosis. These bones fuse between third and sixth years of age. The connection between the two posterior neural arches is known as the posterior synchondrosis. They fuse posteriorly during the second and third years of the age. During the ossification process, the neural arches fuse posteriorly, subsequent by the closure of the neurocentral

synchondroses. The spinal canal achieves its mature size after the end of the primary ossifications of the cervical vertebrae (24)(51).

Moreover, the secondary ossification centers are at the tips of the transverse processes and spinous processes may stay unfused until early of the third decade of life and can be confused with a fracture. Furthermore, the secondary ossification centers can appear at the superior and inferior surfaces of the cervical vertebral bodies and may stay unfused until early adulthood (24)(51)(52)(61).

1.2.2.3 Cervical vertebral maturation (CVM) methods for the age estimation:

There are many methods to evaluate cervical vertebral maturation (CVM), ranging from simple qualitative assessment of the cervical vertebral size and shape, to quantitative measurements of cervical vertebral shape, height, width, distances, ratios, depth of the inferior concavity, and to other measurements, ranging from geometric morphometric assessment or linear regression formulae (39).

During the maturation of cervical vertebrae, the body of cervical vertebrae changes from a trapezoid to a rectangular shape with increasing of the height-width ratio and the formation of the concavity at the inferior margin. These characteristics are used by several staging systems to assess the cervical vertebral maturation (42). These stage have been improved and changed several times. The first CVM method was suggested by Lamparski DG (1972) (62). Then, other methods to evaluate cervical vertebral maturation were suggested by, Hassel B and Farman G (1995) (16), Baccetti et al. (2002) (63), and Seedat AK and Forsberg CD (2005) (64).

In 1972, lamparski DG (62) evaluated the changes in the shape of the five cervical vertebrae (C2, C3, C4, C5, and C6) on the cephalometric radiographs as these types of radiographs are routinely used in orthodontic treatment. So, extra radiation to the patient was eliminated (17)(19)(44)(63). Lamparski DG (62) generated stages for assessing the cervical vertebral maturation in females and males as following:

A. The cervical vertebrae maturation stages for females:

The 1st stage:

- All lower borders of the cervical vertebral bodies are flat.

- All bodies of the cervical vertebrae taper from the posterior side to the anterior side.

The 2nd stage:

- A concavity is developed in the lower border of the second cervical vertebral body.
- The anterior height of the cervical vertebrae is increased.

The 3rd stage:

- A concavity is developed at the lower border of the third cervical vertebral body.
- The lower borders of the other cervical vertebral bodies are still flat.

The 4th stage:

- The concavity at the third cervical vertebral body is increased.
- The body of fourth cervical vertebra has a definite concavity.
- Concavities at the fifth and sixth cervical vertebrae are beginning to form.
- All bodies of cervical vertebrae are rectangular in shape.

The 5th stage:

- Small spaces between the cervical vertebral bodies.
- Concavities are now well defined at the lower borders of all cervical vertebral bodies.
- The cervical vertebral bodies are nearly square in shape.

The 6th stage:

- All of cervical vertebral bodies are increased in vertical height.
- The height of the all cervical vertebrae are higher than the width.
- All the lower borders of cervical vertebral bodies have deep concavities.

B. The cervical vertebrae maturation stages for males:

The 1st stage:

- All lower borders of the cervical vertebral bodies are flat.
- All bodies of the cervical vertebrae taper from the posterior to the anterior side.

The 2nd stage:

- A concavity is developed at the lower border of the second cervical vertebral body.

The 3rd stage:

- The concavity at the lower border of the second cervical vertebra is deepened.
- The height of the cervical vertebra is increased.

The 4th stage:

- A concavity is developed at the lower border of the third cervical vertebral body.
- The anterior cervical vertebral body height is increased.

The 5th stage:

- The concavity at the third cervical vertebral body is increased.
- Concavities at the fourth cervical vertebrae are beginning to form.
- All bodies of cervical vertebrae are rectangular in shape.

The 6th stage:

- Small spaces between the cervical vertebral bodies.
- The concavity at the fourth cervical vertebral body is increased.
- Concavities at the fifth and sixth cervical vertebrae are beginning to form.
- The cervical vertebral bodies are nearly square in shape (26).

In 1995, the cervical vertebral maturation was assessed by Hassel B and Farman G (16), who studied the changes on the second, third, and fourth cervical vertebrae. They generated six stages for cervical vertebral maturation (CVM) as following:

At initiation stage:

- 80% to 100% of adolescent growth is expected.
- Inferior borders of the second, third and fourth cervical vertebrae are flat.
- The body of these cervical vertebrae are wedge in the shape.

- The superior borders of these cervical vertebrae are tapered from the posterior to the anterior side.

At acceleration stage:

- 65% to 85% of adolescent growth is expected.
- Concavities are developed at the inferior borders of the second and third cervical vertebrae.
- The inferior border of the fourth cervical vertebrae is still flat.
- The bodies of the second and third cervical vertebrae are nearly rectangular in shape.

At transition stages:

- 25% to 65% of adolescent growth is expected.
- Prominent concavities are seen in the inferior borders of the second and third cervical vertebrae.
- A concavity is developed at the inferior border of the fourth cervical vertebrae.
- The bodies of the third and the fourth cervical vertebrae are rectangular in shape.

At deceleration stage:

- 10% to 25% of adolescent growth is expected.
- Prominent concavities are seen at the inferior borders of the second, third, and fourth cervical vertebrae.
- The cervical vertebral bodies of the third and the fourth become more square in shape.

At maturation stage:

- 5% to 10% of adolescent growth is expected.
- More prominent concavities are seen in the inferior borders of the second, the third, and the fourth cervical vertebrae.

- The bodies of the third and the fourth cervical vertebrae are approximately square in shape.

At completion stage:

- Growth is considered to be complete.
- Little or no adolescent growth is expected.
- Deep concavities are seen in the inferior borders of C2, C3, and C4.
- The bodies of C3 and C4 are square or were greater in the vertical dimension than that in the horizontal dimension.

Generally, the initiation and acceleration stages are seen during the prepubertal period, the transition and deceleration stages are seen during the circumpubertal period, and the maturation and completion stages are seen during the postpubertal period (17).

In 2005, Seedat AK and Forsberg CD (64) assessed the changes in the body of the third cervical vertebrae (C3) on the cephalograph. They created three stages for cervical vertebral maturation (CVM) by modifying the six stages of cervical vertebral maturation proposed by Hassel et al. (16) as following:

- In active adolescent growth, the upper edge of C3 becomes S-shape, indicating the initiation and acceleration stages.
- The lower edge of C3 becomes Lip-shape, indicating of the transition and deceleration stages.
- The lower corners of the body become round, indicating a little or the end of growth, which occurs at final stages of maturation (23)(44)(65).

In 2002, Roman et al. (66) assessed the changes in the lower border, the shape and the height of cervical vertebral bodies from C2 to C6, and suggested the stages for cervical vertebral maturation as the following :

- Stages for concavity:

Stage 1: All the lower borders of cervical vertebral bodies are flat.

Stage 2: The lower border of C2 has a concavity.

Stage 3: The lower border of C3 has a concavity.

Stage 4: The lower borders of C4, C5 and C6 have concavity with deep concavities at C2 and C3.

Stage 5: Deep concavities are at the lower border of all cervical vertebral bodies.

Stage 6: Deep concavities are at the lower border of all cervical vertebral bodies and the lower angles become rounded.

- **Stages for shape of C3 and C4:**

Stage 1: The third and forth cervical vertebral bodies are taper from the posterior to the anterior and wedge-shaped.

Stage 2: The third cervical vertebral body is wedge-shaped. However, the forth cervical vertebral body is approximately rectangular in shaped with absence of the upper anterior angle.

Stage 3: The third and the forth cervical vertebral bodies are rectangular in shape.

Stage 4: The third and the forth cervical vertebral bodies are nearly square in shape.

Stage 5: The third and the forth cervical vertebral bodies are square in shape.

Stage 6: The third and the forth cervical vertebral bodies are rectangular in shape (height greater than width).

- **Stages for height of C3 and C4:**

Stage 1: The third and the forth cervical vertebral body's height are less than 80% of the width.

Stage 2: The third and the forth cervical vertebral body's height are between 80% and 99% of the width.

Stage 3: The third and the forth cervical vertebral body's height and width are equal.

Stage 4: The third and the forth cervical vertebral bodies height are greater than width (26)(66).

In 2005, Baccetti et al. (45) suggested six new stages for cervical vertebral maturation (C2 to C4) based on two sets of variables:

- The presence or absence of the concavity at the lower border of second, third and forth cervical vertebral bodies.
- The shape of third and forth cervical vertebral bodies.
- **Trapezoid shape:** The superior border of cervical vertebrae are tapered from the posterior to the anterior border.
- **Rectangular-horizontal shape:** The posterior and the anterior borders of cervical vertebrae have the same length. Furthermore, the superior and the inferior borders of cervical vertebrae are longer than the anterior and posterior borders.
- **Squared shape:** The anterior, posterior, inferior, and superior borders of cervical vertebrae have the same length.
- **Rectangular-vertical shape:** The anterior and posterior borders of cervical vertebrae are longer than the inferior and superior borders.

The characteristics of cervical vertebrae in the stages as suggested by Baccetti et al. (45) can be summarized as follows:

Stage 1:

- 23.3% of the subjects have a concavity at the lower border of the second cervical vertebra.
- 100% of the subjects have no concavity at the lower borders of the third and forth cervical vertebral bodies.
- The bodies of the third and forth cervical vertebrae are a trapezoid in shape.

Stage 2:

- In 73.3% of the subjects have a concavity at the lower border of the second cervical vertebra.
- The concavity is absence at the lower borders of the third and forth cervical vertebral bodies.
- The third and forth cervical vertebral bodies are still trapezoid in shape.
- In 13.3% of the subjects, the third and forth cervical vertebrae are rectangular or horizontal in shape.

Stage 3:

- The concavity is present at the lower border of the second and third cervical vertebral bodies.
- The concavity is absent at the lower border of the fourth cervical vertebra.
- The third and fourth cervical vertebral bodies are either trapezoid or rectangular-horizontal in shape.

Stage 4:

- The concavity is present at the lower borders of the second, third and fourth cervical vertebral bodies.
- The bodies of both third and fourth cervical vertebrae are the rectangular-horizontal in shape.

Stage 5:

- The concavity is present at the lower borders of the second, third, and fourth cervical vertebral bodies.
- In the most subjects, the body of the third cervical vertebra is the rectangular-horizontal and square in shape.
- In most subjects, the body of the fourth cervical vertebra is the rectangular-horizontal or square in shape.

Stage 6:

- The concavity is present at the lower borders of all 3 cervical vertebrae.
- In 50% of the cases, the body of the third cervical vertebra is squared or rectangular in shape.
- In 53.3% of the cases, the body of the fourth cervical vertebra is square in shape and rectangular vertical in shape in the remaining cases (45)(63).

1.2.2.4 Advantages of the Cervical Vertebral Maturation (CVM) methods:

The CVM methods have many advantages comparing the hand-wrist method in which:

- These methods assess the maturation of the cervical vertebrae on the lateral cephalography, which is routinely taken as a pretreatment record for orthodontic

diagnosis and treatment planning and the cervical vertebrae are easily seen in it. So, there is no need for hand-wrist radiograph to assess the bone maturation, and that leads to the reduction of radiation exposure and shortening of the examination time.

- It can predict the pubertal peak of the mandibular growth with the same validity (23)(27)(32)(39)(45).
- This method provides analysis of the second, third, and fourth cervical vertebral bodies that can be seen when a protective radiation collar wears by the patient.
- Prediction of stages is not dependent on the assessment of changes between-stages, so the stages can be predicted easily on a single cephalograph (67).

Franchi et al (45) explained the main characteristics of CVM methods as the following:

- In approximately 95% of the North American subjects, the growth in CVM relates with the pubertal peak in both mandibular growth and body height.
- The cervical vertebrae can be seen on in the lateral cephalograph, which is taken routinely for orthodontic diagnosis and treatment planning.
- Assessment of the shape of the cervical vertebrae is simple.
- High reliability between examiners during the estimation of CVM stages (about 98%).
- This method can be used for the anticipation of the pubertal peak in mandibular growth (19)(45)(68).

The method suggested by Baccetti et al. (45) is accepted to be highly reliable and valid enough to replace the hand-wrist method. Furthermore, each stage is a biological indicator, demonstrating the degree of physical growth, specially the degree of mandibular growth. The peak of mandibular growth takes place after stage 3 when concavities at the lower border of second and third cervical vertebral bodies appear. Also, this method provides information about the time and rate of growth in the whole body, especially of the cranio-facial and the mandibular regions (14)(43)(44)(67).

In 2010, Marques etl al. (65) compared between the cervical vertebral maturation methods suggested by Hassel B and Farman G (16), Baccetti et al. (45), and Seedat AK and Forsberg CD (64) to assess which method is the best to use in orthodontic patients. The results showed that all of the three methods were clinically applicable. Nevertheless, the method recommended by baccetti et al. (45) was the best, followed by the Hassel B and Farman G

(16), and the Seedat AK and Forsberg CD (64) methods. Additionally, the Baccetti et al. (45) method was an easy method to use as just two anatomical variables were used for staging. On the other hand, the easier method is suggested by Seedat AK and Forsberg CD (64), who uses the six stages suggested by Hassel B and Farman G (16). They only evaluated the body of third cervical vertebrae (the concavity on the lower edge, its shape, the lip shape on the lower corners, the S-shape on the upper edge and the rounding of the lower corners). In contrast, this method has a doubt regarding the estimation of maturation stage. The most difficult method for assessing the maturation is suggested by Seedat AK and Forsberg CD (64), as they used high anatomical details in this method (23)(44)(65).

1.2.2.5 Disadvantages of the Cervical Vertebral Maturation (CVM):

The usage of the CVM method has been questioned. It encounters several problems as there are continues changes in bone during the growth period, and a high level of intra-and inter examiner error during the assessment on lateral cephalograph (43). All CVM methods use either the geometric shape, the linear dimensional measurements or the lower border concavity of the cervical vertebral body to evaluate the stages. However, when the geometric shape is used, high subjectivity and individual variation can be expected. Furthermore, the linear measurements can be affected by the type of the radiographic technique or magnification (22).

1.2.2.6 Application of the Cervical Vertebral Maturation (CVM) methods to dentofacial orthopedics:

- The CVM method can be used only when the cervical vertebrae from C2 to C6 are visible on cephalograph (45).
- The CVM method has six maturational stages (CVMS1 to CVMS6). The peak of the mandibular growth takes place during the years between CVMS3 and CVMS4, once the concavities at the lower border of the second and third cervical vertebral bodies are appearent (14)(68).
- The stages of the CVM method are applicable to high-angle patients, who are planned for orthognathic treatment. The stability of this treatment is possible only when bone maturation is complete (19). The peak of pubertal is approaching during CVMS2 and it will start at CVMS3. However, the active growth is almost completed when stage 6 starts (45).

- The treatment of Class II is successful when the peak of mandibular growth is reached (19)(45)(63).
- The treatment of Class III by protraction and expansion of maxilla is successful only at CVMS1 or CVMS2 (19)(45).
- The effects of maxillary expansion for treatment of transverse maxillary deficiency are successful if this treatment is done during prepubertal stages (45).
- At the peak of mandibular growth (CVMS3), the deficiency of the mandibular ramus height can be treated noticeably by increasing the vertical facial dimension.
- The CVM method is a powerful diagnostic tool, which is useful for the evaluation of growth activity, and the correction of facial disharmonies (45)(63).

1.2.3 Hyoid bone:

1.2.3.1 Anatomy and function of the hyoid bone:

The hyoid bone is an important bone for the life of human; anatomically, phylogenetically, and functionally (69).

Anatomically, the hyoid bone is a U-shaped free-floating bone, located between the chin and the thyroid cartilage (68)(70)(71). It alters its location relative to the cervical vertebrae during development and growth. In infancy, it is located in front of the second and third cervical vertebrae. Then in adults, it declines to be anterior to the fourth and fifth cervical vertebrae. Its decline occurs simultaneously with the decline of structures related to its function, like the epiglottis and larynx (1)(4)(69)(72).

The hyoid bone has five parts. The body in the center and two pairs of lesser and greater cornu laterally (1)(12)(69)(72)(73)(74)(75).

The body: It is an uneven and quadrilateral in shape. Its anterior surface is slightly convex anterosuperiorly and intersects by a transverse ridge. The upper part of the body divides by a vertical median ridge. Its posterior surface is even and concaves posteroinferiorly.

The greater cornu: They curve posterolaterally. At early life, the body and the greater cornu are joined by cartilage, and then they fuse after middle age.

The lesser cornu: They are a pair of small conical projections located at the connection of the body and greater cornu. Its base connects to the body through fibrous tissue and connects to the greater cornua through a synovial joint (70)(71)(73).

Functionally, the inferior margin of the hyoid body is connected to the muscles of the infrahyoid group, which depress the hyoid bone inferiorly. While the superior margin is connected to the hyoid elevator muscles (Geniohyoid, Mylohyoid, Stylohyoid, Genioglossus and Hyoglossus muscle). The protruded position of the hyoid body is due to the interacting of these muscles during swallowing or mastication in taller individuals (71)(73). In addition, these muscles play a role in supporting the tongue, preventing regurgitation, and maintaining the airway space clearance (69)(73)(76).

1.2.3.2 Ossification of the hyoid bone:

Phylogenetically, the hyoid bone originates from the second and third pharyngeal arches. The upper part of the body and lesser cornu develop from the cartilage of the second branchial arch, while the lower part of the body and greater cornu develop from the cartilage of the third branchial arch. Chondrification starts at the fifth week of intrauterine life and ends in the third and fourth months of intrauterine life (1)(69).

The hyoid bone has six ossification centers for development; two ossification centers in the body, two ossification centers in greater horns, and two ossification centers in lesser horns. The ossification of the greater cornu starts at the end of intrauterine life while the ossification of lesser cornu starts around puberty (1)(69)(73)(74)(75)(20). The frequency of fusion between the greater cornu and the body increases with age. Even though, the greater cornu and the body of hyoid bone usually fuse at middle life, many middle-aged and elderly women may have non-fused hyoid bones (1)(69)(77). The cause of non-fusion is still somewhat unclear; it may link to the age (10).

1.2.3.3 The fusion stages of hyoid bone:

There is a great variety of methods to assess hyoid maturation stages (HMS). In 2010, Kaur Harjeet et al. (78) assessed the area between the body and the greater cornu on radiographs and classified fusion stages as follows:

Stage 1: No fusion between the body and the greater cornu.

Stage 2: Initiation fusion of less than one-fourth between the body and the greater cornu starts at one side or in the middle.

Stage 3: Partial fusion of more than the half between the body and the greater cornu.

Stage 4: Fusion of more than three-fourth or complete fusion (78).

In 2012, Kyoichi Ito et al. (73) evaluated the degree of ossification of the hyoid bone by aging in the right and left bones, then they classified the hyoid bone ossification into three stages as follows:

Stage 1: No fusion between the body and the greater cornu.

Stage 2: Incomplete fusion between the body and the greater cornu.

Stage 3: Complete fusion between the body and the greater cornu (73).

In 2013, Biswas et al. (79) classified hyoids fusion into four groups namely;

Stage 1: Bilateral non-fusion.

Stage 2: Unilateral fusion of the left side or unilateral fusion of the right side.

Stage 3: Bilateral fusion (79).

In 2016, Austin et al. (69) examined the hyoid bone on Computed Tomography (CT) images and measured the distance between the body and the greater horn in the axial plane, which was used for fusion staging as the following:

Stage 0: The space between the hyoid body and greater cornu is ≥ 2.5 mm.

Stage 1: The space between the bones is < 2.5 mm.

Stage 2: Non uniform and partial fusion between the bones.

Stage 3: Complete fusion between the bones with or without dividing lines between them (69).

1.2.3.4 Importance of the hyoid bone:

In physical and forensic anthropology, the fusion of hyoid has three important medico-legal implications. The First, the fracture of hyoid is more common related to the fusion of

hyoid bone. The Second, the experts use the time of hyoid fusion for age estimation in decomposed bodies and skeletal remains forensics (1)(77)(78)(79). The Third, the morphology of hyoid bone can provide information about the biological profile of an individual (71).

The fracture of hyoid bone is an evidence for strangulation or hanging in forensic medicine (68). Moreover, the fractures are evidences for neck injuries specially, in a badly decomposed or skeletal remains than in young victims with unfractured hyoid bones (77). It was recorded that, susceptibility of the hyoid bone to fracture was directly related to age. The fusion between greater horns and body increases the rigidity between the bones making them susceptible to fracture (1)(75).

Moreover, the fracture of the hyoid was found to be influenced by the shape of the hyoid bone. Fractured hyoids are longer in the anteroposterior plane and are more steeply sloping when compared with unfractured hyoids (1).

1.2.4 Spheno-occipital synchondrosis:

1.2.4.1 Anatomy of spheno-occipital synchondrosis:

The skeletal age can also be assessed by evaluating the closure of the spheno-occipital synchondrosis. This is defined as the cartilaginous joint (hyaline cartilage or fibro-cartilage) located between two immovable bones, the occipital bone and the body of the sphenoid bone in front of the foramen magnum, that allows the area to grow until the cartilage is mineralized (41)(80)(81)(82).

1.2.4.2 Ossification of spheno-occipital synchondrosis:

Ossification of the spheno-occipital synchondrosis initiates from the endocranial surface to the ectocranial surface. In addition, it begins superiorly and progresses inferiorly between sphenoid and occipital bones. Early, the gap between these bones may be identify on lateral radiographs of the skull base. As ossification of the synchondrosis proceeds, the cartilage between these bones becomes progressively thinner and later, completely replaced by bone at a later period of adolescence. In these cases, the gap between these bones are not visible neither on lateral radiographs, nor on CT images (83)(84)(85)(86).

1.2.4.3 Fusion stages of spheno-occipital synchondrosis:

In the literature, there are no uniform scoring systems to assess the spheno-occipital synchondrosis stages (SOSS)(84). Some researchers scored the status as "open/unfused, closing / fusing, closed\ fused " (87)(88). When El-Sheikh et al. (89) evaluated the base of the skull in a CT images, they found that the spheno-occipital synchondrosis could be open, partially closed or closed. Similarly, Kahana et al. (90), classified sutures into “open” and “closed” categories. Shani et al.(85) classified the degree of fusion as complete (stage 2), partial (stage 1), and unfused (stage 0).

Franklin D and Flavel A (86) evaluated the cranial base using three-dimensional Multiplanar Reformatting (MPR) images and assessed the fusion status of spheno-occipital synchondrosis in the sagittal plane. The fusion status of the spheno-occipital synchondrosis is scored according to a four-stage system, modified from Bassed et al. (91) and Shirley N and Jantz R (87) as the following:

Stage 0: No fusion between the occipital and the sphenoid bones.

Stage 1: No more than the half-length fusion between the occipital and the sphenoid bones endocranially.

Stage 2: More than the half-length fusion between the occipital and the sphenoid bones ectocranially.

Stage 3: Complete fusion between the occipital and the sphenoid bones (86).

Recently, Bassed et al. (91) assessed spheno-occipital synchondrosis in the midsagittal plane of multi-slice CT images and adjusted this scoring system to five stages. These additional stages are to assess the scar formation at the fusion site, acquire more specific information, and decrease the subjectivity of evaluation within and between observers. The stages are as follows:

Stage 1: The spheno-occipital synchondrosis is totally unfused.

Stage 2: The fusion is on the superior edge, while the remaining areas are open..

Stage 3: Half the length of the spheno-occipital synchondrosis is closed.

Stage 4: The spheno-occipital synchondrosis is completely closed. However, the site still has a fusion scar.

Stage 5: The site is completely obliterated with normal bone.

Lottering et al. (82) evaluated the fusion status of the spheno-occipital synchondrosis in both the sagittal and axial planes as the following:

Stage 1: The spheno-occipital synchondrosis is completely open appearing as a hypodense zone without calcification in the joint space.

Stage 2: The fusion between the occipital and the sphenoid bones began endocranially at one or both lateral margins. If one margin appears fused, an ossification nodule may appear on the contralateral margin.

Stage 3: Median hyperdense ossification nodule appears. Also, the fusion appears on both right and left lateral margins of the joint space endocranially, however no bony bridging appears on the median sagittal plan.

Stage 4: Less than half the length of the spheno-occipital synchondrosis fuses endocranially with high density ossification nodules that fill the joint space which joins with adjacent borders by bony bridging.

Stage 5: More than half the length of the spheno-occipital synchondrosis fuses mostly at endocranial margins with the disappearing of bony bridging.

Stage 6: Complete and homogenous fusion between the occipital and the sphenoid bones with no radiolucency along the endocranial and ectocranial borders (82).

1.2.4.4 Importance of spheno-occipital synchondrosis:

- This area is an important growth site for craniofacial development. As the spheno-occipital synchondrosis continues growth; it translates the maxilla upward and forward relative to the mandible, leading to an increase in the facial height and depth (84).
- After fusion of the sphenoid and occipital bones is complete, the sphenoid sinuses extend into the basilar part of the occipital bone (41)(83)(84)(92)(93).

- The degree of fusion between the occipital and the sphenoid bones is considered to be particularly important in forensics for age estimation, due to its late ossification in adolescent age groups and for craniofacial development (80)(86).

1.3 Different radiographic techniques for assessing the age and the sex:

Many studies used different methodological approaches to estimate the age and sex of a subject through assessing the closure stages of spheno-occipital synchondrosis, hyoid bone, and cervical vertebra on conventional radiography, Computed Tomography (CT), and Cone Beam Computed Tomography (CBCT) (13)(63)(86)(94)(95)(96)(97). Even though, the use of conventional radiography is cheap and practical, its use has limitations, due to superimposition and low resolution. Therefore, it is impossible to use if spheno-occipital synchondrosis initiates to close or if it is consequently completely closed (13)(41).

Several studies have been done using the lateral cephalometric and CBCT in limited two dimensions (2D) applications to evaluate the status of spheno-occipital synchondrosis, hyoid bone, and cervical vertebrae growth (16)(32)(98)(99). However, there were limitations in these previous studies as they assessed human growth using 2D data, whereas human growth changes in three dimensions (3D). Growth in width occurs first, followed by the growth in the anteroposterior dimension and, lastly, growth in height (23)(95). The growth of the maxillary skeletal width completes before the peak pubertal growth; the growth in the anteroposterior dimension and height continues throughout puberty. Therefore, a three-dimensional (3D) approach is required to evaluate bone maturation (43)(100)(101).

More recently, CT and CBCT have been used to evaluate spheno-occipital synchondrosis, Hyoid bone, and cervical vertebra due to their superior visualization achieved using 3D radiographic scans and more accuracy in determining age and sex (13)(83)(85)(96).

With development of contemporary imaging technologies, CT scans can display the third dimension of the subject. These new imaging modalities allow getting a clear image and examination of non-accessible anatomical structures such as the spheno-occipital synchondrosis. CT scans have advantages over conventional radiographic methods for earlier detection, more accurate, reliable interpretation, evaluation the third dimension of the subject, and a high resolution of the region of interest. In contrast, the price, attainability, and high radiation dose are stated to be drawbacks for CT uses (102)(103). As the result of these, CBCT is a new imaging modality in the field of Dentomaxillofacial Radiology that is

becoming more popular and is recommended for several purposes. It has advantages as dramatically decreased radiation dose comparing to other imaging modalities, such as CT. In addition, it can eliminate superimposition of adjacent structures by displaying a third dimension when compared to 2D conventional radiography. Therefore, its use as age and sex estimation marker has been a point of interest and investigated in different populations (13)(83)(93).

1.3.1 Background of Cone Beam Computed Tomography (CBCT):

In 1972, the computerized transverse axial scanning was introduced by Hounsfield, which led to develop the concept of CT. CT is a multi-planar imaging technique, which offers the facility of creating different sections of images at different flat and curved planes. Subsequently, a volume of data can be acquired, stored, and reformatted in any form of images that eliminate the superimposition of the investigated area with adjacent structures. Soon after, Arai et al. (104) in Japan and Mozzo et al. (105) in Italy worked independently for introducing the concept of CBCT in radiology. Firstly, It was used for angiography in the early 1980s. Then later, it was gradually used in dentistry for other applications, for example; maxillofacial surgery, endodontics, orthodontics, and implant planning (106)(107)(108).

In the late 1990s, the technology facilitated the production of acceptably priced CBCT units that are different from conventional CT as it is small enough to be employed in the dental office for maxillofacial imaging, x-ray detectors capable of rapid multiple image acquisition, high-output X-ray generators, suitable image acquisition and integration algorithms, and affordable computers powerful enough to process the vast quantity of acquired image data (107)(109).

The CBCT machine uses a cone-shaped beam, hence the name cone beam CT, and a reciprocating solid state flat panel detector, which rotates once around the patient (180-360 degrees) and covers the entire field of interest (complete dental/maxillofacial volume or limited regional area of interest) rather than a fan shaped X-ray beam captures a series of axial plane slices from a continuous spiral motion over the axial plane in conventional CT. Therefore, less ionizing radiation is used in regards to conventional CT units (109)(110)(111).

However, CBCT imaging has higher radiation then that of conventional dental radiography. For that reason, it is essential to understand the principles for dental CBCT

imaging in order to obtain the advantages of this technique with decreasing risk to patient. This review offers an outline of technical aspects of dental CBCT imaging including hardware, acquisition, image reconstruction, and visualization (107)(112)(113)(114).

Most CBCT machines have multiple defined field of view (FOV) sizes. The sizes of FOV depend generally on size and shape of the detector, the collimation of the beam, and geometry of the x ray beam (113)(115).

The dose of radiation emitting from CBCT is greater than that emitting from conventional radiography like intraoral, cephalometric, and panoramic radiography, but it is lower than that emitting from multiple detector computed tomography (112)(113).

1.3.2 Image reconstruction on Cone Beam Computed Tomography (CBCT):

When the projection data are obtained, data are processed to form the volumetric data. This process is known as reconstruction. Once a single cone-beam rotation is complete, it produces 100 to more than 600 individual projection frames. Each projection frame consists from more than a million pixels and each pixel consists from 12 to 16 bits (110)(115).

To handling the data, it is usually assimilated by acquisition computer and then transferred to a workstation computer. Comparing to conventional CT, reconstruction of data in CBCT is done by personal computer not by platforms. The time for reconstruction process depends on following parameters:

- Parameters of the acquisition (FOV, number of projections, and voxel size)
- Hardware (transfer data from acquisition to workstation computer and processing speed)
- Software (reconstruction algorithms).

Reconstruction should be completed in an acceptable time (less than 3 minutes for standard resolution scans) to complement patient flow. The reconstruction process consists of two stages. Each composes of numerous steps:

1. Acquisition stage: It is performed on the acquisition computer. After acquiring of projection images, they undergo several steps to eliminate defects related to variations in detector dark current, gain and pixel defects.

2. Reconstruction stage: In this stage, the other data-processing steps are worked on the reconstruction computer. Once images are corrected, they must be interrelated to each other and gathered. The corrected images are transformed into a sinogram. The first sinogram consists from a series of the first rows in each projection. If there are 300 projections, then the sinogram will have 300 rows. This step is known as the radon transformation. The final image contains multiple sine waves of different amplitude (110)(112)(115).

The algorithm of reconstruction filter converts the sinogram into 2D CT slice. Once all slices have been reconstructed, they are joint together to form a single volume for visualization (112)(115).

1.3.3 Image visualization on Cone Beam Computed Tomography (CBCT):

1.3.3.1 Multiplanar reformatting (MPR):

After cone beam reconstruction process complete, the volumetric data set is displayed on screen as a series of 2D cross-sectional images in a three planar like:

- The axial planes: A set of 2D images in the volume from the bottom to top.
- The sagittal planes: A set of 2D images from the right to left.
- The coronal planes: A set of 2D images from the posterior to anterior.

In the MPR window, these planes are with each other through crosshairs or intersection lines, allowing for navigation and orientation. The modes of MPR are oblique reformation, curved planar reformation and serial transplanar reformation (providing cross-sections) (107)(113)(116).

1.3.3.2 Oblique reformation:

The operator can use oblique reformation to pass through the axial images at any angle. The handling of oblique reformation can be done by rotating the intersection lines or the image itself. It can be used for evaluation the impacted third molars, tempromandibular joint and the mandibular canal (107)(109).

1.3.3.3 Curved reformation:

To create a curved planar images, on an axial image; you can manually or automatically drawn a planning line through adjusting multiple nodes at the centerline of each the jaw arch. This generates a set of panoramic images for both the teeth and bone.

However, thickness of these images is small. It may be impossible to see the upper and lower jaw on one image. For this reason, it should draw a planning line for the upper and lower jaw separately (107)(109)(113)(117)(118).

1.3.3.4 Cross-sectional (oblique coronal) view:

In this view, successive cross-sectional images perpendicular to curved slice can be created in which the thickness and spacing of images can be adjusted. It used to evaluate alveolar bone for implant placement, the relationship of impacted mandibular third molar with the mandibular canal, condylar surface and shape in the symptomatic Temporomandibular Joint (TMJ), and pathological conditions affecting the jaws (109)(117).

1.3.3.5 Ray sum:

This allows showing the thickened MPR slices by adding up adjacent voxels. The produced image represents exact volume of the patient that can be used to create virtual projections, such as panoramic or cephalometric images identical to conventional radiographs without magnification and parallax distortion. However, the superimposition of multiple structures analogous to 2D imaging can be seen in the images (109)(113)(117)(118).

1.3.3.6 Three-dimensional volume rendering:

It is a technique allowing demonstration the data by combination of adjacent voxels and selectively display the data through either a direct volume rendering (DVR) or an indirect volume rendering (IVR).

DVR; Maximum Intensity Projection (MIP) technique is used to display an image which has highest voxels density values within a particular thickness. Voxel values that are below an arbitrary threshold are excluded. MIP images are used for locating impacted teeth, assessment of TMJ, assessment of fractures, craniofacial analysis, surgical follow-up, and visualization of soft tissue calcifications.

IVR: It is a complicated process needing selection and displaying special density of the voxels within the data. This process called, “segmentation”. Two kinds of views are possible by this process: solid view (the surface rendering) and transparent views (volumetric rendering). IVR is usually used for visualization and analysis of craniofacial conditions and

evaluation the relationships of various anatomic features, such as the inferior alveolar canal to the mandibular third molar (107)(117)(118).

1.3.4 Advantages of Cone Beam Computed Tomography (CBCT) over Computed Tomography (CT):

The use of CT in dentistry has been restricted due to its disadvantages like; higher dose of radiation, availability, longer scanning time, cost, poor soft tissue resolution and difficulty in interpretation. These disadvantages overcome with development of CBCT, which provides a number of advantages for oral and maxillofacial imaging comparing with conventional CT as the following (109)(115)(119) :

1.3.4.1 X-ray beam limitation:

The CBCT machines can restrict the primary X-ray beam to the area of interest by using collimator. This procedure minimizes scattered radiation and reduces unnecessary exposure to the patient (109)(115)(120)(121).

1.3.4.2 Image accuracy:

The CBCT machines provide sub-millimeter isotropic voxels (equal in all three proportions.) As compared to anisotropic voxels found in conventional CT. Although the surfaces of CT can be 625 mm square and their depth can be 1–2 mm. CBCT provides sub-millimeter resolution varying between 0.4 mm and 0.09 mm. Subsequently, spatial resolution of axial, coronal, sagittal, and MPR images is high enough for use in maxillofacial applications where accuracy of dimensions is significant, like analysis in orthodontic and assessment of the implant sites (109)(115)(122)(123).

1.3.4.3 Rapid scan time:

During scanning, the CBCT machine requires 5 to 40 seconds to obtain complete image in a single rotation comparable to panoramic radiography. This short scanning time is desirable as it reduces the artifacts owing to patient movement. However, the time for reconstruction data is substantially longer. It ranges from approximately 1 minute to 20 minutes (115)(109).

1.3.4.4 Dose reduction:

In 2005, International Committee on Radiation Protection-ICRP indicate that, the effective dose for various CBCT devices ranges from 52 to 1025 microsieverts (μsv). It depends on the type and model of CBCT equipment and imaging protocol used. These doses are approximately an equivalent to patient radiation dose of 4 to 77 digital panoramic radiographs (approximately $13.3 \mu\text{sv}$) or 5 to 103 days of background dose (approximately $3600 \mu\text{sv}$) in the United States.

The CBCT provides significant dose reductions of between 98.5% and 76.2% compared with conventional head CT (range 1400 to $2100 \mu\text{sv}$)

Futhermore, up to 40% of the patient radiation dose can be lowered by collimating the beam, elevating the chin, and using thyroid and cervical spine shielding (109)(115)(122)(124)(125)(126)(127).

1.3.4.5 Display modes unique to maxillofacial imaging:

Perhaps the most significant advantage of CBCT is ability to display images features in 3D while the convensial images cannot. This is because the CBCT has software which provides MPR modes include oblique, curved planar reformation (providing “simulated” distortion-free panoramic images), and serial transplanar reformation (providing cross-sections). These modes can be utilized to interrelate the images in three orthogonal planes to accentuate precise anatomic structures and diagnostic functions. Moreover, this software has tools for adjusting the zoom or the magnification, window/level, and add annotation. In addition, cursor-driven measurement algorithms can offer accurate dimensional measurements which free from distortion and magnification (109)(110).

1.3.4.6 Reduced image artifact:

In the CBCT, the presence of artifact suppression algorithms and multiple of projections have led to reduce metal artifact, mainly in secondary reconstructions intended for seeing the jaws and teeth (109)(115)(128).

1.3.5 Limitations of Cone Beam Computed Tomography (CBCT):

Although the clinical applications of CBCT in the field of dentistry have expanded currently, it is not devoid of limitations. The limitations may be related to the “cone-beam” projection geometry, artifacts, detector sensitivity, poor soft tissue contrast and noise.

The artifact is "any distortion or error in the image that is unrelated to the subject being studied." According to cause, the artifacts can be related to beam hardening, patient-related artifacts, scanner-related artifacts and cone beam–related artifacts (109)(115).

1.3.5.1 X-ray beam artifacts:

A. Acquisition artifacts:

The X-ray beam is polychromatic in nature. As an x-ray beam passes through an object, lower energy photons are absorbed in preference to higher energy photons. This phenomenon is called beam hardening, which causes two types of artifact: (1) metallic structures distortion as a result of differential absorption, known as the cupping artifact and (2) streaks and dark bands that can appear between two dense objects.

The acquisition artifacts commonly appear on CBCT images. Because the CBCT x-ray beam is polychromatic and has lower energy than conventional CT. In clinical practice, it is recommended to decrease the field size, modify patient position, or separate the dental arches to prevent scanning regions susceptible to beam hardening (e.g., metallic restorations, dental implants). Lately, many CBCT manufacturers have developed algorithms for artifact reduction during the reconstruction process like Soredex, Helsinki, Scanora 3D, finland. These algorithms decrease metal, noise and motion related artifacts on the image (109)(115).

B. The Patient-related artifacts:

Movement of the patient during scanning can cause misregistration of data obtaining for the reconstructed image, which appears as unsharpness. The unsharpness can be reduced by restraining the head and by decreasing the time of scanning. Furthermore, it is also important to remove metallic items like jewelery before exposure to radiation to prevent the developing of horizontal streaks and noise in the image.

C. The Scanner-related artifacts:

They appear as circular or ring streaks consequently to flaws in the scanner or due to poor calibration, which cause repetitive reading at each angular position of the detector, resulting in a circular artifact.

D. Cone beam–related artifacts:

There are three artifacts that can be related to the of X- ray beam geometry. These are as follows:

- Partial volume averaging.
- Undersampling.
- Cone-beam effect (109)(115)(129).

1. The Partial volume averaging:

The Partial volume averaging appears when the selected voxel size of the scan is larger than the size of the object being imaged. For example, a 1 mm voxel may contain tissues of differing densities, such as, bone and soft tissue. In this case, the displayed pixel is an intermediate value that does not represent either bone or soft tissue. The resulting image is average of the different brightness values. Furthermore, a “step” may appear at the boundaries of the resultant image (115).

2. Undersampling:

During image reconstruction, the number of basis projection images are proportional to data sample. Few basic projections are provided as undersampling data, which cause misregistration and noisier images. This artifact should be considered in relation to the diagnostic information (115).

3. The Cone-beam effect:

The Cone-beam effect may cause an artifact, resulting from the divergence of the beam as the x-ray tube and detector move around the patient in a horizontal plane. Only the areas on the top or bottom of the image field will be exposed to the X-ray. This leads to streaking artifacts, image distortion and noise. Clinically, this reduced by placing the area of interest in the horizontal plane of the X-ray beam (109)(115).

1.3.5.2 The Poor soft tissue contrast:

Contrast is a variation in the spatial of the X-ray photon intensities that vary in attenuation by the patient; resulting in differences in contrast between regions in an image.

One major disadvantage of CBCT is poor contrast resolution, mainly due to three factors including; increased image noise, the divergence of the X-ray beam, and inherent artifacts related to flat-panel detector-based. Also, the cone shape of the beam can irradiate a large area with every basis image projection. Moreover, the large numbers of the photons produce compton scattering radiation which add background signals recorded by pixels on the detector. These signals do not represent the actual attenuation of an object, and it contributes to the increased image noise (109)(115)(130)(131)(132).

1.3.6 Clinical applications of CBCT in the maxillofacial region:

Radiographic examination is important in diagnosis and treatment planning in dentistry. 2D imaging has disadvantages including; magnification, distortion, and superimposition, together leading to misrepresentation of structures. In addition, it cannot show the 3D of the area being radiographed. However, with the development of CBCT, these problems are solved, and the third-dimension can be seen in images which are useful for many oral and maxillofacial situations (109).

1.3.6.1 Applications in oral and maxillofacial surgery:

The most important application of CBCT in oral and maxillofacial surgery is to investigate:

- The exact 3D location, the size, extent of jaw pathologies, and its relation to vital structures of jaw pathologies like malignant or benign tumors.
- The exact location of impacted and supernumerary teeth.
- The alterations of the trabecular and cortical bone in cases of Bisphosphonate-associated necrosis of the jaws.
- The diseases related to paranasal sinuses.
- Mid-facial fracture and inter-operative visualization of the facial bones after the fracture.
- The planning orthognathic and orthomorphic surgeries.
- Soft-tissue calcifications, such as carotid atherosclerosis, tonsilloliths, and sialoliths.

- Dental age, arch segment positioning, cleft size, morphology of the defect.
- Facial growth in cleft lip and palate cases (109)(112)(114)(133)(134)(135)(136).

1.3.6.2 Application in endodontics:

The CBCT is an important application to investigate:

- The differentiate apical lesions, like; apical cysts and apical granulomas by measuring the lesion density(133).
- The CBCT is used to evaluate the root perforation, resorption, number, and morphology of accessory canals, and fractures (mesiodistal or buccolingual directions, vertical and horizontal root fractures) (109)(114)(133)(137).

1.3.6.3 Applications in implant dentistry:

The CBCT has been used on the planning for placements of dental implants as it provides the axial, reformatted panoramic, and serial cross-sectional images of the alveolar bone height, width and angulation at the specific location. In addition, it precisely depicts vital structures such as the inferior alveolar dental nerve canal in the mandible or the sinus in the maxilla. So, the CBCT provides reliable information that aid in case selection and in both qualitative and quantitative measurements of bone.

Third-party software applications have tools that can be used to evaluate and plan both the surgical and prosthetic components of implant therapy. In addition, they can be used to construct a surgical implant guidance stent to assist the accurate placement of implants (112)(114)(133)(138)(139).

1.3.6.4 Applications in orthodontics:

There are many applications of CBCT in orthodontic including:

- The diagnosis, assessment, and analysis of the maxillofacial orthodontic and orthopedic anomalies.
- The provision of the information regarding morphologic features and dimensions of the palatal, tooth inclination, and width of the alveolar bone for buccolingual movement of teeth.
- The evaluation of the pharyngeal airway space and soft tissue relationships.

- The construction conventional two and three dimensional cephalometric images, panoramic, lateral, submentovertex, and posteroanterior cephalometric images.
- The assessment of the relations of dentoskeletal and facial esthetics, and growth and development, features of the skull and air/soft tissue interfaces in high detail (109)(112)(114)(133)(140).

1.3.6.5 Applications in temporomandibular joint (TMJ) imaging:

The CBCT provides multiplanar and potentially 3D images for the position examination of the condyle in the fossa and for the analysis of bone morphologic features, joint space and dynamic function like panoramic and axial images, parasagittal and paracoronal transerial slices. These images can depict the features of TMJ disease, for example: Rheumatoid arthritis disease, ankylosis, developmental anomalies of the condyle, and degenerative joint disease (112)(133)(141)(142)(143)(144)(145).

1.3.6.6 Applications in periodontics:

The CBCT is not indicated as a routine method to evaluate periodontal bone support. However, limited volume and high-resolution of the CBCT may be indicated in selected cases of dehiscence, infrabony defects, furcation lesions and fenestration, where the clinical and conventional radiographic examinations do not provide the information needed for management (109)(114)(133)(146)(147).

1.3.6.7 Applications in forensic dentistry:

The CBCT can be applied in the field of forensic for predicting the sex and accurate dental and skeletal age estimation (109)(114)(133)(148). These application are to be discussed in this thesis.

In summary, Evaluation of the age and sex of the individual are significant factors that help identification of unknown skeletal remains, investigations of the criminal cases and determination of optimal time for orthodontic treatment (3)(20).

The chronologic age is an unreliable factor for evaluating a person's maturation status due to the variations in the time of the pubertal growth between individuals. However, the skeletal maturity is considered as the standard method to estimate sex and age (149).

In recent years, forensic practitioners have worked hardly to find a precise age and sex estimator by studying different skeletal age markers. Since the determination of a person's age from one bone is unreliable, it has become essential to develop techniques for age estimation from many different bones bearing age markers (15).

In previous studies, the evaluation of skeletal maturation was done on hand-wrist radiographs and lateral cephalograms. However, the lateral cephalograms are supported in clinical practices for orthodontic treatment as this type of radiograph is routinely taken in practice with lower exposure to radiation (41).

In addition, the maturation of a person can also be assessed by evaluating the dimensions and the fusion stages of cervical vertebral, the spheno-occipital synchondrosis, and hyoid bone.

On conventional radiographs, it is difficult to evaluate dimensions and the maturation stages of these bones in detail since the superimposition of adjacent structures and the 3D growths of a human body. So the third dimension cannot be seen on conventional skull radiographs (43)(76). With advances in the field of radiology; the CBCT allows the examination of non-accessible anatomical areas of head and neck in all three planes of space and the estimation of gender and age (41)(73).

To our knowledge, there are no published researchs that studied the correlation between hyoid bone, cervical vertebra, and spheno-occipital bone in regards to dimension and degree of their fusion and to estimate age and sex from CBCT images. It seems reasonable to investigate this correlation. If a correlation is confirmed, the closure status of spheno-occipital synchondrosis and hyoid bone maturation might be an additional resource that could be used to predict the skeletal maturation status and can be used as a means of age and sex estimation in cases of absent cervical vertebrae in a given set of images or bone remain.

The aims of this study were to assess:

- The intra and inter-examiner reliability.
- The mean chronological age at each stage over the lifespan.
- Gender difference, age-related changes in cervical vertebrae, hyoid, and spheno-occipital bone.

- Correlation between fusion stages, chronological age, and parameters derived from of spheno-occipital synchondrosis, cervical vertebrae, and hyoid bone.
- Correlation between spheno-occipital synchondrosis, cervical vertebra, and hyoid bone fusion stages.



2. MATERIALS AND METHODS

2.1 Radiographic material:

This study was planned as a retrospective cross-sectional study. A total of 1205 CBCT images were obtained for various clinical reasons; mainly for dental implant, oral surgery, tumor, impacted teeth, orthodontic treatment and others at the Department of Dentomaxillofacial Radiology, Faculty of Dentistry at the Yeditepe University between 2014 and 2019 years. These images were retrospectively evaluated and subjected to inclusion and exclusion criteria. The inclusion criteria are:

1. Being a Turkish citizen.
2. The CBCT images were taken from the archives of oral diagnosis and radiology.
3. Patients between 8-48 years of age.
4. The field of vision is included cervical vertebrae, hyoid bone, and spheno-occipital region.
5. No image artifacts.
6. High sharpness and good contrast of cone beam computed tomography image.
7. No a systemic disease that may affect general development such as hormonal disease.
8. No congenital or postnatal malformation or syndrome.
9. No trauma or surgical trauma in head and neck.
10. No pre-existing conditions potentially affecting vertebral development.

Whereas the exclusion criteria are:

1. Small FOV.
2. Image artifact.
3. Non Turkish patients.
4. Patient with age more than 48 years of age.
5. Have systemic disease, trauma, malformation or syndrom

Over all 1205 CBCT, 129 CBCT images were finally selected (78 female and 51 males) (Figure 2.1). The age of patients were between 8-48 years old, which was taken from electronic files in the database of the centers. The sample was divided into eight age groups; 8-12 years, 13-17 years, 18-22 years, 23-27 years, 28-32 years, 33-37 years, 38-42 years, and

43-48 years. For the saved CBCT images, a list with corresponding names and protocol numbers was made in an encrypted file for protection reasons and patient privacy. All procedures were done following the standards of the Ethics Committee of Clinical Research at Yeditepe University (Ref no: 925).

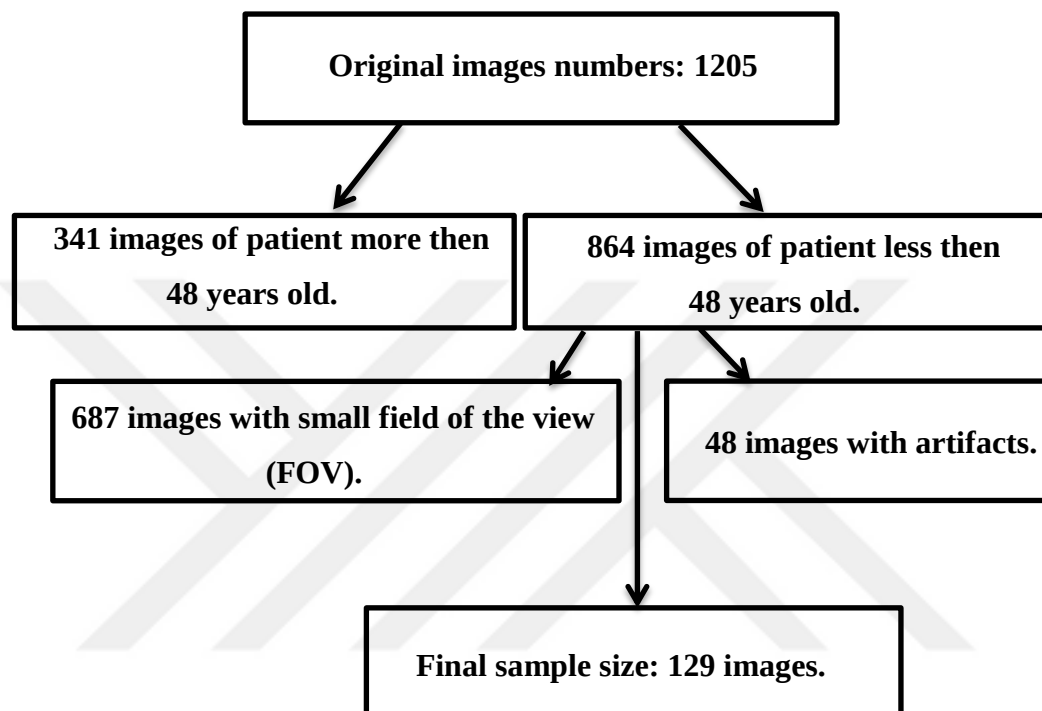


Figure 2. 1 Algorithm showing how the images are subjected to inclusion and exclusion criteria.

As regarding the imaging system, the images were taken using CBCT scanner unit with a flat panel detector (i-CAT model 17-19; Hatfield, Imaging Sciences International Inc, Pennsylvania, USA), which provided axial, coronal, and sagittal views through multiplanar reconstructions (Figure 2.2). The contrast and the brightness of the images were adjusted using the image processing tools in software to ensure an optimal view.

All images were taken using standard exposure parameters and patient positioning protocol: exposure parameters were followed the radiation protection standards, maintaining the “ALADA” principle; the tube current of 5 mA, the voltage of 120 kvp, 8.9 s scan time, 17 cm FOV, and 0.3 mm voxel size with high-resolution bone filter. The patients were exposed in the sitting position. The head-rest was used to adjust the head position with the occlusal

plane parallel to the floor of the room and the mid-sagittal plan aligned perpendicular to the horizontal plan. The CBCT images were evaluated and processed using a workstation computer unit with pre-installed software (InVivodental 5 version 5.2 Anatomage, 2010; USA). This software was used for measuring all parameters in CBCT images under standard conditions.



Figure 2 .2 CBCT scanner (i-CAT model 17-19; Hatfield, Imaging Sciences International Inc, Pennsylvania, USA).

The specific objective of this study is to analyze the metric and fusion stages of the cervical vertebrae, the hyoid bone, and the spheno-occipital synchondrosis in the adolescent and young adult patients using CBCT. The following parameters were evaluated in this study:

1. Cervical Vertebral Maturation Stags (CVMS).
2. Anterior Vertebral Body Height-second (AVBH2).
3. Posterior Vertebral Body Height-second (PVBH2).
4. Vertebral Body Width-second (VBW2).
5. Superior Vertebral Body Thickness-second (SVBT2).
6. Inferior Vertebral Body Thickness-second (IVBT2).
7. Vertebral Body Concavity Depth-second (VBCD2).
8. Anterior Vertebral Body Height-third (AVBH3).
9. Posterior Vertebral Body Height-third (PVBH3).
10. Vertebral Body Width-third (VBW3).
11. Superior Vertebral Body Thickness-third (SVBT3).
12. Inferior Vertebral Body Thickness-third (ISVBT3).
13. Vertebral Body Concavity Depth-third (VBCD3).
14. Anterior Vertebral Body Height-forth (AVBH4).
15. Posterior Vertebral Body Height-forth (PVBH4).
16. Vertebral Body Width-Forth (VBW4).
17. Superior Vertebral Body Thickness-forth (SVBT4).
18. Inferior Vertebral Body Thickness-forth (IVBT4).
19. Vertebral Body Concavity Depth-forth (VBCD4)
20. Hyoid Maturation Stage (HMS).
21. Maximal Hyoid Body Width (max HBW).
22. Minimal Hyoid Body Width (min HBW).
23. Hyoid Body Thickness (HBT).
24. Hyoid Body Depth (HBD).
25. Hyoid Body Height (HBH).
26. Spheno-Occipital Synchondrosis Stage (SOSS).
27. Basion to Sella length (BSL).

All CBCT images were assessed and processed in axial, coronal, sagittal, and cross-sectional to identify and measure the previously mentioned parameters as described in the following steps:

- **ICAT vision** software was turned on and the image of interest was selected according to the protocol number or the patient name on the list. Then, **CT** option was chosen and

Start Invivodental was clicked. Consequently, an external application in the form of **DICOM** file was opened.

- The **section** option was chosen; the head was adjusted to be in an upright position on axial, sagittal, and coronal plans (**Figure 2.3**).



Figure 2.3 The Section Window illustrating the three plans; axial, sagittal, and coronal sections, and the 3-D reconstructed image of the head in an upright position. Image obtained with i-CAT® Model 17-19; CBCT Imaging Unit: (InVivoDental5 Version 5.2 Anatomage, software): Dentomaxillofacial Radiology Department; Faculty of Dentistry- University of Yeditepe.

- The main objective of this process was to slowly drag one plan through one section (axial, sagittal, or coronal), and at the same time evaluate the same structure (cervical vertebrae, hyoid bone, and sphenoccipital region) on different planes and different sections.
- On the coronal sections, the horizontal plan was placed at the level of the connection between odontoid process and the body of second cervical vertebra and the vertical plan was slowly dragged by free hand movement of the cursor towards the midpoint of odontoid process, and simultaneously on the sagittal sections (**Figure 2.3**).
- On the sagittal section, the anterior and the posterior cervical vertebral body height, the superior and the inferior cervical vertebral body thickness (**Figure 2.4**), and vertebral body concavity depth (**Figure 2.5**) were measured in mm by means of “**distance measurement**” tool.

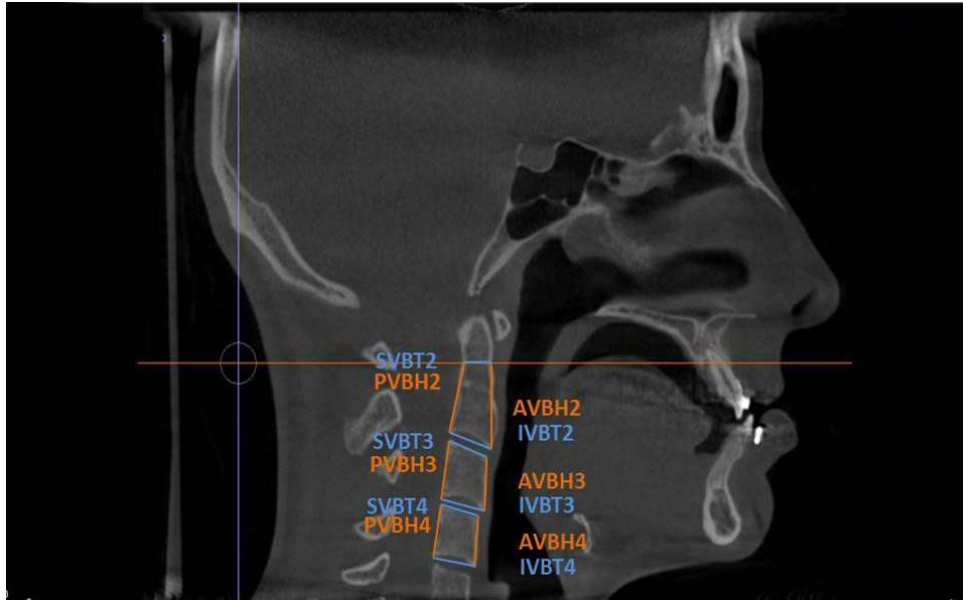


Figure 2.4 Mid-sagittal CBCT images demonstrating cervical vertebrae measurements. Anterior Vertebral Body Height-second (AVBH2), Posterior Vertebral Body Height-second (PVBH2), Superior Vertebral Body Thickness-second (SVBT2), Inferior Vertebral Body Thickness-second (IVBT2), Anterior Vertebral Body Height-third (AVBH3), Posterior Vertebral Body Height-third (PVBH3), Superior Vertebral Body Thickness-third (SVBT3), Inferior Vertebral Body Thickness-third (IVBT3), Anterior Vertebral Body Height-fourth (AVBH4), Posterior Vertebral Body Height-fourth (PVBH4), Superior Vertebral Body Thickness-fourth (SVBT4), Inferior Vertebral Body Thickness-fourth (IVBT4).

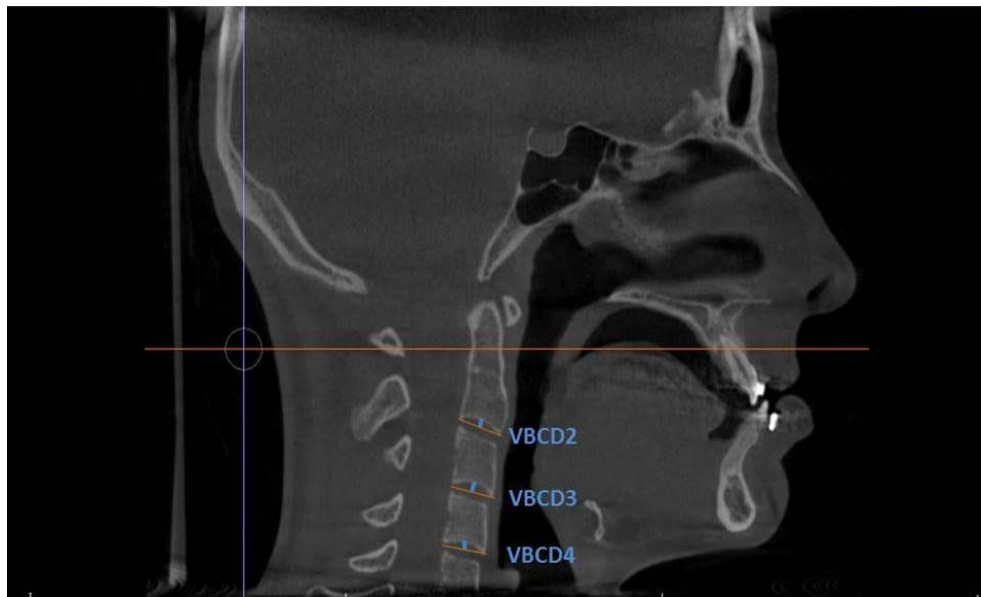


Figure 2.5 Mid-sagittal CBCT images demonstrating Vertebral Body Concavity Depth measurements. Vertebral Body Concavity Depth-second (VBCD2), Vertebral Body Concavity Depth-third (VBCD3), Vertebral Body Concavity Depth-fourth (VBCD4).

- On the axial section, cervical vertebral body width measured in mm by means of “**distance measurement**” tool (**Figure 2.6**). Double checking the parameters was achieved by clicking on **change layout** then axial **on light box** option, and **then 12 cross section** make.

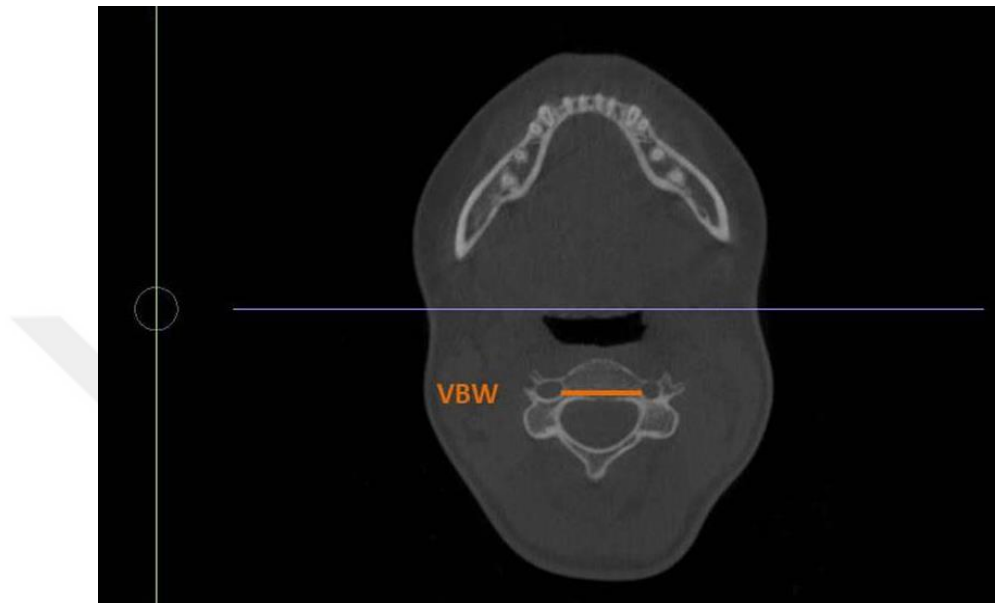


Figure 2. 6 Mid-axial CBCT images demonstrating Cervical Vertebral Body Width measurement (**VBW**)

- The following parameters were measured:
 - Anterior Vertebral Body Height (AVBH): Distance between the most upper anterior point and the most lower anterior point of cervical vertebra in sagittal section.
 - Posterior Vertebral Body Height (PVBH): Distance between the most upper posterior point and the most lower posterior point of cervical vertebra in sagittal section.
 - Superior Vertebral Body Thickness (SVBT): Distance between the most anterior and the most posterior point on upper margin of cervical vertebra in sagittal plane.
 - Inferior Vertebral Body Thickness (IVBT): Distance between the most anterior and the most posterior point on lower margin of cervical vertebra in sagittal plane.
 - Vervical Body Concavity Depth (VBCD): Distance from line connecting between the most lower anterior and the most lower posterior to deepest point on lower border of cervical vertebra body.
 - Vertebral Body Width (VBW): Distance between the most lateral points on axial plane.
 - Maximal Hyoid Body Width (max HBW): Maximal distance between lateral edges of hyoid body on mid axial plane.

- Minimal Hyoid Body Width (min HBW): Minimal distance between lateral edges of hyoid body on mid axial plane.
- Hyoid Body Thickness (HBT): Distance between the most anterior and the most posterior points of body on mid axial plane.
- Hyoid Body Height (HBH): Distance between the most upper and the most lower edge in mid sagittal plane.
- Hyoid Body Depth (HBD): Maximum depth of concavity on the posterior surface of the body in midline on axial plane.
- Basion to Sella length (BSL): Distance between sella to basion on mid sagittal plane.
- Cervical Vertebral Maturation Stages (CVMS) were evaluated on sagittal view, according to last version described by Baccetti et al. (45) who depended on two sets of variables to make stages as following:
 - The Presence or absence of concavity at the lower border of the body of cervical vertebral C3 and C4.
 - The shape of the body of cervical vertebral C3 and C4.

According to these two sets of variables, patients were divided into six stages of skeletal maturation, CVMS1 to CVMS6 (**Figure 2.7**). The cervical vertebral maturation stages (CVMS) are as follow:

CVMS1:

- All the lower borders of the three cervical vertebrae (C2 - C4) are flat.
- The superior borders of the C3 and C4 vertebral body are tapered from posterior to anterior (trapezoid in shape).

CVMS2:

- A concavity is present at the lower border of C2.
- The bodies of C3 and C4 are still trapezoidal in shape.

CVMS3:

- A concavity is present at the lower border of both C2 and C3.
- The bodies of C3 and C4 may be either trapezoidal or rectangular horizontal in shape.

CVMS4:

- Concavities are now present at the lower border of C2, C3 and C4.
- The bodies of both C3 and C4 are rectangular horizontal in shape.

CVMS 5:

- The concavities are still present at the lower border of C2, C3, and C4.
- At least one of the body of C3 or C4 is squared in shape; if not squared, the body of the other cervical vertebrae is still rectangular horizontal.

CVMS6:

- The concavities are still present at the lower borders of C2, C3, and C4.
- At least one of the body of C3 or C4 is rectangular vertical in shape; if not rectangular vertical, the body of the other cervical vertebrae is squared.

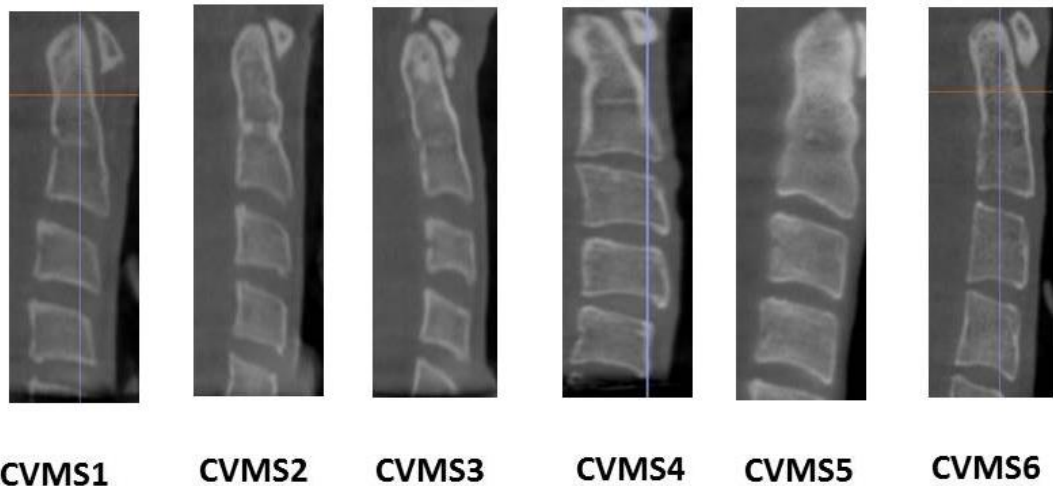


Figure 2. 7 Mid-sagittal CBCT images demonstrating Cervical Vertebrae Maturation Stages (CVMS).

- On the axial section, hyoid body width (**Figure 2.8**), depth (**Figure 2.9**) and thickness (**Figure 2.10**), were measured in mm by means of “**distance measurement**” tool. Double checking the parameters was achieved by clicking on **change layout** then axial **on light box** option, then 12 cross section make.
- On the sagittal section, hyoid body height was measured in mm by means of “**distance measurement**” tool (**Figure 2.11**).

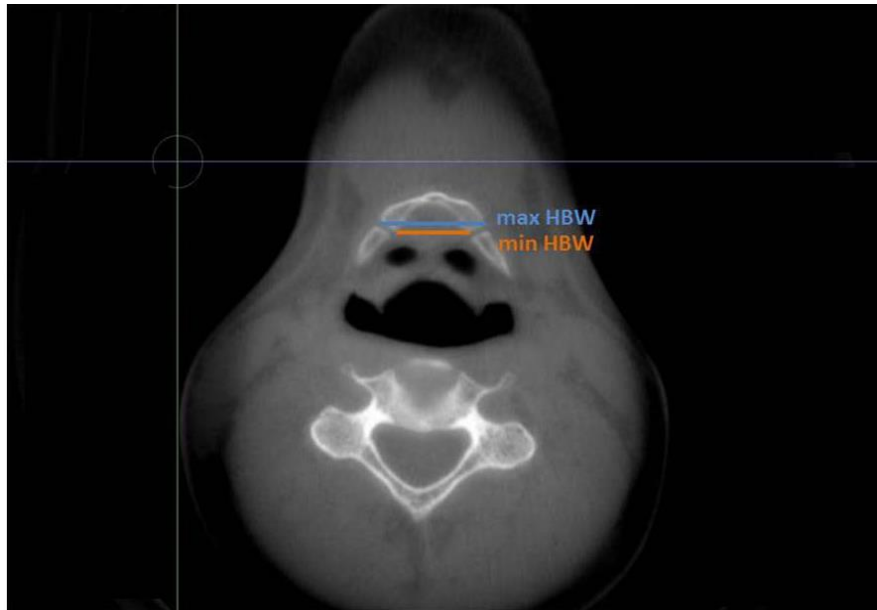


Figure 2.8 Mid-axial CBCT images demonstrating Hyoid Body Width measurements; maximal Hyoid Body Width (maxHBW) and minimal Hyoid Body Width (minHBW).

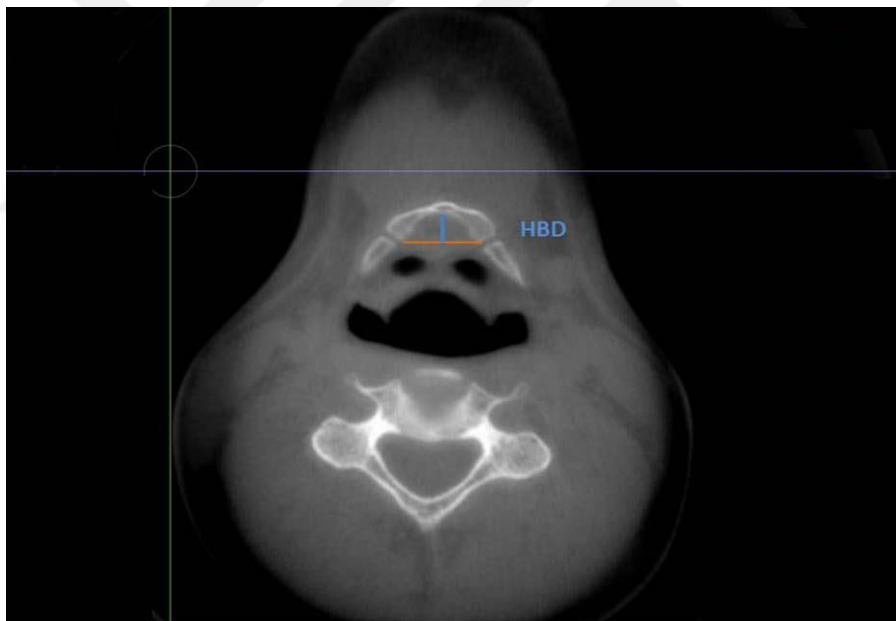


Figure 2.9 Mid-axial CBCT images demonstrating Hyoid Body Depth (HBD).



Figure 2.10 Mid-axial CBCT images demonstrating Hyoid Body Thickness (HBT).



Figure 2.11 Mid- sagittal CBCT images demonstrating Hyoid Body Height (HBH).

- The fusion stages of hyoid bone was evaluated on axial plane, according to last version described by Austin et al. (69) by measuring the distance between the greater cornua and the hyoid body on each side (**Figure 2.12**) as the following:

HMS0: In the axial plane, the distance between the nearest points of the hyoid body and greater cornu is greater than or equal to 2.5 mm.

HMS1: In the axial plane, the distance between the nearest points of the hyoid body and greater cornu is less than 2.5 mm.

HMS2: Part and non uniform fusion between the body and greater cornu has begun, but there are one or more gaps between the structures.

HMS3: No space between the hyoid body and greater cornu. A line of fusion may be or may be not visible in all 3 views (axial, sagittal, and coronal).

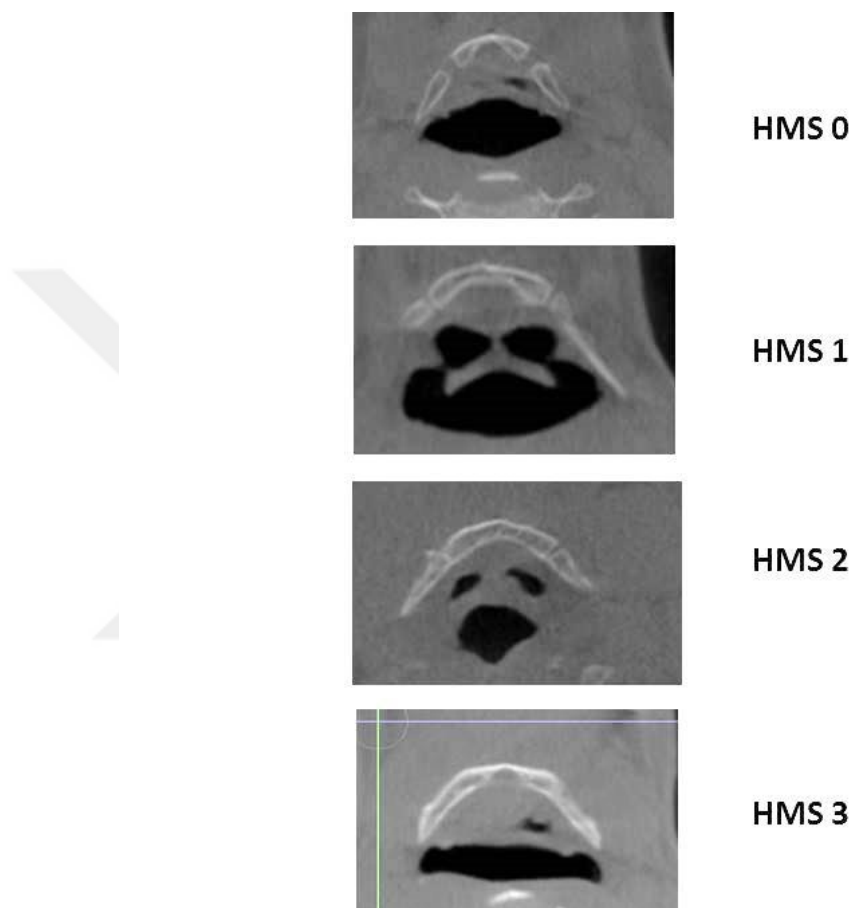


Figure 2 .12 Mid-axial CBCT images demonstrating Hyoid Maturation Stages (HMS).

- On the sagittal section Basion to Sella Length (BSL) were measured in mm by means of “**distance measurement**” tool (**Figure 2.13**).

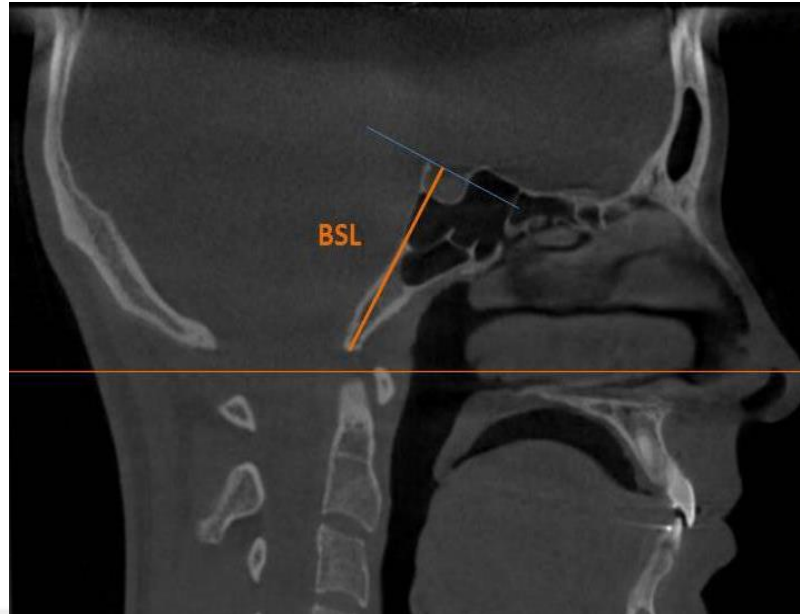


Figure 2. 13 Mid- sagittal CBCT images demonstrating Basion to Sella length (BSL).

- For assess of spheno-occipital synchondrosis stages (SOSS); on **section** option was select, the vertical plan was slowly dragged towards the midpoint of odontoid process on both the sagittal and axial section. The double checking the parameters stages was achieved by: the **arch section** option was selected and the cross section was constructed by clicking on **change layout** then **axial, panoramic, and 10 cross section** option. Following that, the central focal trough plan was slowly moved forewords and backwards by the scrolling button on the mouse through the axial sections at level of spheno-occipital and moving the cursor (vertical plan) very slowly and gradually from the right side to the left side (simultaneously slide the plan through the axial section and observe the structures on the sagittal section) to determine the spheno-occipital stages. The ossification status of the spheno-occipital synchondrosis was assessed using the five stages system developed by Powell and Brodie et al. (99) (**Figure 2.14**). The sphenooccipial stags are as follows:

SOSS1: The synchondrosis is completely open and unfused.

SOSS2: The superior border is fused, while the remainder of the fusion site is patent.

SOSS3: Half the length of the synchondrosis is closed.

SOSS4: Closure is essentially complete, but the site is still visible by way of a fusion scar.

SOSS5: The site is completely obliterated with the appearance of normal bone.

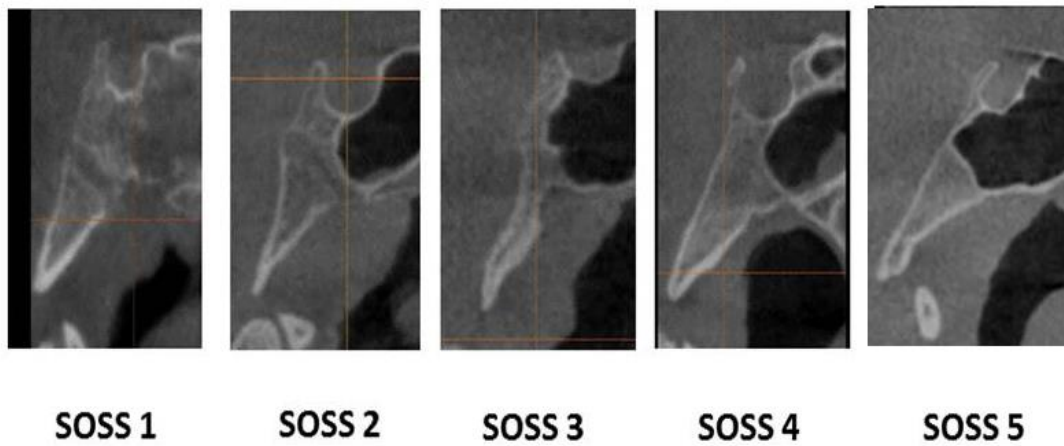


Figure 2 .14 Mid-axial CBCT images demonstrating Spheno-Occipital Synchondrosis Stages (SOSS)

Two dentomaxillofacial radiologists, independently, examined the CBCT images, following the previously mentioned procedure. For the intra-observer agreement analysis, the first radiologist measured all parameters in 129 images two times with a one month interval in between. For the inter-observer agreement analysis, 30 images randomly selected and examined two times, following the same procedure with a one month interval in between.

The images were evaluated in a quite darkened room with dual monitors (HP LP2475W, resolution 1920 x 1200). One viewing session was limited to 30 minutes. Care was taken to ensure that 24 hours elapsed between the specialist's viewing sessions. The contrast and brightness of the image were adjusted using image processing in software to ensure the optimal visualization

To ensure that the subjects were in or close to the circumpubertal period, different age ranges for the sexes were selected for this study. This is because of the difference in the onset of the circumpubertal periods between boys and girls.

2.2 Statistical analysis:

- Statistical analysis was performed using SPSS for windows (SPSS 25, Chicago, IL, USA). The measurements of the parameter were presented as continuous or categorical variables. The continuous variables were presented as mean, median and standard deviation values. While the categorical variables were presented as frequencies and percentages. The threshold for statistical significance was set at ($p < 0.05$).
- Kolmogorov-Smirnov test was used to evaluate if the measurements were normally distributed or not.

- Intraclass Correlation Coefficient (ICC) test was used to evaluate the intra-examiner and inter-examiner reliability of reading.
- Two independent sample t-test was used to compare the mean of parameters between sexes. Kruskal-Wallis test was used to compare the mean value of the parameters between age groups.
- The Pearson Chi-Square test was used to compare the frequencies of stages between sex and age groups. Also to assess the distribution of CVMS at each of HMS and SOSS.
- Mann-Whitney U test was used to compare the mean age of males and females between different stages. And it was used to compare the mean value of the continuous parameters between sex at different age groups and between sex at different stages.
- The Pearson's Correlation Coefficient test was used to assess the correlation between all parameters.
- Spearman's rho test was used to assess the correlation between age, CVMS, HMS, and SOSS.

3. RESULTS

- The sample in this study (n=129) consisted of 78 (60.5%) female images aged between 9 to 47 years with a mean age of 24.62 years, and 51 (39.5%) males aged between 8 to 48 years with a mean age of 24.70 years. The sex distribution between the age groups was presented in **Table 3.1**. The result of the Pearson Chi-Square showed that there was no significant difference in sex distribution between the age groups.
- The result of the Kolmogorov-Smirnov test showed that the measurements were normally distributed ($p > 0.05$).
- The intra-observers' reliability was tested for the first observer. The reliability ranged between 0.90-0.99 for 129 images indicating excellent reliability (95% confidence interval).
- The intra-observers' reliability was tested for the second observer. The reliability ranged between 0.817-1.000 for the 30 images indicating excellent reliability (95% confidence interval).
- As regarding the inter-observers' agreement analysis, the reliability ranged between 0.91-1.00 for the same 30 images indicating excellent reliability.

Table 3 .1 The age groups and sexes distribution.

Age Group	Female	Male	Total	p-value
8-12	8 (53.3%)	7 (46.7%)	15 (100.0%)	0.95
13-17	11 (64.7%)	6 (35.3%)	17 (100.0%)	
18-22	14 (60.9%)	9 (39.1%)	23 (100.0%)	
23-27	18 (66.7%)	9 (33.3%)	27 (100.0%)	
28-32	10 (55.6%)	8 (44.4%)	18 (100.0%)	
33-37	10 (62.5%)	6 (37.5%)	16 (100.0%)	
38-42	3 (42.9%)	4 (57.1%)	7 (100.0%)	
43-48	4 (66.7%)	2 (33.3%)	6 (100.0%)	
Total	78 (60.5%)	51 (39.5%)	129 (100.0%)	

Pearson Chi-Square test $*p \leq 0.05$

3.1 Results for cervical vertebral maturation stages (CVMS) and parameters:

- In consideration to the mean age, standard deviation, and p-value of females and males at different cervical vertebral maturation stages, the result of the Mann-Whitney U test showed that there were no significant differences between the mean age of males and females at different stages ($p > 0.05$) (**Table 3.2**).

Table 3.2 The mean age, standard deviation (SD), and P -value of females and males at different cervical vertebral maturation stages (CVMS).

Stages	Sex	N	Mean age $\pm$ SD	P- value
CVMS1	F	3	9.33 $\pm$.577	0.71
	M	6	9.33 $\pm$ 1.50	
	Total	9	9.33 $\pm$ 1.22	
CVMS2	M	3	12.33 $\pm$ 1.15	-
	Total	3	12.33 $\pm$ 1.15	
CVMS3	F	3	19 $\pm$ 14.00	1
	M	1	19 $\pm$ 1.00	
	Total	4	17.50 $\pm$ 11.81	
CVMS4	F	8	22.87 $\pm$ 11.90	0.60
	M	9	22.88 $\pm$ 7.63	
	Total	17	22.88 $\pm$ 9.55	
CVMS5	F	40	24.80 $\pm$ 9.20	0.10
	M	16	24.43 $\pm$ 7.89	
	Total	56	26.69 $\pm$ 9.28	
CVMS6	F	24	27.54 $\pm$ 7.107	0.85
	M	16	27.81 $\pm$ 7.721	
	Total	40	27.65 $\pm$ 7.262	

Mann-Whitney U test * $p \leq 0.05$

- In consideration to the frequency and percentage of CVMS in different age groups, the result of the Pearson Chi-Square test showed that there was a significant difference between the age groups regarding the distribution of CVMS in both males ($p=0.00$) and females ($p=0.00$) (**Table 3.3**).

Table 3.3 The frequency and percentage of cervical vertebral maturation stages (CVMS) in different age groups.

Stages		8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	TOTAL
CVMS1	F	3(37.5%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	3(3.8%)
	M	6(85.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	6(11.8%)
CVMS2	M	1(14.3%)	2(3.33%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	3(5.9)
CVMS3	F	1(12.5%)	1(9.1%)	0(0.0%)	0(0.0%)	0(0.0%)	1(10%)	0(0.0%)	0(0.0%)	3(3.8%)
	M	0(0.0%)	1(16.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(2%)
CVMS4	F	2(25.0%)	2(18.2%)	0(0.0%)	2(11.1%)	0(0.0%)	1(10%)	0(0.0%)	1(25%)	8(10.3%)
	M	0(0.0%)	3(50%)	2(22.2%)	2(22.2%)	1(12.5%)	0(0.0%)	1(25%)	0(0.0%)	9(17.6%)
CVMS5	F	2(25%)	8(72.7%)	9(64.3%)	8(44.4%)	4(40%)	6(60%)	1(33.3%)	2(50%)	40(51.3%)
	M	0(0.0%)	0(0.0%)	3(33.3%)	3(33.3%)	2(25%)	4(66.7%)	3(75%)	1(50%)	16(31.4%)
CVMS6	F	0(0.0%)	0(0.0%)	5(35.7%)	8(44.4%)	6(60%)	2(20%)	2(66.7%)	1(25%)	24(30%)
	M	0(0.0%)	0(0.0%)	4(44.4%)	4(44.4%)	5(62.5%)	2(33.3%)	0(0.0%)	1(50%)	16(31.4%)
Total	F	8(100%)	11(100%)	14(100%)	18(100%)	10(100%)	10(100%)	3(100%)	4(100%)	78(100.0%)
	M	7(100%)	6(100%)	9(100%)	9(100%)	8(100%)	6(100%)	4(100%)	2(100%)	51(100.0%)

Pearson Chi-Square test * $p \leq 0.05$

- In consideration to the frequency, percentage, and p-value of CVMS for both sexes, the result of the Pearson Chi-Square test showed that there was a significant difference between the sexes regarding the distribution of CVMS ($p=0.03$) (**Table 3.4**).

Table 3.4 The frequency, percentage, and p-value of cervical vertebral maturation stags (CVMS) for both sexes.

Stages	Females	Males	Total	p- value
CVMS1	3(33.3%)	6(66.7%)	9(100%)	0.03
CVMS2	0(0%)	3(100%)	3(100%)	
CVMS3	3(75 %)	1(25%)	4(100%)	
CVMS4	8(47.1%)	9(52.9%)	17(100%)	
CVMS5	40(71.4%)	16(28.6%)	56(100%)	
CVMS6	24(60%)	16(40%)	40(100%)	
TOTAL	78(60.5%)	51(39.5%)	129(100%)	

Pearson Chi-Square test * $p \leq 0.05$

- In consideration to the mean value and standard deviation of all parameters in different age groups, the mean value of all parameters increased with age in both sexes. In regards to female and age groups; the result of the Kruskal-Wallis test showed that there were significant differences between age groups in terms of the mean value of all parameters ($p < 0.05$) except for the mean value of AVBH2, VBW2, VBW3, VBCD3, VBCD4, BSL, HBT, and HBH. In regards to male and age groups; the Kruskal wallis test showed that there were significant differences between age groups in terms of the mean value of AVBH2, PVBH2, VBCD2, AVBH3, PVBH3, VBCD3, AVBH4, PVBH4, VBCD4, maxHBW, minHBW, and HBD ($p < 0.05$) (Table 3.5, 3.6, 3.7).

In consideration to the six difference among the different age groups:

In the 8-12 age group; there were significant differences between males and females regarding the mean value of the following parameters: SVBT2, VBW2, IVBT3, VBW3, VBCD3, and VBW4 ($p < 0.05$) (Table 3.5, 3.6, 3.7).

In the 13-17 age group; there were significant differences between males and females regarding the mean value of the following parameters: IVBT3 and SVBT4 ($p < 0.05$) (Table 3.5).

In the 18-22 age group; there were significant differences between males and females regarding the mean value of the following parameters AVBH2, PVBH2, IVBT2, PVBH3, IVBT3, SVBT4, IVBT4, VBW4, BSL, max HBW, and HBH ($p < 0.05$) (Table 3.5, 3.6, 3.7).

In the 23-27 age group; there were significant differences between males and females regarding the mean value of the following parameters: PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, VBCD4, BSL, maxHBW, minHBW, HBT, HBH, and HBD ($p<0.05$) (**Table 3.5, 3.6, 3.7**).

In the 28-32 age group: There were significant differences between males and females regarding the mean value of the following parameters: PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH4, PVBH4, SVBT4, IVBT4, maxHBW, and minHBW ($p<0.05$) (**Table 3.5, 3.6, 3.7**).

In the 33-37 age group: There were significant differences between males and females regarding the mean value of the following parameters: PVBH2, SVBT2, AVBH3, PVBH3, VBW3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, BSL, maxHBW, minHBW, and HBD ($p<0.05$) (**Table 3.5, 3.6, 3.7**).

In the 38-48 age group: There were no significant differences regarding the mean value of all parameters between males and females for all age groups($p>0.05$) (**Table 3.5, 3.6, 3.7**).

Table 3.5 The mean value and standard deviation (SD) of all cervical vertebra parameters in different age groups.

Parameters			8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	p-value
AVBH2	M	Mean	18.50±2.22	20.46±1.57	22.75±2.47	22.66±1.21	23.34±2.58	23.36±1.65	22.55±2.13	23.27±0.46	0.00**
		Median	18.01	20.50	22.90	22.65	22.37	23.54	23.06	23.27	
	F	Mean	18.30±2.81	21.476±2.22	20.67±1.92	21.13±2.18	21.44±1.14	21.90±1.83	21.26±2.20	22.19±0.63	0.09
		Median	19.22	21.9100	19.98	21.13	21.44	21.98	21.39	21.90	
	p-value	1	0.35	0.04*	0.07	0.08	0.14	0.40	0.26		
PVBH2	M	Mean	16.34±2.03	17.29±1.30	19.19±2.21	19.68±1.95	21.02±1.52	19.54±1.63	19.92±0.83	20.68±1.13	0.00**
		Median	17.04	16.99	19.26	19.65	21.53	20.03	19.73	20.68	
	F	Mean	14.88±2.08	18.02±2.29	18.06±1.20	17.83±1.81	18.26±1.50	17.65±1.67	18.47±1.07	17.83±0.99	0.04**
		Median	14.94	18.16	18.08	17.75	18.09	18.08	18.91	17.68	
	p-value	0.09	0.73	0.03*	0.02*	0.00*	0.01*	0.11	0.13		
SVBT2	M	Mean	10.04±1.22	10.87±0.77	10.28±1.05	10.91±0.67	11.12±0.64	10.80±0.70	11.19±0.61	11.50±1.99	0.27
		Median	9.42	10.92	10.26	10.76	10.93	10.91	11.17	11.50	
	F	Mean	8.77±0.65	9.59±2.30	9.97±0.87	10.10±0.77	9.89±1.03	9.59±0.80	10.14±1.59	10.14±0.22	0.04**
		Median	8.65	9.89	9.87	10.26	9.99	9.31	10.33	10.05	
	p-value	0.02*	0.06	0.51	0.02*	0.01 *	0.00	0.40	0.53		
IVBT2	M	Mean	12.25±1.80	13.33±1.33	14.05±2.29	13.68±1.38	13.92±1.38	13.32±1.59	14.15±1.78	13.81±0.79	0.69
		Median	12.20	13.3200	13.31	13.94	14.16	13.08	14.48	13.81	
	F	Mean	10.27±1	12.4±1.19	12±1.25	12.32±1.07	12.30±0.77	12.06±1.92	12.71±1.51	12.88±0.71	0.01**
		Median	10.20	12.23	12.11	12.44	12.26	12.34	12.91	12.97	
	p-value	0.05	0.21	0.02*	0.02*	0.02*	0.09	0.40	0.26		
VBW2	M	Mean	28.96±2.87	26.12±3.91	29.31±2.39	29.56±4.25	29.03±4.83	32.85±3.57	34.41±3.11	29.68±2.22	0.05
		Median	30.12	25.73	29.74	30.13	30.12	32.45	34.94	29.68	
	F	Mean	24.79±3.15	28.68±3.94	27.63±2.47	28.91±2.97	27.95±3.07	30.05±5	29.90±5.42	26.67±3.32	0.20
		Median	24.76	29.00	27.59	28.56	28.19	30.22	27.44	25.88	
	p-value	0.02*	0.30	0.09	0.40	0.57	0.31	0.40	0.53		
VBCD2	M	Mean	10±0.27	1.73±0.79	1.87±0.64	1.70±0.58	1.58±0.49	1.49±0.58	2±0.49	2.08±0.41	0.00**
		Median	0.00	1.5900	1.56	1.60	1.54	1.50	1.77	2.08	
	F	Mean	0.89±0.80	1.86±0.48	1.45±0.40	1.65±0.35	1.44±0.25	1.56±0.51	1.40±0.10	1.86±0.37	0.04**
		Median	0.99	1.78	1.42	1.66	1.41	1.43	1.42	1.85	
	p-value	0.07	0.59	0.10	0.98	0.82	0.79	0.05	0.53		
AVBH3	M	Mean	8.20±2.33	10.92±2.75	13.51±1.96	14.45±1.20	14.83±1.02	14.79±0.99	14.52±0.73	15.29±1.95	0.00**
		Median	7.82	11.18	13.47	14.86	14.77	14.79	14.52	15.29	
	F	Mean	83.0±2.57	12.17±1.22	12.46±0.84	13.10±1.14	13.42±0.90	12.91±1.34	13.40±1.23	12.66±0.34	0.00**
		Median	8.65	12.61	12.42	12.94	13.28	12.62	13.51	12.69	
	p-value	0.95	0.73	0.07	0.01*	0.00*	0.1*	0.22	0.13		
PVBH3	M	Mean	8.90±2.74	11.28±2.15	13.93±1.93	14.78±1.20	15.04±1.17	14.61±1.06	14.61±0.64	15.29±1.95	0.00**
		Median	7.6200	11.42	13.47	14.89	15.04	14.73	14.41	15.29	
	F	Mean	9.18±2.15	12.52±1.62	12.46±0.84	13.10±1.26	13.65±0.85	13.12±1.35	13.40±0.50	12.75±0.40	0.00**
		Median	9.08	12.52	12.46	12.48	13.56	12.77	13.58	12.75	
	p-value	0.39	0.40	0.01*	0.00*	0.00*	0.02*	0.05	0.13		
SVBT3	M	Mean	11.16±2.45	13.38±2.02	12.63±1.69	13.14±1.152	13.68±1.98	13.16±1.68	14.39±0.58	13.89±0.12	0.17
		Median	12.05	14.26	12.01	13.11	14.37	13.05	14.24	13.89	
	F	Mean	10.04±1.36	12.21±1.32	11.40±1	11.97±1.16	11.56±1.04	12.16±1.55	12.24±1.46	12.32±1.03	0.04**
		Median	10.10	11.84	11.14	12.08	11.39	11.62	12.14	12.69	
	p-value	0.28	0.21	0.07	0.02*	0.02*	0.11	0.05	0.13		
IVBT3	M	Mean	12.29±1.56	14.48±1.17	13.58±1.82	14.40±0.99	14.31±1.86	14.53±1.83	15.38±1.50	14.40±0.84	0.17
		Median	12.21	14.54	14.02	14.27	14.32	14.74	15.31	14.40	
	F	Mean	10.75±1.10	12.91±1.42	12.10±0.68	12.90±0.96	12.98±0.88	13.28±1.86	12.86±1.27	13.09±1.04	0.00**
		Median	10.84	12.63	12.15	12.95	13.14	13.21	13.02	12.96	
	p-value	0.02*	0.02*	0.04*	0.00*	0.04*	0.11	0.11	0.26		
VBW3	M	Mean	24.42±1.42	24.63±2.12	24.42±2.25	25.24±1.85	25.37±1.17	25.81±1.53	26.20±1.43	25.95±0.17	0.58
		Median	24.02	24.93	24.68	24.31	25.15	25.59	25.88	25.95	
	F	Mean	21.68±1.22	24.12±2.49	23.01±0.812	23.74±1.63	23.64±0.63	22.95±1.87	23.84±0.95	22.94±0.44	0.11
		Median	21.59	24.14	23.03	23.72	23.60	22.77	24.00	22.90	
	p-value	0.00*	0.40	0.14	0.06	0.03*	0.00*	0.05	0.13		
VBCD3	M	Mean	00±0.00*	1.29±0.93	1.84±0.45	1.79±0.41	1.67±0.34	2.29±0.74	1.55±0.41	2.16±0.34	0.00**
		Median	0.00	1.36	2.02	1.80	1.66	2.23	1.50	2.16	
	F	Mean	1.11±1	1.57±0.48	1.79±0.39	1.87±0.45	1.72±0.37	1.96±0.88	1.45±0.78	1.58±0.49	0.37
		Median	1.3150	1.60	1.86	1.99	1.72	1.82	1.04	1.40	
	p-value	0.04*	0.35	0.60	0.32	0.96	0.11	0.62	0.26		

Parameters			8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	p-value
AVBH4	M	Mean	7.35±1.43	10.17±1.77	12.59±1.11	14.10±1.49	14.81±1.30	13.91±1.36	13.81±0.80	15.04±0.60	0.00**
		Median	7.32	9.93	12.39	14.11	15.08	14.39	13.65	15.04	
	F	Mean	7.91±2.15	11.67±1.52	12.05±0.97	12.49±1.46	12.96±1.08	11.98±1.29	12.76±0.48	12.28±1.06	0.00**
		Median	7.79	12.23	12.13	12.30	13.02	11.84	13.35	12.33	
		p-value	0.69	0.12	0.30	0.01*	0.00*	0.03*	0.62	0.13	
PVBH4	M	Mean	8.85±2.22	11.17±2.13	13.14±1.03	13.91±1.04	14.69±1.25	14.27±0.92	13.60±1.06	14.78±0.50	0.00**
		Median	8.01	10.96	13.01	13.66	15.00	14.44	13.53	14.78	
	F	Mean	8.85±2.06	12.39±1.34	12.30±0.86	12.61±1.20	13.11±0	12.30±1.44	13.05±1.51	12.51±1.02	0.00**
		Median	8.90	12.61	12.47	12.44	13.13	12.22	13.83	12.85	
		p-value	1	0.35	0.07	0.00*	0.00*	0.00*	0.60	0.13	
SVBT4	M	Mean	11.92±1.56	13.74±1.47	13.16±1.36	13.934±1.0	13.88±1.79	14.54±1.53	15.09±2.58	14.85±0.52	0.09
		Median	12.28	13.30	13.13	13.67	13.50	15.01	14.28	14.8500	
	F	Mean	10.39±1.43	12.24±1.31	11.36±0.79	12.35±1.20	12.11±0.89	12.75±2.21	12.45±1.21	12.60±0.60	0.10**
		Median	10.11	12.02	11.05	12.30	12.20	12.13	12.08	12.53	
		p-value	0.07	0.04*	0.00*	0.00*	0.034	0.03*	0.11	0.13	
IV4BT4	M	Mean	12.55±2.22	14.16±1.47	13.47±1.55	15.08±1.07	14.56±1.56	14.29±0.87	14.76±2.00	13.63±2.35	0.18
		Median	12.23	14.12	13.11	15.31	14.85	14.24	15.50	13.63	
	F	Mean	10.83±1.06	12.97±1.67	11.89±0.91	12.81±1.08	12.95±0.81	13.11±2.07	13.06±1.21	13.68±0.94	0.00**
		Median	10.41	12.82	12.07	12.73	12.73	12.99	13.00	13.40	
		p-value	0.09	0.14	0.00*	0.00*	0.02*	0.04*	0.40	1	
VBW4	M	Mean	25.16±1.30	24.98±1.62	25.53±1.70	26.07±1.28	25.46±0.98	27.01±2.62	26.46±2.44	28.83±0.45	0.27
		Median	25.13	24.59	25.81	26.02	25.5	26.08	26.25	28.83	
	F	Mean	22.38±1.15	24.68±1.95	23.56±1.26	23.76±1.52	24.81±1.02	23.51±2.12	24.43±1.48	23.02±0.95	0.02**
		Median	22.73	24.00	23.38	23.52	25.02	23.35	24.71	23.03	
		p-value	0.00*	0.73	0.01*	0.00*	0.31	0.00*	0.62	0.13	
VBCD4	M	Mean	0.00±0.00	0.75±0.86	1.64±0.50	1.95±0.42	1.57±0.27	1.56±0.27	2.02±1.07	2.32±0.65	0.00**
		Median	0.00	0.64	1.84	1.95	1.48	1.51	1.64	2.32	
	F	Mean	1±1.27	1.20±0.53	1.35±0.40	1.54±0.37	1.57±0.51	1.45±1.01	1.34±0.33	1.49±0.37	0.37
		Median	0.46	1.25	1.44	1.45	1.46	1.17	1.25	1.46	
		p-value	0.12	0.35	0.12	0.01*	0.89	0.18	0.62	0.26	

Kruskal-Wallis test: *the mean value of parameters were significantly different from the same age group of the opposite sex. ** The mean value of parameters were significantly different between age groups of the same sex
**p≤0.05*

Table 3.6 The mean value and standard deviation (SD) of BSL in different age groups.

Parameters			8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	p-value
BSL	M	Mean	43.10±4.85	43.68±2.76	46.68±4.42	46.54±2.44	45.30±2.67	46.95±2.66	48.40±2.29	42.28±5.25	0.16
		Median	42.43	43.42	46.96	45.88	46.15	47.14	49.30	42.28	
	F	Mean	39.51±3.63	43.46±3.04	41.78±3.38	42.77±3.66	43.03±2.63	43.01±3.38	43.63±1.26	44.18±2.59	0.23
		Median	40.50	43.52	41.92	42.90	43.00	42.78	43.38	44.00	
		p-value	0.12	0.80	0.01*	0.01*	0.06	0.03*	0.05	0.80	

Kruskal-Wallis test: *the mean value of parameters were significantly different from the same age group of the opposite sex. ** The mean value of parameters were significantly different between age groups of the same sex
**p≤0.05*

Table 3.7 The mean value and standard deviation (SD) of all hyoid bone parameters in different age groups.

Parameters			8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	p-value
maxHBW	M	Mean	17.10±3.54	18.70±1.93	21.44±3.20	24.79±1.03	23.90±3.11	25.48±2.77	24.27±3.55	24.36±0.48	0.00**
		Median	16.51	17.96	21.31	24.69	24.35	26.23	23.87	24.36	
	F	Mean	15.49±0.83	18.06±2.23	18.95±1.51	21.16±3.33	20.58±1.89	21.39±2.46	21.20±.85	20.48±1.13	0.00**
		Median	15.45	17.71	18.86	20.03	19.63	20.59	21.18	20.26	
	p-value	0.23	0.59	0.03*	0.00*	0.01*	0.03*	0.22	0.13		
minHBW	M	Mean	12.86±2.34	14.831.80	17.37±2.72	19.47±1.58	19. ±2.60	19.95±2.23	18.23±2.95	19.67±1.32	0.00**
		Median	13.46	14.52	17.06	19.35	18.94	20.50	18.21	19.67	
	F	Mean	12.07±.92	14.02±1.89	15.25±1.85	16.81±3	16.46±1.56	16.48±2.11	16.51±0.27	16.37±.90	0.00**
		Median	12.24	14.25	15.33	16.15	16.11	15.79	16.38	16.08	
	p-value	0.39	0.52	0.07	0.00*	0.03*	0.01*	1	0.13		
HBT	M	Mean	3.28±1.22	3.55±.962	4.83±1.58	5.99±2.49	4.35±1.48	4.18±1.58	4.83±1.57	4.68±0.28	0.10
		Median	3.08	3.14	5.33	5.50	4.01	3.59	4.16	4.68	
	F	Mean	2.52±0.64	2.83±1.39	3.86±1.51	3.77±1.64	3.34±1.57	3.70±1.81	3.54±0.39	3.25±1.41	0.27
		Median	2.39	2.51	3.56	3.42	2.69	3.15	3.36	3.32	
	p-value	0.33	0.12	0.30	0.01*	0.08	0.42	0.11	0.26		
HBH	M	Mean	8.88±0.83	10.46±1.74	10.83±.99	10.73±.77	10.94±1.70	10.31±1.22	10.14±1.91	9.77±0.37	0.10
		Median	8.55	10.25	11.00	10.89	11.04	10.51	11.07	9.77	
	F	Mean	8.37±0.68	9.88±2.12	9.15±1.52	8.98±1.09	9.40±1.50	9.28±1.34	8.39±2.21	9.42±1.07	0.52
		Median	8.32	9.41	9.0150	9.29	9.68	9.33	7.41	9.59	
	p-value	0.53	0.40	0.01*	0.00*	0.10	0.18	0.22	1		
HBD	M	Mean	2.87±1.17	4.09±1.08	5.08±1.68	6.71±1.30	6.37±2.28	7.16±1.35	7.66±1.90	5.26±1.20	0.00**
		Median	2.50	3.81	4.12	6.34	6.38	7.01	7.64	5.26	
	F	Mean	2.51±1.09	4.45±1.31	4.87±1.55	5.34±1.75	5.35±0.92	5.21±1.13	3.42±1.44	5.37±1.52	0.00**
		Median	2.39	4.29	5.23	4.94	5.21	4.94	3.06	5.11	4.77
	p-value	0.69	0.46	0.64	0.00*	0.17	0.01*	0.05	1		

Kruskal-Wallis test: *the mean value of parameters were significantly different from the same age group of the opposite sex. ** The mean value of parameters were significantly different between age groups of the same sex
* $p \leq 0.05$

- In consideration to the mean, standard deviation, and p-values of all parameters for both sexes, the result of an independent samples t-test showed that there were significant differences between females and males regarding the mean value of all parameters ($p < 0.05$), except for VBCD2, AVBH3, VBCD3, AVBH4, VBCD4, SOSS, and HMS. ($p > 0.05$) (**Table 3.8**).

Table 3.8 The mean, standard deviation (SD), and P-value of all parameters in both sexes.

Parameters	Sex	N	Mean± SD	P-Value
AVBH2	F	78	21 ±2.18	0.01*
	M	51	22.05 ± 2.51	
PVBH2	F	78	17.65 ±1.90	0.00*
	M	51	19.10 ±2.23	
SVBT2	F	78	9.78 ±1.18	0.00*
	M	51	10.74 ±0.93	
IVBT2	F	78	12.08 ±1.34	0.00*
	M	51	13.54 ±1.67	
VBW2	F	78	28.17 ±3.63	0.02*
	M	51	29.72 ±4.03	
VBCD2	F	78	1.53 ±0.50	0.87
	M	51	1.51 ±0.79	
AVBH3	F	78	12.34 ±1.96	0.05
	M	51	13.15 ±2.84	
PVBH3	F	78	12.57 ±1.73	0.02*
	M	51	13.44 ±2.69	
SVBT3	F	78	11.70 ±1.33	0.00*
	M	51	13.02 ±1.85	
IVBT3	F	78	12.60 ±1.33	0.00*
	M	51	14.05 ±1.67	
VBW3	F	78	23.30 ±1.69	0.00*
	M	51	25.10 ±1.72	
VBCD3	F	78	1.70 ±0.62	0.18
	M	51	1.53 ±0.82	
AVBH4	F	78	11.82 ±1.98	0.08
	M	51	12.55 ±2.81	
PVBH4	F	78	12.17 ±1.69	0.03*
	M	51	12.93 ±2.35	
SVBT4	F	78	11.99 ±1.43	0.00*
	M	51	13.69 ±1.69	
IVBT4	F	78	12.58 ±1.44	0.00*
	M	51	14.08 ±1.68	
VBW4	F	78	23.80 ±1.63	0.00*
	M	51	25.87 ±1.77	
VBCD4	F	78	1.38 ±0.65	0.90
	M	51	1.40 ±0.83	
BSL	F	78	42.53 ±3.34	0.00*
	M	51	45.59 ±3.63	
CVMS	F	78	4.97 ±1.09	0.03*
	M	51	4.45 ±1.65	
SOSS	F	78	4.05 ±1.00	0.14
	M	51	3.76±1.20	
HMS	F	78	0.97 ±0.78	0.45
	M	51	1.09 ±1.06	
maxHBW	F	78	19.67 ±2.85	0.00*
	M	51	22.31 ±3.91	
minHBW	F	78	15.53 ±2.49	0.00*
	M	51	17.54 ±3.23	
HBT	F	78	3.42 ±1.49	0.00*
	M	51	4.51 ±1.77	
HBH	F	78	9.17 ±1.45	0.00*
	M	51	10.36 ±1.36	
HBD	F	78	4.75 ±1.61	0.01*
	M	51	5.60 ±2.11	

Independent samples t-test: *the mean value of parameters were significantly different between sex

* $p \leq 0.05$

- In consideration to the mean value and standard deviation of all cervical vertebrae parameters at the six stages in males and females, the result of Mann-Whitney U test showed that:

In regards to CVMS 1, there were significant differences between males and females regarding the mean value of AVBH2, PVBH2, SVBT2, VBW3, and VBW4 ($p < 0.05$).

In regards to CVMS 2 and CVMS 3, there were no significant differences between males and females regarding the mean value of all cervical vertebral parameters ($p > 0.05$).

In regards to CVMS4, there were significant differences between males and females regarding the mean value of SVBT2, PVBH3, IVBT3, PVBH4, SVBT4, and HBH ($p < 0.05$).

In regards to CVMS5 and CVMS 6, there were significant differences between males and females regarding the mean value of AVBH2, PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, and VBCD4 ($p < 0.05$) (Table 3.9).

Table 3.9 The mean value and standard deviation (SD) of all cervical vertebra parameters at all Cervical Vertebral Maturation Stages (CVMS) in both sexes.

Parameters	Sex		CVMS1	CVMS2	CVMS3	CVMS4	CVMS5	CVMS6
AVBH2	F	Mean± SD	15.18±1.45		20.55±1.24	21.52±3.26	21.05±1.48	21.54±1.94
		Median	14.75		19.91	21.50	21.27	21.81
	M	Mean± SD	18.42±2.42	18.89±0.50	21.27±1.07	22.93±1.85	23.11±2.01	22.69±1.83
		Median	16.91	19.02	20.59	22.00	21.53	21.94
	p-value		0.04*		1	0.16	0.00*	0.16
PVBH2	F	Mean± SD	12.78±0.87		15.94±2.70	18.09±2.52	17.69±1.34	18.25±1.58
		Median	13.03		15.08	17.00	18.04	18.08
	M	Mean± SD	16.06±2.08	16.82±1.26	18.36±2.70	19.14±1.84	19.30±2.24	20.50±1.12
		Median	16.11	17.01	18.36	19.09	19.57	20.12
	p-value		0.02*		1	0.20	0.00*	0.00*
SVBT2	F	Mean± SD	8.44±0.28		9.50±0.48	9.84±0.96	9.80±1.42	9.94±0.83
		Median	8.42		9.75	9.9450	9.95	10.22
	M	Mean± SD	9.78±1.11	11.10±1.01	11.59±0.48	10.88±0.75	10.99±0.93	10.65±0.82
		Median	9.42	11.61	11.59	10.64	10.84	10.78
	p-value		0.02*		0.50	0.01*	0.00*	0.03*
IVBT2	F	Mean± SD	9.81±1.08		11.99±2.13	12.66±2.33	12.16±1.05	12.06±1.10
		Median	10.0000		12.00	12.81	12.26	12.03
	M	Mean± SD	12.07±1.90	13.46±0.49	15.19±2.13	14.38±2.19	13.81±1.41	13.28±1.37*
		Median	11.9±900	13.36	15.19	13.91	13.96	13.21
	p-value		0.16		0.50	0.13	0.00*	0.00*
VBW2	F	Mean± SD	23.29±4.22		27.54±4.08	28.69±5.64	28.47±3.19	28.19±3.31
		Median	22.05		27.56	26.54	28.25	27.64
	M	Mean± SD	28.77±3.10	28.30±3.55	24.23±	29.59±4.80	30.36±4.71	30.10±3.37
		Median	30.13	30.09	24.23	30.03	30.08	30.54
	p-value		0.09		1	0.48	0.11	0.05
VBCD2	F	Mean± SD	0.00±.00		1.23±0.36	1.80±.73	1.60±.38	1.54±.28
		Median	0.00		1.03	1.61	1.56	1.56
	M	Mean± SD	0.00±.00	1±.28	0.97±0.36	2.06±0.65	1.79±0.58	1.62±0.49
		Median	0.00	0.98	0.97	1.82	1.75	1.63

	p-value		1		0.50	0.37	0.28	0.61
AVBH3	F	Mean± SD	5.32±1.80		9.62±1.70	11.61±1.68	12.57±0.96	13.41±1.05
		Median	6.19		9.39	11.59	12.67	13.06
	M	Mean± SD	8.27±2.55	8.11±.98	8.96±1.70	13.35±1.52	14.50±1.28	14.72±1.14
		Median	7.67	7.82	8.96	13.56	14.56	14.89
	p-value		0.16		1	0.05*	0.00*	0.00*
PVBH3	F	Mean± SD	7.23±1.27		9.84±1.92	12.18±2.11	12.80±0.98	13.32±1.10
		Median	7.89		10.55	11.73	12.56	13.13
	M	Mean± SD	8.75±2.97	9.43±1.03	9.81±1.92	13.87±1.24	14.45±1.42	14.93±1.32
		Median	7.53	9.82	9.81	13.6±400	14.56	15.02
	p-value		1		1	0.04*	0.00*	0.00*
SVBT3	F	Mean± SD	9.92±2.02		11.38±1.79	12.99±1.82	11.89±1.12	11.23±0.94
		Median	9.95		10.44	12.85	11.94	11.25
	M	Mean± SD	10.92±2.59	12.93±1.30	14.96±0	14.33±1.93	13.49±1.36	12.50±1.25
		Median	11.45	12.57	14.96	14.99	13.83	12.22
	p-value		0.54		0.50	0.13	0.00*	0.00*
IVBT3	F	Mean± SD	10.15±1.33		13.53±1.88	13.76±2.26	12.63±1.03	12.36±0.81
		Median	10.24		13.27	13.42	12.68	12.16
	M	Mean± SD	12.31±1.71	13.40±1.09	15.14±	15.67±1.27	14.50±1.51	13.42±1.19
		Median	12.12	13.63	15.14	16.21	14.60	13.88
	p-value		0.09		1	0.03*	0.00*	0.00*
VBW3	F	Mean± SD	20.53±0.66		23.99±4.22	23.35±2.79	23.33±1.42	23.50±1.06
		Median	20.21		22.06	22.22	23.17	23.47
	M	Mean± SD	24.22±1.45	24.72±2.57	26.93±4.22	25.35±1.82	25.54±2.03	24.80±1.23
		Median	23.92	25.58	26.93	25.02	25.32	24.48
	p-value		0.02*		1	0.11	0.00*	0.00*
VBCD3	F	Mean± SD	0.00±0.00		1.14±0.09	2.08±0.93	1.71±0.43	1.83±0.46
		Median	0.00		1.17	1.88	1.78	1.98
	M	Mean± SD	0.00±0.00	0.21±0.36	0.96±0.40	2.07±0.40	1.80±0.62	1.82±0.37
		Median	0.00	0.00	0.96	1.83	1.83	1.89
	p-value		1		0.50	0.48	0.85	0.57
AVBH4	F	Mean± SD	5.70±.83		9.02±1.81	10.62±1.48	12.21±1.11	12.68±1.36
		Median	5.29		8.91	10.55	12.27	12.39
	M	Mean± SD	7.22±1.52	8.41±0.39	9.11±1.81	12.39±1.66	14.10±1.16	14.08±1.43
		Median	6.7700	8.24	9.11	12.81	14.28	14.23
	p-value		0.16		1	0.05	0.00*	0.00*
PVBH4	F	Mean± SD	6.87±1.22		9.80±1.98	11.57±1.42	12.44±1.06	12.89±1.16
		Median	7.57		10.27	11.17	12.59	12.68
	M	Mean± SD	8.83±2.44	9±0.66	10.26±1.98	13.24±1.12	13.98±1.16	14.15±1.13
		Median	7.95	8.98	10.26	13.01	14.28	14.24
	p-value		0.09		1	0.02*	0.00*	0.00*
SVBT4	F	Mean± SD	10.19±2.29		11.73±1.54	13.30±2.67	12.05±1.16	11.72±0.76
		Median	9.81		11.37	12.67	12.11	11.65
	M	Mean± SD	11.87±1.70	12.48±0.66	12.86±1.54	15.54±1.44	14.26±1.37	13.04±1.01
		Median	11.92	12.28	12.86	15.35	14.45	13.00
	p-value		0.26		1	0.02*	0.00*	0.00*
IVBT4	F	Mean± SD	10.50±1.34		12.90±2.42	13.89±2.46	12.56±1.18	12.39±0.94
		Median	9.78		13.96	13.04	12.81	12.22
	M	Mean± SD	12.61±2.43	12.56±0.84	14.71±2.42	15.63±1	14.34±1.39	13.76±1.37
		Median	12.10	12.23	14.7100	15.81	14.71	13.77
	p-value		0.26		0.50	0.09	0.00*	0.00*
VBW4	F	Mean± SD	21.68±1.37		24.11±2.99	24.38±2.61	23.68±1.31	24.04±1.46
		Median	21.88		23.73	23.48	23.41	24.01
	M	Mean± SD	24.87±1.15	25.53±2.19	27.13±2.99	25.73±1.77	26.61±2.14	25.58±1.37
		Median	24.93	26.68	27.13	25.33	26.57	25.67
	p-value		0.02*		1	0.16	0.00*	0.00*
VBCD4	F	Mean± SD	0.00±.000		0.12±.021	1.75±0.99	1.46±0.52	1.47±0.40
		Median	0.00		0.00	1.40	1.365	1.46
	M	Mean± SD	0.00±0.00	0.00±0.00	0.00±0	1.79±0.48	1.81±0.64	1.65±0.38
		Median	0.00	0.00	0.00	1.9	1.64	1.55
	p-value		1		1	0.48	0.00*	0.16

Mann-Whitney U test: *the mean value of parameters were significantly different from the same stage group of the opposite sex * $p \leq 0.05$.

- In consideration to the degree of the correlation between all parameters including the age and the stages, the result of Pearson Correlation test showed that there were significant correlations between all these parameters measured on images ($p < 0.05$) except the correlation between:
- Age with VBW3 and HBH.
- CVMS with SVBT2, IVBT2, VBW2, SVBT3, IVBT3, VBW3, SVBT4, IVBT4, VBW4, HBT, and HBH.
- SVBT2 with CVMS, VBW2, VBCD3, VBCD4, and HMS.
- BSL with VBCD2, VBCD3, and VBCD4.
- HBH with VBW2, VBCD3, HMS, and HBT.
- HMS with SVBT2, IVBT2, VBW2, VBCD2, VBW4, HBH and VBW3.
- SOSS with VBW2, IVBT2, VBW3, VBW4, BSL, and HBT.
- HBT with VBCD2, and VBCD3 (**Tables 3.10, 3.11, 3.12**).

Table 3.10 The degree of the correlation between all parameters including the age and the stages.

Parameters		Age	CVMS	AVBH2	PVBH2	SVBH2	IVBH2	VBW2	VBCD2	AVBH3
AGE	r	1	0.50**	0.41**	0.37**	0.21*	0.20*	0.23**	0.29**	0.57**
CVMS	r	0.50**	1	0.44**	0.46**	0.10	0.07	0.13	0.52**	0.75**
AVBH2	r	0.41**	0.44**	1	0.71**	0.36**	0.59**	0.46**	0.57**	0.73**
PVBH2	r	0.37**	0.46**	0.71**	1	0.47**	0.50**	0.48**	0.41**	0.71**
SVBT2	r	0.21*	0.10	0.36**	0.47**	1	0.48**	0.13	0.19*	0.33**
IVBT2	r	0.20*	0.07	0.59**	0.50**	0.48**	1	0.31**	0.34**	0.41**
VBW2	r	0.23**	0.13	0.46**	0.48**	0.13	0.31**	1	0.21*	0.39**
VBCD2	r	0.29**	0.52**	0.57**	0.41**	0.19*	0.34**	0.21*	1	0.54**
AVBH3	r	0.57**	0.75**	0.73**	0.71**	0.33**	0.41**	0.39**	0.54**	1
PVBH3	r	0.54**	0.68**	0.74**	0.71**	0.36**	0.51**	0.36**	0.51**	0.92**
SVBT3	r	0.29**	0.02	0.59**	0.47**	0.47**	0.77**	0.30**	0.41**	0.39**
IVBT3	r	0.33**	0.02	0.63**	0.54**	0.45**	0.75**	0.41**	0.38**	0.51**
VBW3	r	0.16	0.05	0.59**	0.59**	0.45**	0.60**	0.53**	0.29**	0.43**
VBCD3	r	0.34**	0.61**	0.54**	0.43**	0.09	0.24**	0.36**	0.66**	0.63**
AVBH4	r	0.57**	0.75**	0.69**	0.66**	0.38**	0.45**	0.30**	0.51**	0.93**
PVBH4	r	0.52**	0.69**	0.73**	0.69**	0.40**	0.50**	0.34**	0.53**	0.90**
SVBT4	r	0.37**	0.02	0.61**	0.52**	0.46**	0.69**	0.46**	0.39**	0.49**
IVBT4	r	0.31**	0.042	0.55**	0.47**	0.42**	0.72**	0.34**	0.33**	0.50**
VBW4	r	0.19*	0.03	0.52**	0.55**	0.41**	0.52**	0.49**	0.26**	0.37**
VBCD4	r	0.39**	0.57**	0.48**	0.42**	0.12	0.26**	0.29**	0.60**	0.61**
SOSS	r	0.56**	0.72**	0.45**	0.46**	0.19*	0.14	0.14	0.44**	0.74**
BSL	r	0.20*	0.18*	0.49**	0.47**	0.18*	0.43**	0.35**	0.16	0.42**
HMS	r	0.63**	0.41**	0.25**	0.27**	0.12	0.15	0.12	0.15	0.46**
maxHBW	r	0.54**	0.35**	0.59**	0.61**	0.46**	0.58**	0.38**	0.28**	0.68**
minHBW	r	0.51**	0.39**	0.54**	0.55**	0.41**	0.52**	0.30**	0.28**	0.66**
HBT	r	0.18*	0.10	0.24**	0.37**	0.20*	0.25**	0.24**	0.06	0.28**
HBH	r	0.08	0.14	0.40**	0.42**	0.31**	0.42**	0.15	0.21*	0.36**
HBD	r	0.46**	0.38**	0.46**	0.45**	0.28**	0.33**	0.23**	0.31**	0.53**

Pearson Correlation test: *Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). * $p \leq 0.05$

Table 3.11 The degree of the correlation between all parameters including the age and the stages.

Parameters		PVBH3	SVBT3	IVBT3	VBW3	VBCD3	AVBH4	PVBH4	SVBT4	IVBT4
AGE	r	0.54**	0.29**	0.33**	0.16	0.34**	0.57**	0.52**	0.37**	0.31**
CVMS	r	0.68**	0.02	0.02	0.05	0.61**	0.75**	0.69**	0.02	0.04
AVBH2	r	0.74**	0.59**	0.63**	0.59**	0.54**	0.69**	0.73**	0.61**	0.55**
PVBH2	r	0.71**	0.47**	0.54**	0.59**	0.43**	0.66**	0.69**	0.52**	0.47**
SVBT2	r	0.36**	0.47**	0.45**	0.45**	0.09	0.38**	0.40**	0.46**	0.42**
IVBT2	r	0.51**	0.77**	0.75**	0.60**	0.24**	0.45**	0.50**	0.69**	0.72**
VBW2	r	0.36**	0.30**	0.41**	0.53**	0.36**	0.30**	0.34**	0.46**	0.34**
VBCD2	r	0.51**	0.41**	0.38**	0.29**	0.66**	0.51**	0.53**	0.39**	0.33**
AVBH3	r	0.92**	0.39**	0.51**	0.43**	0.63**	0.93**	0.90**	0.49**	0.50**
PVBH3	r	1	0.51**	0.59**	0.49**	0.56**	0.89**	0.91**	0.58**	0.60**
SVBT3	r	0.51**	1	0.86**	0.55**	0.28**	0.42**	0.53**	0.80**	0.76**
IVBT3	r	0.59**	0.86**	1	0.69**	0.34**	0.50**	0.59**	0.89**	0.86**
VBW3	r	0.49**	0.55**	0.69**	1	0.23**	0.41**	0.49**	0.69**	0.65**
VBCD3	r	0.56**	0.28**	0.34**	0.23**	1	0.55**	0.56**	0.35**	0.24**
AVBH4	r	0.89**	0.42**	0.50**	0.41**	0.55**	1	0.93**	0.46**	0.50**
PVBH4	r	0.91**	0.53**	0.59**	0.49**	0.56**	0.93**	1	0.57**	0.57**
SVBT4	r	0.58**	0.80**	0.89**	0.69**	0.35**	0.46**	0.57**	1	0.84**
IVBT4	r	0.60**	0.76**	0.86**	0.65**	0.24**	0.50**	0.57**	0.84**	1
VBW4	r	0.43**	0.51**	0.59**	0.78**	0.17*	0.37**	0.43**	0.61**	0.53**
VBCD4	r	0.57**	0.23**	0.33**	0.22*	0.74**	0.61**	0.56**	0.34**	0.29**
SOSS	r	0.70**	0.24**	0.26**	0.10	0.50**	0.73**	0.71**	0.22**	0.26**
BSL	r	0.47**	0.39**	0.42**	0.41**	0.14	0.37**	0.42**	0.37**	0.40**
HMS	r	0.45**	0.27**	0.26**	0.05	0.25**	0.44**	0.44**	0.28**	0.25**
maxHBW	r	0.70**	0.58**	0.65**	0.47**	0.39**	0.66**	0.69**	0.68**	0.62**
minHBW	r	0.66**	0.48**	0.57**	0.37**	0.37**	0.66**	0.65**	0.60**	0.56**
HBT	r	0.26**	0.21*	0.23**	0.20*	0.09	0.26**	0.23**	0.32**	0.23**
HBH	r	0.40**	0.39**	0.46**	0.39**	0.16	0.38**	0.43**	0.37**	0.40**
HBD	r	0.54**	0.43**	0.48**	0.26**	0.33**	0.53**	0.56**	0.44**	0.35**

Table 3.12 The degree of the correlation between all parameters including the age and the stages

parameters		VBW4	VBCD4	SOSS	BSL	HMS	MaxHBW	minHBW	HBT	HBH	HBD
AGE	r	0.19*	0.39**	0.56**	0.20*	0.63**	0.54**	0.51**	0.18*	0.08	0.46**
CVMS	r	0.03	0.57**	0.72**	0.18*	0.41**	0.35**	0.39**	0.10	0.14	0.38**
AVBH2	r	0.52**	0.48**	0.45**	0.49**	0.25**	0.59**	0.54**	0.24**	0.40**	0.46**
PVBH2	r	0.55**	0.42**	0.46**	0.47**	0.27**	0.61**	0.55**	0.37**	0.42**	0.45**
SVBT2	r	0.41**	0.12	0.19*	0.18*	0.12	0.46**	0.41**	0.20*	0.31**	0.28**
IVBT2	r	0.52**	0.26**	0.14	0.43**	0.15	0.58**	0.52**	0.25**	0.42**	0.33**
VBW2	r	0.49**	0.29**	0.14	0.35**	0.12	0.38**	0.30**	0.24**	0.15	0.23**
VBCD2	r	0.26**	0.60**	0.44**	0.16	0.15	0.28**	0.28**	0.06	0.21*	0.31**
AVBH3	r	0.37**	0.61**	0.74**	0.42**	0.46**	0.68**	0.66**	0.28**	0.36**	0.53**
PVBH3	r	0.43**	0.57**	0.70**	0.47**	0.45**	0.70**	0.66**	0.26**	0.40**	0.54**
SVBT3	r	0.51**	0.23**	0.24**	0.39**	0.27**	0.58**	0.48**	0.21*	0.39**	0.43**
IVBT3	r	0.59**	0.33**	0.26**	0.42**	0.26**	0.65**	0.57**	0.23**	0.46**	0.48**
VBW3	r	0.78**	0.22*	0.10	0.41**	0.05	0.47**	0.37**	0.20*	0.39**	0.26**
VBCD3	r	0.17*	0.74**	0.50**	0.14	0.25**	0.39**	0.37**	0.09	0.16	0.33**
AVBH4	r	0.37**	0.61**	0.73**	0.37**	0.44**	0.66**	0.66**	0.26**	0.38**	0.53**
PVBH4	r	0.43**	0.56**	0.71**	0.42**	0.44**	0.69**	0.65**	0.23**	0.43**	0.56**
SVBT4	r	0.61**	0.34**	0.22**	0.37**	0.28**	0.68**	0.60**	0.32**	0.37**	0.44**
IVBT4	r	0.53**	0.29**	0.26**	0.40**	0.25**	0.62**	0.56**	0.23**	0.40**	0.35**
VBW4	r	1	0.18*	0.07	0.41**	0.10	0.45**	0.39**	0.23**	0.35**	0.29**
VBCD4	r	0.18*	1	0.49**	0.09	0.32**	0.39**	0.41**	0.17*	0.22*	0.36**
SOSS	r	0.07	0.49**	1	0.17	0.41**	0.44**	0.43**	0.16	0.21*	0.43**
BSL	r	0.41**	0.09	0.17	1	0.20*	0.44**	0.36**	0.23**	0.34**	0.39**
HMS	r	0.10	0.32**	0.41**	0.20*	1	0.58**	0.55**	0.18*	0.06	0.49**
maxHBW	r	0.45**	0.39**	0.44**	0.44**	0.58**	1	0.93**	0.38**	0.42**	0.67**
minHBW	r	0.39**	0.41**	0.43**	0.36**	0.55**	0.93**	1	0.36**	0.38**	0.62**
HBT	r	0.23**	0.17*	0.16	0.23**	0.18*	0.38**	0.36**	1	0.07	0.28**
HBH	r	0.35**	0.22*	0.21*	0.34**	0.06	0.42**	0.38**	0.07	1	0.33**
HBD	r	0.29**	0.36**	0.43**	0.39**	0.49**	0.67**	0.62**	0.28**	0.33**	1

Pearson Correlation test: *Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

3.2 Results for Hyoid Bone Maturation Stages (HMS) and parameters:

- In consideration to the mean age, standard deviation, and p-value of females and males at different hyoid bone maturation stages, the result of the Mann-Whitney U test showed that there were no significant differences between the mean age of males and females at different stages ($p>0.05$) (**Table 3.13**).

Table 3.13 The mean age, standard deviation (SD), and p-value of females and males at different hyoid bone maturation stages (HMS).

Stages	Sex	N	Mean±Sd	P- value
HMS0	F	20	14.80±5.62	0.78
	M	18	14.05±4.33	
	Total	38	14.44±5	
HMS1	F	45	26.55±7.20	0.21
	M	18	28.50±6.16	
	Total	63	27.11±6.93	
HMS2	F	8	31.20±6.97	0.88
	M	7	32.37±9.39	
	Total	15	31.92±8.25	
HMS3	F	5	33.57±7.41	0.83
	M	8	34.25±10.27	
	Total	13	33.93±8.74	

Mann-Whitney U test * $p\leq 0.05$

- In consideration to the frequency and percentage of HMS in different age groups the result of the Pearson Chi-Square test showed that there was a significant difference between the the age groups regarding the distribution of HMS in both males ($p=0.00$) and females ($p=0.00$) (**Table 3.14**).

Table 3.14 The frequency and percentage of Hyoid Bone Maturation Stages (HMS) in different age groups.

Stages	Sex	8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	TOTAL
HMS0	F	7(87.5%)	8(72.7%)	4(28.6%)	0(0.0%)	0(0.0%)	1(10%)	0(0.0%)	0(0.0%)	20(25.6%)
	M	7(100%)	5(83.3%)	6(66.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	18(35.3%)
HMS1	F	1(12.5%)	3(27.3%)	9(64.3%)	14(77.8%)	9(90%)	6(60%)	1(33.3)	2(50%)	45(57.7%)
	M	0(0.0%)	1(16.7%)	2(22.2%)	4(44.4%)	6(75%)	4(66.7%)	1(25%)	0(0.0%)	18(35.3%)
HMS2	F	0(0.0%)	0(0.0%)	1(7.1%)	2(11.1%)	0(0.0%)	2(20%)	1(33.3%)	2(50%)	8(10.3%)
	M	0(0.0%)	0(0.0%)	0(0.0%)	3(33.3%)	0(0.0%)	2(33.3%)	1(25%)	1(50%)	7(13.7%)
HMS3	F	0(0.0%)	0(0.0%)	0(0.0%)	2(11.1%)	1(10%)	1(10%)	1(33.3%)	0(0.0%)	5(6.4%)
	M	0(0.0%)	0(0.0%)	1(11.1%)	2(22.2%)	2(25.0%)	0(0.0%)	2(50%)	1(50%)	8(15.7%)
TOTAL	F	8(100%)	11(100%)	14(100%)	18(100%)	10(100%)	10(100%)	3(100%)	4(100%)	78(100.0%)
	M	7(100%)	6(100%)	9(100%)	9(100%)	8(100%)	6(100%)	4(100%)	2(100%)	51(100.0%)

Pearson Chi-Square test * $p\leq 0.05$

- In consideration to the frequency, percentage, and p-value of HMS for both sexes, the result of the Pearson Chi-Square test showed that there were no significant differences between sexes regarding the distribution of HMS ($p=0.06$) (**Table 3.15**).

Table 3.15 The frequency, percentage, and p-value of Hyoid Bone Maturation Stages (HMS) for both sexes.

Stages	Female	Male	Total	p- value
HMS0	20(52.6%)	18(47.4%)	38(100%)	0.06
HMS1	45(71.4%)	18(28.6%)	63(100%)	
HMS2	8(53.3%)	7(46.7%)	15(100%)	
HMS3	5(38.5%)	8(61.5%)	13(100%)	
TOTAL	78(60.5%)	51(39.5%)	129(100%)	

Pearson Chi-Square test $*p \leq 0.05$

- In consideration to the mean value and standard deviation of all hyoid bone parameters at the four stages, the result Mann-Whitney U test showed that:

In regards to HMS0 and HMS3, there were no significant differences between males and females regarding all hyoid bone parameters ($p > 0.05$).

In regards to HMS1, there were significant differences between males and females regarding all hyoid bone parameters ($p < 0.05$).

In regards to HMS2, there were significant differences between males and females regarding all hyoid bone parameters except for HBT ($p < 0.05$) (**Table 3.16**).

Table 3.16 The mean value and standard deviation of all hyoid bone parameters at the six stages in males and females.

parameters			HMS0	HMS1	HMS2	HMS3
maxHBW	F	N	20	45	8	5
		Mean	17.65±2.57	19.97±2.20	20.07±1.51	24.39±4.33
		Median	17.22	19.66	20.04	24
	M	N	18	18	7	8
		Mean	18.58±3.06	23.32±2.62	26.18±1.61	25.07±2.28
		Median	18.08	23.50	26.41	25.29
		p-value	0.34	0.00*	0.00*	0.28
minHBW	F	N	20	45	8	5
		Mean	13.65±2.19	15.92±1.952	15.88±1.43	18.93±4.17
		Median	13.35	15.83	16.24	18
	M	N	18	18	7	8
		Mean	14.64±2.68	18.38±2.28	20.07±1.57	19.94±2.43
		Median	14.19	18.72	20.61	20.10
		p-value	0.22	0.00*	0.00*	0.28
HBT	F	N	20	45	8	5
		Mean	2.99±1.56	3.58±1.52	3.28±0.95	4.05±1.61
		Median	2.44	3	3.42	4
	M	N	18	18	7	8
		Mean	3.56±1.20	5.37±2.16	4.73±1.82	4.53±0.58
		Median	3.18	5.22	4.88	4.46
		p-value	0.05	0.00*	0.28	0.35
HBH	F	N	20	45	8	5
		Mean	9.34±1.86	9.12±1.35	8.77±1.08	9.52±1.10
		Median	8.87	9.41	8.32	9.77
	M	N	18	18	7	8
		Mean	10.11±1.47	10.40±1.63	10.57±0.86	10.66±0.77
		Median	10.10	10.51	10.89	10.95
		p-value	0.08	0.00*	0.00*	0.09
HBD	F	N	20	45	8	5
		Mean	4±1.85	4.92±1.14	5.12±1.38	5.71±3.36
		Median	3.89	4.86	4.99	4.92
	M	N	18	18	7	8
		Mean	3.66±1.85	6.10±1.65	7.22±1.57	7.43±1.62
		Median	3.75	5.99	7.39	7.54
		p-value	0.65	0.00*	0.02*	0.09

Mann-Whitney U test: * The mean of parameters were significantly different from the same stage group of the opposite sex. * $p \leq 0.05$

3.3 Results for Spheno-Ocipital Maturation Stages (SOSS) and parameters:

- In consideration to the mean age, standard deviation, and p-value of females and males at different sphenooccipital synchondrosis maturation stages, the result of the Mann-Whitney U test showed that there were no significant differences between the mean age of males and females at different stages ($p > 0.05$) (Table 3.17).

Table 3.17 The mean age, standard deviation (SD), and p-value of females and males at different Sphenooipital Synochondrosis Stages (SOSS).

Stages	Sex	N	Mean age±Sd	P- value
SOSS1	F	3	9.33±0.57	1
	M	4	10±2.16	
	Total	7	9.71±1.60	
SOSS2	F	6	11.50±1.51	1
	M	5	11.60±1.67	
	Total	11	11.54±1.50	
SOSS3	F	1	19±3.42	0.33
	M	5	19.80±3.42	
	Total	6	18.66±4.13	
SOSS4	F	42	25.30±8.71	0.11
	M	22	28.13±8.25	
	Total	64	26.28±8.60	
SOSS5	F	26	28.76±7.52	1
	M	15	29.60±9.51	
	Total	41	29.07±8.19	

Mann-Whitney U test * $p \leq 0.05$

- In consideration to the frequency and percentage of SOSS in different age groups, the result of the Pearson Chi-Square test showed that there was a significant difference between the age groups regarding the distribution of SOSS in both males ($p=0.00$) and females ($p=0.00$) (**Table 3.18**).

Table 3.18 The frequency and percentage of Sphenooipital Synochondrosis Stages (SOSS) in different age groups.

Stages		8-12	13-17	18-22	23-27	28-32	33-37	38-42	43-48	Total
SOSS1	F	3(37.3%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	3(3.8%)
	M	3(42.9%)	1(16.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	4(7.8%)
SOSS2	F	4(50%)	2(18%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	6(7.7%)
	M	3(42.9%)	2(33.3%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	5(9.8%)
SOSS3	F	0(0.0%)	1(9.1%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	1(1.3%)
	M	0(0.0%)	1(16.7%)	3(33.3%)	1(11.1%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	5(9.8%)
SOSS 4	F	1(12.5%)	8(72.7%)	8(57.1%)	12(66.7%)	4(40%)	5(50%)	2(66.7%)	2(50%)	42(53.8%)
	M	1(14.3%)	1(16.7%)	4(44.4%)	4(44.4%)	4(50%)	6(100%)	2(50%)	0(0.0%)	22(43.1%)
SOSS5	F	0(0.0%)	0(0.0%)	6(42.9%)	6(33.3%)	6(60%)	5(50%)	1(33.3%)	2(50%)	26(33.3%)
	M	0(0.0%)	1(16.7%)	2(22.2%)	4(44.4%)	4(50%)	0(0.0%)	2(50%)	2(100%)	15(29.4%)
Total	F	8(100%)	11(100%)	14(100%)	18(100%)	10(100%)	10(100%)	3(100%)	4(100%)	78(100.0%)
	M	7(100%)	6(100%)	9(100%)	9(100%)	8(100%)	6(100%)	4(100%)	2(100%)	51(100.0%)

Pearson Chi-Square test * $p \leq 0.05$

- In consideration to the frequency, percentage, and P-value of SOSS for both sexes, the result of the Pearson Chi-Square test showed that there were no significant differences between sexes regarding the distribution of SOSS ($p=0.15$) (**Table 3.19**).

Table 3.19 The frequency, percentage and p value of Sphenooipital Synochondrosis Stages (SOSS) for both sexes.

Stages	Female	Male	Total	P-value
SOSS1	3(42.9%)	4(57.1%)	7(100%)	0.15
SOSS2	6(54.5%)	5(45.5%)	11(100%)	
SOSS3	1(16.7%)	5(83.3%)	6(100%)	
SOSS4	42(65.6%)	22(34.4%)	64(100%)	
SOSS5	26(63.4%)	15(36.6%)	41(100%)	
TOTAL	78(60.5%)	51(39.5%)	129(100%)	

Pearson Chi-Square test * $p \leq 0.05$

- In consideration to the mean value and standard deviation of BSL at the five stages. the result of the Kruskal-Wallis test shows that there is a significant difference only between SOSS1 and SOSS4 regarding the mean value of BSL ($p < 0.05$) (**Table 3.20**).

Table 3.20 The mean value and standard deviation (SD) of Basion to Sella Lenght (BSL) at the five stages

Stages	N	Mean± SD of BSL
SOSS1	7	38.91±4.188
SOSS2	11	43.32±2.78
SOSS3	6	45.52±4.22
SOSS4	64	44.32±3.64
SOSS5	41	43.49±3.51
TOTAL	129	43.74±3.76

Kruskal-Wallis test * $p \leq 0.05$

3.4 Distribution of CVMS at both of SOSS and HMS:

- In consideration to the distribution of CVMS and P-value at each SOSS for the study population, the result of the Pearson Chi-Square test showed that there were significant differences regarding the distribution of SOSS at each CVMS ($p = 0.00$) (**Table 3.21**).

Table 3.21 Distribution of SOSS and p-value at each Cervical Vertebral Maturation Stages (CVMS) of study population.

Stages	SOSS1	SOSS2	SOSS3	SOSS4	SOSS5	Total	P value
CVMS1	6(66.7%)	2(22.2%)	0(0.0%)	1(11.1%)	0(0.0%)	9(100 %)	0.00
CVMS2	1(33.3%)	2(66.7%)	0 (0.0%)	0(0.0%)	0(0.0%)	3(100%)	
CVMS3	0(0.0%)	3(75.0%)	0(0.0%)	0(0.0%)	1(25.0%)	4(100%)	
CVMS4	0 (0.0%)	2(11.8%)	4(23.5%)	6(35.3%)	5(29.4%)	17(100%)	
CVMS5	0(0.0%)	2(3.6%)	2(3.6%)	36(64.3%)	16 (28.6%)	56(100%)	
CVMS6	0(0.0%)	0(0.0%)	0(0.0%)	21(52.5%)	19(47.5%)	40(100%)	
TOTAL	7(5.4%)	11(8.5%)	6(4.7%)	64(49.6%)	41(31.8%)	129(100%)	

Pearson Chi-Square test * $p \leq 0.05$

- In consideration to the distribution of stages of CVMS and P-value at each HMS for the study population, the result of Pearson Chi-Square test showed that there were significant differences regarding distribution of HMS at each CVMS ($p=0.00$) (**Table 3.22**).

Table 3.22 Distribution of HMS and p-value at each cervical vertebral maturation stage (CVMS) of study population.

Stages	HMS0	HMS1	HMS2	HMS3	Total	P-value
CVMS1	9(100%)	0(0%)	0(0%)	0(0.0%)	9(100%)	0.00
CVMS2	3(100%)	0(0%)	0(0%)	0(0.0%)	3(100%)	
CVMS3	3(75%)	1(25%)	0(0%)	0(0.0%)	4(100%)	
CVMS4	7(41.2%)	7(41.2%)	1(5.9%)	2(11.8%)	17(100%)	
CVMS5	12(21.4%)	29(51.8%)	9(16.1%)	6(10.7%)	56(100%)	
CVMS6	4(10%)	26(65%)	5(12.5%)	5(12.5%)	40(100%)	
TOTAL	38(29.5%)	63(48.8%)	15(11.6%)	13(10.1%)	129(100%)	

Pearson Chi-Square test * $p \leq 0.05$

3.5 Results for correlation between CVMS, HMS, and SOSS:

- In consideration to correlation coefficients between CVM, HMS, SOSS, and age, the result of spearman's rho test showed that there is significant correlation between CVMS and age (females: $r = 0.32$; males: $r = 0.57$; $p < 0.05$), significant correlation between CVMS and HMS (females: $r = 0.33$; males: $r = 0.49$; $p < 0.05$) and significant correlation between CVMS and SOSS (females: $r = 0.38$; males: $r = 0.61$; $p < 0.05$), significant correlation between SOSS and age (females: $r = 0.50$; males: $r = 0.57$; $p < 0.05$), significant correlation between SOSS and HMS (females: $r = 0.27$; males: $r = 0.52$; $p < 0.05$), and significant correlation between HMS and age (females: $r = 0.66$; males: $r = 0.75$; $p < 0.05$) (**Table 3.23**).

Table 3.23 Correlation coefficients between age, CVMS, HMS, and SOSS.

Sex	Stages		CVMS	AGE	SOSS	HMS
F	CVMS	r	1	0.32**	0.38**	0.33**
		p	.	0.00	0.00	0.00
		n	78	78	78	78
	AGE	r	0.32**	1	0.50**	0.66**
		p	0.00	.	0.00	0.00
		n	78	78	78	78
	SOSS	r	0.38**	0.50**	1	0.27*
		p	0.00	0.00	.	0.01
		n	78	78	78	78
	HMS	r	0.33**	0	0.27*	1
		p	0.00	0.00	0.01	.
		n	78	78	78	78
M	CVMS	r	1	0.57**	0.61**	0.49**
		p	.	0.00	0.00	0.00
		n	51	51	51	51
	AGE	r	0.57**	1	0.57**	0.75**
		p	0.00	.	0.0	0.00
		n	51	51	51	51
	SOSS	r	0.61**	0.57**	1	0.52**
		p	0.00	0.00	.	0.00
		n	51	51	51	51
	HMS	r	0.49**	0.75**	0.52**	1
		p	0.00	0.00	0.00	.
		n	51	51	51	51

Spearman's rho test: *correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01level (2-tailed).

4. DISCUSSION

Sex and age estimation of living or dead bodies is an interesting task in forensic medicine and orthodontic field by using the bone, the tooth, and the hair. The estimation of sex and age based on the data of the bone is sometimes the only evidence and is an effective tool in the identification of dead bodies, because they remain intact for many years after death (73)(77)(150)(151). The complete reliance on one bone for estimation of an individual's age is not so reliable. For this reason, it has become essential to develop methods for age estimation from every bone as nearly as every bone has age markers. It should be clear to "know where to look and how to recognize and interpret them" to correctly identify which areas of the bone exhibit dimensions and morphological changes with age (15).

Most of the previous studies have been carried out using corpses or skeletal material, making it hard to answer clinical questions that involved the living individual. Recently, the demand for estimating the age of living individuals has been reported to grow as a result of the worldwide rise in immigration, criminal, and civil over the past few years. In addition, estimation of the age of a living person is more accurate than that of the deceased (13).

The osteological analysis of sex and age estimation can be done by using non-metric and metric methods. The non-metric methods depend on using the morphological features of the bone. These methods are subjective, non-reproducible, non-practical, and their accuracy are dependent on the experience of the observer. The metric methods depend on using dimensions of the bone. These methods are more objective and they remove the observer bias resulting from identifying the presence or absence of prominent characteristics that are utilized in morphological methods (12)(151)(152).

Several researches have measured the metric dimensions of the bone directly from the cadaver (152)(153)(154)(155)(156), photography (20)(77), and radiologic images (12)(20)(73)(157). Imaging techniques offer the chance to analyze the sex differences in living subjects. Comparing with two-dimensional imaging technologies, 3D imaging technologies have become more commonly used in many researches. As a consequence, collecting the information in thin slices became easily accessible, and the precision of metric measurements, like are width, length, angle, and volume of the bone on 3D images are enhanced (2)(12)(73)(155)(158).

The current study was done for evaluation the correlation between cervical vertebra, hyoid bone, and speno-occipital bone in regards to dimensions and degree of their maturation. The correlation between these variables was evaluated on CBCT images for determine whether these variables can be used as a tool for age and sex estimation or not.

4.1 Cervical vertebrae:

The cervical vertebral maturation method has been gained interest during the last centuries. The increasing popularity of this method is due to a series of investigations that have confirmed the validity of this method when compared to the hand and wrist method (27)(159).

For the determination of cervical vertebral maturation stages, two sets of variables should be considered; the shape and the presence or absence of the concavity at the lower border of cervical vertebral body (45).

The cervical vertebral body changes in shape with age from a wedge shape to a rectangle shape after that they change to a square shape. Consequently, the vertical dimensions of bodies become greater than the horizontal dimensions. The concavity at the lower border of the vertebral body was the best parameter to estimate the maturation (28). As the skeleton matured, the concavity was appeared in sequence from C2 to C3, then to C4 (16)(160)(161).

In 2005, Baccetti et al. (45) made the same analysis and summarized the characteristics of cervical vertebral maturation at six consecutive stages as follows:

Stage 1: The majority of subjects had no concavity at the lower border of C2. 100% of the subjects have no concavity at the lower borders of both C3 and C4. The subjects had trapezoid bodies for C3 and C4.

Stage 2: 80% of the subjects had concavity at the lower borders of C2. The majority of subjects had no concavity at the lower borders of both C3 and C4. The subjects still had trapezoid bodies for C3 and C4, with exceptions of 3% and 13% of the subjects had rectangular horizontal bodies for C3 and C4.

Stage 3: 100% of the subjects had concavity at the lower borders of C2. The majority of subjects have concavity at the lower borders of C3 and absent at the lower border of C4. The subjects have either a trapezoid or rectangular horizontal bodies for both C3 and C4.

Stage 4: The majority of subjects had concavity at the lower borders of C2, C3, and C4. 100% of the subjects had rectangular horizontal bodies for both C3 and C4.

Stage 5: The majority of subjects had concavity at the lower borders of C2, C3 and C4. 40% of the subjects had rectangular horizontal bodies for C3 and had squared in the remaining subjects. 47% of the subjects had rectangular horizontal bodies for C4 and had squared bodies in the remaining subjects.

Stage 6: All examined three cervical vertebrae had a concavity at the lower border. The body of C3 was squared in 50% of the subjects and rectangular vertical bodies in the remaining subjects. 53% of the subjects had squared bodies for C4 and rectangular vertical bodies in the remaining subjects.

4.1.1 The mean age for Cervical Vertebral Maturation Stages (CVMS):

Knowing the mean chronological age of different CVMS is important for the clinical orthodontic and forensic field (98). Racial and sex variations in mean age at different CVMS were reported by previous studies (93)(94)(160).

A longitudinal study by Altan et al. (160) assessed CVMS in females aged between 8 and 17 years on lateral cephalometric radiographs of the Turkish population. Their results showed that when the lower borders of all cervical vertebrae were flat, this stage was defined as CVMS1 and the mean age at this stage was 9.46 years. Furthermore, when the lower border of C2 became slightly concave and the anterior height of C2 increased, the stage was known as CVMS2 and the mean age at this stage was 11.14 years. When the lower border of C3 became concave, the stage was known as CVMS3 and the mean age at this stage was 12.37 years. Also, when the concavity on the lower border of C3 became distinct and the lower border of C4 was concave, the stage was known as CVMS4 and the mean age at this stage was 13.62 years. However, when all the lower borders of the cervical vertebrae became concave and the bodies became squarer, the stage was known as CVMS5 and the mean age at this stage was 14.36 years. Also, when the vertical heights of all vertebral bodies became greater than their width, the stage was known as CVMS6 and the mean age at this stage was 15.56 years.

Montasser et al. (94) evaluated 60 lateral cephalography of white, African-American and Hispanic subjects; aged between 7 and 18 years for assessing whether there are racial and sex

differences regarding CVMS or not. Their results showed that the mean chronologic age of the CVMS affected by sex and race of subjects. When they evaluated gender differences in each group, in Hispanic subjects; the mean ages for CVMS1, CVMS2, and CVMS3 were significantly greater in the males (10.83, 12.01, and 13.45 years; respectively) than in the females (9.51, 10.89, and 12.59 years; respectively). In addition, in African American subjects; the mean ages for CVMS2 and CVMS3 were significantly greater in the males (12.14 and 14.30 years; respectively) than in the females (11.53 and 13.02 years; respectively). Moreover, in white subjects; the mean ages for CVMS2 and CVMS3 were significantly greater in the males (12.23 and 14.05 years; respectively) than the females (11.59 and 12.79 years; respectively). Among females, racial variances were seen in the mean ages of CVMS2, CVMS3, CVMS4, and CVMS5. Among males, racial variances were seen only in the mean ages of CVMS3.

Similarly, Montasser et al. (38) found gender differences in CVMS of subjects aged ranged between 7 to 18 years in a North American and a Denver groups. In the North American group, the males began their growth later than females by about 1 year (CVMS1 at 11.4 and 10.4 years; respectively) and then the growth accelerated in the later stages and completed nearly at the same age as females (CVMS4 and CVMS5 at 14 years, CVMS6 at 15 years). In the Denver group, the females and the males began their growth nearly at the same age (CVMS1 at 10 years). However, starting from CVMS4, the males reached significantly older age than the females (CVMS4 at 15.2 and 14.3 years; respectively) and completed their maturation later (CVMS6 at 15.8 and 17.1 years; respectively).

This finding is compatible with the findings of Kocasarac et al. (93) who found that the oldest age at CVMS1 is 10 years in both females and males. The CVMS2, CVMS3, and CVMS4 generally began later in males (12.33, 14.8, and 20.85 years; respectively) than in females (8.5, 13, and 16.31 years; respectively). However, the mean age of the male and female at CVMS5 was 17 years. The youngest age at CVMS6 is 20 years in males and 18 years in females.

This finding is also compatible with Perinetti et al. (162) who evaluated gender differences in the time of CVMS of subjects aged between 10 to 16 years. Their results showed that there were non-significant differences between the sexes at the beginning of CVM2 (11 years). On the contrary, CVMS3, CVMS4, and CVMS5 generally began 1.5 years later in males (13.2, 14.4, and 15.5 years; respectively) than in females (11.6, 12.7, and 14.1 years; respectively).

In the current study, the mean ages of CVMS1, CVMS2, CVMS3, CVMS4, CVMS5 and CVMS6 for females and males were nearly equal with non-significant differences (9.33, 12.33, 19, 22.87, 24.43, and 27.54 years; respectively). These are contrast to result reported by Montasser et al. (94), Montasser et al. (38), and Kocasarac et al. (93).

Genetic differences, environmental conditions, socioeconomic status, nutrition, hygiene conditions, regional, climatic, and even seasonal differences have been listed as possible contributors to the differences in the timing of skeletal maturation between ethnic groups (94).

4.1.2 The percentage of Cervical Vertebral Maturation Stages (CVMS) at different age groups:

Previous studies concerted to study the relationship between CVMS and chronological age as this relationship will help for age estimation in the forensic and dentistry field. The result of these studies revealed that the cervical vertebral maturation progressively increased with age (23)(93)(163).

Sun L and Ran L (164) evaluated the cervical vertebral maturation of 1038 females; aged between 8 to 16 years old. Their results showed that CVMS1 was seen in 55 (65.5%) of the females at the age group of 8-9 years, CVMS2 was seen in 55 (45.8%) of the females at the age group of 9-10 years, CVMS3 was seen in 55 (45.8%) of the females at the age group of 10-12 years, CVMS4 was seen in 51 (29.3%) of the females at age group of 12-13 years, and the most maturation level was seen in CVMS5 and CVMS6; 91 (79.8%) and 141 (97.9%) respectively, at the age group of 14-16 years.

Moreover, Majeed O and Quadeer T (23) evaluated lateral cephalometric radiographs of 53 individuals aged between 8-18 years. Their results revealed that the cervical vertebrae maturation progressively increased with age, as found that CVMS1 was seen in 5 (62%) of the adults at the age group of 8-10 years, CVMS2 was seen in 7 (63%) of the adults at the age group of 10-12 years, CVMS3 was seen in 12 (75%) of the adults at the age group of 12-14 years, CVMS5 was seen in 4 (50%) of the adults at the age group of 14-16 years were in CVMS5, CVMS6 was seen in 6 (60%) of the adults at the age group of 16-18 years. Accordingly, there was a statistically significant correlation between chronological age and cervical vertebral maturation stages ($r=0.90$).

Similarly, in the current study, CVMS1 was only seen in 6 (85.7%) males and 3 (37.5%) females at the age group of 8-12 years and was not seen after this age. Also, CVMS2 was seen only in 2 (33.3%) males at the age group of 13-17 years and this stage was not seen after this age. In addition, CVMS3 was beginning to be seen in 1(16.7%) males and 1 (9.1%) females at the age group of 13-17 years and not see after this age. Moreover, CVMS4 was seen in 2 (11.1%) females and 2 (22.2%) males between the age of 23-27 years. Furthermore, the percentage of CVMS5 increases with age to become 6 (60%) for the females at the age group of 33-37 years, and 3 (75%) for males at the age group of 38-42 years. Additionally, the percentage of CVMS6 increased with age to become 2 (66.7%) for the females at the age group of 38-42 years, and 1(50%) for the males at the age group of 43-48 years. There was a significant difference regarding the distribution of CVMS between age groups in both males and females.

4.1.3 Cervical vertebrae parameters at different age groups:

During the individual's growth, the changes in the dimension and morphology of the vertebrae can be used as an indicator of bone maturation (17). Recently, the changes in the size of C3 and C4 vertebrae body of growing individuals with age has gained increasing interest in the last decades to use as a biological indicator of individual skeletal maturity (63)(160). The dimensions of the cervical vertebrae follow a somatic pattern, reaching their final size at the end of maturation (160). The increase in the anterior height of vertical bodies is due to the condral growth of vertebral bodies which reaches its maximum high between CVMS3 and CVMS4. The increase in superior and inferior width is due to appositional growth, which reaches their maximum growth rate between CVMS2 and CVMS3 (160). Previous study reported that C1 and C4 reached their peak size just about 11.5 years old, and C3 reached its maximal size just about 10.5 years of age (24).

According to Ezra et al. (161), cervical vertebral bodies become wider and elongated with age. However, changes in the length dimension are much more pronounced than that of the width dimension. Notably, the body shape of the cervical vertebrae changes gradually from a more round shape to a more oval one. This is due to the fact that the length dimensions from C3 to C7 increase by approximately 10%, the width dimensions increase by almost 40%. Moreover, they found that a significant reduction in body height occurs with age in C3–C6 and the increase in vertebral body width and length by age.

It has been demonstrated in the literature that the increases in vertical height, horizontal length, and concavity depth at the lower border of the cervical vertebral body during skeletal maturation were under the influence of environmental and genetic factors (32).

Regards to AVBH and PVBH, Aguiar et al. (17) evaluated AVBH and PVBH of C3 and C4 for 76 males and 64 females aged between 7 and 14.9 years, using cephalometric radiographs. For both male and female groups, a greater increase in AVBH3, AVBH4, PVBH3, and PVBH4 was observed from the age of 12 years. These are in agreement with the results of Mito et al. (165), who reported an accelerated increase in AVBH and PVBH in female subjects from the age of 10 and 13 years.

This is in agreement with the results of Caldas et al. (166), who reported that in regards to females, the AVBH3 and PVBH3 increased in an accelerated way from the age of 10 to 13 years. AVBH4 and PVBH4 increased in an accelerated way from the age of 11 to 13 years. As regarding males, the AVBH3 and PVBH3 increased in an accelerated way from the age of 12 to 15 years. On the other hand, AVBH4 and PVBH4 did not increase at all.

In addition, Hellsing E (167) assessed the cervical body of subjects aged between 8 to 17 years, they found that AVBH2, AVBH3, and AVBH4 increased from the age of 8 to 17 years to be 6, 7.3, and 6 mm; respectively. The VBH of the vertebrae increased non-significantly with age between children. 15 year-old males showed significantly smaller values for vertebral height and length than the adult. These findings were consistent with the results of Altan et al. (160) except for the AVBH2, which was found to be 8.66 mm.

Alhadlaq M and Maflehi S (25) evaluated the dimensions of C3 and C4 on 122 lateral cephalometric images of Saudi male children aged between 10-15 years old. They found that from the ages of 10 to 15 years; AVBH3 increased steadily from 6.65 to 13.17 mm, PVBH3 increased steadily from 11.43 to 14.98 mm, AVBH4 increased steadily from 7.13 to 12.38 mm, and PVBH4 increased steadily from 11.25 to 15.19 mm.

Regards to VBT3 and VBT4, Alhadlaq M and Maflehi S (25) reported that there were nearly unchanged in both VBT3 and VBT4 after the age of 12 years (13.87 mm). These observations were compatible with the observation of Mito et al. (165), Hellsing E (167), and Aguiar et al. (17) studies, who reported minor changes in VBT3 and VBT4 with age. However, a study by Caldas et al. (166) found that VBT3 increased in an accelerated way from the age of 12 to 15 years, whereas VBT4 did not increase at all. Similarly, a study by

Israel H (168) showed that the VBT2, VBT3, and VBT4 increased in adult females from the age of 24 to 47 years.

There was difference between the results found by Caldas et al. (166) and Mito et al. (165). This is because the study by Caldas et al. (166) was conducted in the city Piracicaba, SP, in the south eastern part of Brazil without distinction of social condition, and the study by Mito et al. (165) was conducted in a population of Japanese girls.

The results of Aguiar et al. (17), Mito et al. (165), Caldas et al. (166), Hellsing E (167), Alhadlaq M and Maflehi S (25) studies are compatible with the current study.

In the current study, the mean value of these parameters were compared between sex from age 8 to 48 years old. Regarding C2, the mean value of AVBH2 increased from 18.50 to 23.27 mm in males and from 18.30 to 23.27 mm in females. In addition, the mean value of PVBH2 increased from 18.34 to 20.68 mm in the male group and from 14.88 to 17.83 mm in the female group. Also, the mean value of SVBT2 increased from 10.04 to 11.50 mm in the male group and from 8.77 to 10.14 mm in the female group. Moreover, the mean value of IVBT2 increased from 12.25 to 13.81 mm in the male group and 10.27 to 12.88 mm in the female group. Furthermore, the mean value of VBW2 increased from 28.96 to 34.41 mm in the male group and from 24.7 to 30.03 mm in the female group. Besides, the mean value of VBCD2 increased from 0.10 to 2.08 mm in the male group and from 0.89 to 1.86 mm in the female group.

Regarding C3, the mean value of AVBH3 increased from 8.20 to 15.29 mm in the male group and from 8.03 to 12.66 mm in the female group. Also, the mean value of PVBH3 increased from 8.90 to 15.29 mm in the male group and from 9.18 to 12.75 mm in the female group. Furthermore, the mean value of SVBT3 increased from 11.16 to 13.89 mm in the male group and from 10.04 to 12.32 mm in the female group. Moreover, the mean value of IVBT3 increased from 12.29 to 15.38 mm in the male group and from 10.75 to 13.09 mm in the female group. In addition, the mean value of VBW3 increased from 24.42 to 26.20 mm in the male group and from 21.68 to 23.84 mm in the female group. Also, the mean value of VBCD3 increased from 0 to 2.16 mm in the male group and from 1.11 to 1.96 mm in the female group.

Regarding C4, the mean value of AVBH4 increased from 7.35 to 15.04 mm in the male group and 7.91 to 12.76 mm in the female group. Additionally, the mean value of PVBH4

increased from 8.85 to 14.78 mm in the male group and from 8.85 to 13.11 mm in the female group. Moreover, the mean value of SVBT4 increased from 11.92 to 15.09 mm in the male group and 10.39 to 12.60 mm in the female group. Furthermore, the mean value of IVBT4 increased from 12.55 to 14.76 mm in the male group and 10.83 to 13.68 mm in the female group. Also, the mean value of VBW4 increased from 25.16 to 28.83 mm in the male group and from 22.38 to 24.43 mm in the female group. Finally, the mean value of VBCD4 increased from 0 to 2.32 mm in the male group and from 1.27 to 1.49 mm in the female group.

While comparing the mean values of these parameters between the different female age groups, there were significant differences in PVBH2, SVBT2, IVBT2, VBCD2, AVBH3, PVBH3, SVBT3, IVBT3, AVBH4, PVBH4, SVBT4, IVBT4, and VBW4.

Moreover, while comparing the mean values of these parameters between the different male age groups, there were significant differences in AVBH2, PVBH2, VBCD2, AVBH3, PVBH3, VBCD3, AVBH4, PVBH4, and VBCD4.

Additionally, there were significant differences between female and male groups from the age of 8 to 12 years old regarding the mean values of SVBT2, VBW2, IVBT3, VBW3, VBCD3, VBW4, and VBCD4.

Also, there were significant differences between the female and the male groups from the age of 13 to 17 years old regarding the mean values of IVBH3 and SVBH4.

Moreover, there were significant differences between the female and the male groups from the age of 18 to 22 years old regarding the mean values of AVBH2, PVBH2, IVBT2, PVBH3, IVBT3, SVBT4, IVBT4, and VBW4.

Furthermore, there were significant differences between the female and the male groups from the age of 23 to 27 years old regarding the mean values of PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, and VBCD4.

Besides, there were significant differences between the female and the male groups from the age of 28 to 32 years old regarding the mean values of PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH4, PVBH4, SVBT4, and IVBT4.

Additionally, there were significant differences between the female and the male groups from the age of 33 to 37 years regarding the mean values of PVBH2, SVBT2, AVBH3, PVBH3, VBW3, AVBH4, PVBH4, SVBT4, IVBT4, and VBW4.

Finally, there were non-significant differences between the female and the male groups after the age of 38 years old.

Since in the literature there is no study evaluated the difference in the SVBT, IVBT, VBW, and VBCD between different age groups. No comparison could be made with the current literature.

4.1.4 Cervical vertebral parameters for males and females:

The identification of anatomic gender differences in cervical vertebral geometry is important in the forensic field. Ezra et al. (161) evaluated the size of cervical vertebral bodies of 277 individuals using 3D digitizer. Their results showed that the mean values of AVBH3, AVBH4, VBW3, and VBW4 in the females (11.75, 11.16, 16.52, and 17.81 mm; respectively) were significantly smaller than the males (13.18, 12.55, 17.72, and 18.57 mm; respectively). This is disagreement with current study as the mean values of AVBH3 and AVBH4 in the females (12.34 and 11.82 mm; respectively) were non significantly smaller than the in males (13.15 and 12.55 mm; respectively). However, the mean values of VBW3, and VBW4 in the females (23.30 and 23.80 mm; respectively) were significantly smaller than the in males (25.10 and 25.87 mm; respectively). This result is also in agreement with the result of Stemper et al. (169), who found that vertebral body width was not significantly different between males (26.7 mm) and females (25.5 mm).

In the current study, liner parameters from the cervical vertebrae were measured including; AVBH2, PVBH2, SVBH2, VBW2, AVBH3, PVBH3, SVBH3, IVBH, VBW3, VBCD3, PVBH4, SVBH4, IVBH4, VBW4, and VBCD4.

For the female group, the mean values of these parameters were 21 mm, 17.65 mm, 9.78 mm, 12.08 mm, 28.17 mm, 1.53 mm, 12.34 mm, 12.57 mm, 11.70 mm, 12.60 mm, 23.30 mm, 1.70 mm, 11.82 mm, 12.17 mm, 11.99 mm, 12.58 mm, 23.80 mm, and 1.38 mm; respectively.

For the male group, the mean values of these parameters were 22.05 mm, 19.10 mm, 10.74 mm, 13.54 mm, 29.72 mm, 1.51 mm, 13.15 mm, 13.44 mm, 13.02 mm, 14.05 mm,

25.10 mm, 1.53 mm, 12.55 mm, 12.93 mm, 13.69 mm, 14.08 mm, 25.87 mm, and 1.40 mm; respectively.

While comparing the mean value of these parameters between sex, the cervical vertebrae of the male was not significantly larger than the cervical vertebrae of the females for all these parameters except AVBH3, AVBH4, VBCD2, VBCD3, and VBCD4. These are compatible with the results of Ezra et al. (161).

Since in the literature, there is no study evaluated the difference between males and females regards the other parameters. No comparison could be made with the current literature.

The environmental factor was considered as an important factor responsible for time variation in skeletal maturation in both genders, with females being affected by environmental conditions than males (94).

4.1.5 Cervical vertebrae parameters at different maturation stages:

Comparing the mean values of cervical vertebrae parameters between different fusion stages (CVMS1 to CVMS6) in the current study, in regards to C2; the mean value of AVBH2 ranged between 15.18 - 21.54 mm for the females and 18.42 - 22.69 mm for the males. In addition, the mean value of PVBH2 ranged between 12.78 - 18.25 mm for the females and 16.06 - 20.50 mm for the males. Also, the mean value of SVBT2 ranged between 8.44 - 9.94 mm for the females and 9.78 - 10.65 mm for the males. Moreover, the mean value of IVBT2 ranged between 9.81 - 12.06 mm for the females and 12.07 - 15.19 mm for the males. Furthermore, the mean value of VBW2 ranged between 23.29 - 28.19 mm for the females and 28.77 - 30.10 mm for the males. Besides, the mean value of VBCD2 ranged between 0.00 - 1.80 mm for the females and 0.00 - 2.06 mm for the males.

In regards to C3, The mean value of AVBH3 ranged between 5.32 - 13.41 mm for the females and 8.27 - 14.72 mm for the males. Moreover, the mean value of PVBH3 ranged between 7.23 - 13.32 mm for the females and 8.75 - 14.93 mm for the males. Furthermore, the mean value of SVBT3 ranged between 9.92 - 12.99 mm for the females and 10.92 - 14.96 mm for the males. Besides, the mean value of IVBT3 ranged between 10.15 - 13.76 mm for the females and 12.31 - 15.67 mm for the males. Also, the mean value of VBW3 ranged between 20.53 - 23.50 mm for the females and 24.22 - 26.93 mm for the males. Additionally,

the mean value of VBCD3 ranged between 0.00 - 1.83 mm for the females and 0.00 - 2.07 mm for the males.

In regards to C4, the mean value of AVBH4 ranged between 5.70 - 12.68 mm for the females and 7.22 - 14.08 mm for the males. Moreover, the mean value of PVBH4 ranged between 6.87 - 12.89 mm for the females and 8.83 - 14.15 mm for the males. Furthermore, the mean value of SVBT4 ranged between 10.19 - 13.30 mm for the females and 11.87 - 15.54 mm for the males. Also, the mean value of IVBT4 ranged between; 10.50 - 13.89 mm for the females and 12.61 - 15.63 mm for the males. Furthermore, the mean value of VBW4 ranged between 21.68 - 24.38 mm for the females and 24.87 - 27.13 mm for the males. Finally, the mean value of VBCD4 ranged between 0 - 1.75 mm for the females and 0.00 - 1.81 mm for the males.

Since in the literature, there is no study comparing the mean value of these parameters between different fusion stages (CVMS1 to CVMS6). No comparison could be made with the current literature.

4.1.6 Comparing the mean value of cervical vertebrae parameters between sexes at different maturation stages:

While comparing the mean value of cervical vertebrae parameters between sex at different stages (CVMS1 to CVMS6) in the current study, at CVM1; there were statistically significant differences between sexes regarding the mean value of AVBH2, PVBH2, SVBT2, VBW3, and VBW4. Also, at CVM4; there were statistically significant differences between sexes regarding the mean value of SVBT2, PVBH3, IVBT3, PVBH4, and SVBT4. Moreover, at CVM5; there were statistically significant differences between sexes regarding the mean value of AVBH2, PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH4, PVBH4, SVBT4, IVBT4, VBW4, and VBCD4. Finally, at CVM6; there were statistically significant differences between sexes regarding the mean value of PVBH2, SVBT2, IVBT2, AVBH3, PVBH3, SVBT3, IVBT3, VBW3, AVBH4, PVBH4, SVBT4, IVBT4, and VBW4.

Since in the literature, there is no study comparing the mean values of these parameters between sex at different stages (CVMS1 to CVMS6). No comparison could be made with the current literature.

The subjects in the current study, although from the same racial group and definitely with genetic differences, were all influenced by similar environmental factors and were all more or less of the same socioeconomic status. This could have influenced the differences between the groups. In addition, the environmental factor was considered an important contributing factor to time variation related to sex in skeletal maturation, with females less responsive to environmental conditions than males (94).

Furthermore, during growth, the cervical vertebrae sometimes do not develop a concavity at all or develop a concavity very late at the lower border of the body. In these cases, an alternative for the cervical vertebral method should be used when the staging of the CVMS is difficult (170).

4.2 Hyoid bone:

With advanced techniques for the collection of human skeletal remains in archeological and forensic fields, the recovery of hyoid bones is now more frequent in skeletal remains. Therefore, many types of researches try to discover new techniques for assessing sex and age relied on hyoid bodies from archeological sites (10).

Most of the earlier researches concentrated on studying the hyoid bone as a whole including the body and the great horns. Nevertheless, the latest researches excluded the great horns from the study and considered the hyoid body to be more important for assessing the sex and the age of skeletal remains when the bones are poorly preserved, due to the high frequency of unfused hyoid body in skeletal remains (10)(71)(152)(171).

4.2.1 The mean age for the hyoid body and the great horns fusion:

The body of the hyoid bone fuses with the greater cornu during development. This fusion occurs at different ages depending on some factors, such as sex and gender (172)(173)(174). Knowledge of the time of fusion between greater cornua and the body of hyoid bone can aid in the estimation of the age of an individual (174). However, variability in the time of fusion has been observed in many studies (2)(156)(175)(176).

In the current study, no fusion between the body of the hyoid bone and greater cornu was seen before the age of 26 and 28 years for the females and the males respectively. This is consistent with Biswas et al. (79) who evaluated 30 digital X-ray images for an equal number of males and females of hyoids and reported that these bones remained completely open until

the mean age of 30.25 years for males and 34.50 years for the females. These are much lower than were found by Ito et al. (73) who evaluated hyoid bone in CT images of 310 males and 290 females; aged between 20-94 years old and reported that the body of the hyoid bone and greater cornu remained completely open until the mean age of 45.9 years for males and 49.6 years for the females.

Moreover; in the current study, the partial or unilateral fusion of the hyoid bone started approximately 1 year earlier in females (31 years) than in males (32 years). This is consistent with other studies done by Souza et al. (3), Halloran et al. (172), Larsen WJ (177), and Miller et al. (175) who reported that fusion between the body and the greater cornu of hyoid did not usually take place until the 3rd decade. However, Leksan et al. (156) reported that fusion may occur before 30 years. Other researches as Alghazally et al. (178) and Gupta et al. (174) reported that the fusion between these bones began in the 4th decade.

Furthermore, in the current study; the fusion of the hyoid bone completed approximately 1 year earlier in females (33 years) than males (34 years). However, there is no significant difference between the mean age of fusion for the males and the females at all stages. The mean age of complete fusion in the current study is less than that revealed by Biswas et al. (79) (59 years), Ito et al. (73) (male: 67.0 years, female: 67.8 years), Biswas et al. (79) (male: 59 years, female: 55.57 years).

4.2.2 The percentage of Hyoid Bone Maturation Stages (HMS) at different age groups:

As there is a trend towards increasing the incidence of fusion with the increase in age, the grade of fusion between the greater cornua and the body of the hyoid bone could be useful for age estimation of decomposed bodies without other skeletal remains. However, numbers of middle aged and elderly individuals might have non-fusion. The anatomical reasoning behind why some greater cornua fuse to the body and others do not is yet uncertain (172).

The results of Naimo et al. (171), who examined the hyoid bone in 431 CT images of deceased persons aged between 4 days-100 years, reported that complete fusion was not seen in any person under the age of 18 years. Partial or total fusion was seen in 15.4 % of persons aged between 19-24 years and progressively increased being seen in 33 % of adults aged between 24-65 years and in 60% of the elderly aged 65 years old. Similarly, the results of Fisher et al. (69) study showed that partial or unilateral fusion for both sexes increased with

age, with the highest percentages of subjects (50%) at the age of more than 75 years. Complete fusion was not seen below the age of 20 years. These are consistent with the current study as the results showed that partial or total fusion was neither seen in males nor females below the age of 18 years. Partial or total fusion was seen in 1 (7.1%) of the females and 1 (11.10%) of the males between the ages of 18-22 years and this progressively increased, being seen in 50% of the elderly males and females aged between 43-48 years.

Even though the fuse tends to increase with age, this does not indicate that all hyoid bones will be fused in the elderly. The study of Naimo et al. (171) revealed that there was no fusion in 20% of people aged above 65 years. This supported the results of Harjeet et al. (78) and Fisher et al. (69) who also found that the hyoid remained unfused in about 42.1% and 16% respectively in the persons aged above 60 years. However, the results of Gupta et al. (174) study, who evaluated 170 excised hyoid bones from dead bodies aged between 20-65 years, showed that the percentage of the bilateral non-fusion of hyoid bone decreased sharply after the age of 50 years to be 0% after the age of 60 years.

The study of Miller et al. (175) revealed that there was no fusion in 30% of the elderly persons aged above the 4th decade. This supported the results of Ubelaker et al. (179) study, who also found that the hyoid remained unfused in about 30% of the persons aged above 40 years old. In the current study, even though the fusion tends to increase with age, this does not indicate that all hyoid bones in the old subjects will be fused. This study showed that about 2 (50%) of the females aged between 43-48 years had no fusion.

In the current study, there were non-significant sexual differences regarding the distribution of fusion stages in all the age groups. This finding is comparable with the earlier works by Biswas et al. (79) and Harjeet et al. (78), Miller et al. (175), and Shimizu et al. (180), Bhavna et al. (181), and Naimo et al. (171). Also, the current study found a significant age variation in the fusion of the greater cornua to the hyoid body in both males and females, which is in accordance with the study of Miller et al. (175) and Keten et al. (77).

4.2.3 Hyoid bone Parameters at different age groups:

Previous researches on the hyoid bone concentrated mainly on the description of general shape and size variations of this bone (175)(182). They stated that size and shape were changed by functional requirements and were influenced by the individual's sex (152), age (155)(174), ancestry (152)(183), and to a lesser extent body size parameters (71)(74).

In regards to HBW, Naimo et al. (75) who evaluated 431 CT images for deceased persons aged between 1 day to 100 years, reported that HBW of the hyoid increased from infancy (10.33 mm) to adulthood (23.07 mm) in the males and from infancy (10.85 mm) to elderly (19.51 mm) in females. HBW was significantly smaller in pre-pubescent age groups and, displayed sex difference following puberty. This result is in agreement with the result of Priya et al. (11).

According to Shimizu et al. (180), who measured the HBW on radiographs of 238 hyoid bones aged between 20-80 years, reported that for males, HBW was 23.6 mm between the age of 20-39 years, it then non-significant increased to 24.1 mm at the age group of ≥ 80 . For the female group, HBW was non-significant increased from the age of 20 years (19.3 mm) to 80 years (19.6 mm) in both male and female groups. This is in disagreement with Alghazally et al. (178), who found that HBW increases significantly with age ($p < 0.05$).

In the current study, comparing the mean value of these parameters between the age groups for both genders. In the male group, the mean value of maxHBW was 17.10 mm in the age group 8-12 years, it then increased to 25.48 mm in the age group 33-37 years. And it finally decreased to 24.36 mm. In the female group, the mean value of maxHBW was 15.49 mm in the age group 8-12 years, it then increased to 21.58 mm in the age group 38-42 years, and it finally decreased to 20.46 mm in the age group of 43-48 years. In addition, in the male group, the mean value of minHBW was 12.86 mm in the age group 8-12 years, it then increased to 19.95 mm in the age group 43-48 years. In the female group, mean value of minHBW was 12.07 mm in the age group 8-12 years, it then increased to 16.37 mm in the age group 43-48 years. However, the mean value of maxHBW and minHBW were significantly different between the age groups for both genders. These are disagreement with the study of Shimizu et al. (180) and Naimo et al. (75). On comparing the mean value of these parameters between both genders at different age groups, there were significant differences between males and females from the age 18 to 37 years regarding the mean value of maxHBW and minHBW.

In regards to HBT, the study by Naimo et al. (75) reported that HBT increased from infancy (4.50 mm) to adulthood (8.29 mm) in the males and from infancy (4.34 mm) to elderly (7.12 mm) in females. HBT was significantly smaller in pre-pubescent age groups and, displayed sex difference following puberty. This result is in agreement with the result from priya et al. (11).

Similarly, Reesink et al. (184) measured HBT in 300 hyoid bones aged between 0-80 with increased the help of digital vernier caliper reported that mean value of HBT was increase with non-significant sexual differences until the age of 12 years, but thereafter in the males, the measurements increased furthermore till the age of 25 years. In the females above 12 years, the measurements slightly increase till the age of 20 years with no further increase.

Moreover, Shimizu et al. (180) reported that HBT nearly was not significantly changed from the age of 20 years to 80 years (9.8 mm) in both sexes. This result is in agreement with the result of Alghazally et al. (178) who studied 33 hyoid bones (22 males and 11 females) from autopsied cases aged from 14-70 years.

In the current study, compared the mean value of HBT between the age groups for both genders, in the male group, the mean value of HBT was 3.28 mm in the age group 8-12 years, it then increased to 5.99 mm in the age group 23-27 years, and finally decreased to 4.68 mm in the age group 43-48 years. In the female group, the mean value of HBT was 2.52 mm in the age group 8-12 years, it then increased to 3.86 mm in the age group 43-48 years. These are agreement with the study of Naimo et al. (75), Shimizu et al. (180), Reesink et al. (184). However, HBT was non significantly different between the age groups for both genders. On comparing the mean value of this parameter between both genders at different age groups, There was a significant difference between males and females from the age of 23 to 27 years regarding the mean value of HBT.

In regards to HBH, Naimo et al. (75) reported that HBH increased from infancy (7.07 mm) to adulthood (11.95 mm) in the males and from infancy (6.89 mm) to elderly (10.95 mm) in the females. HBH was significantly smaller in pre-pubescent age groups and, displayed sex difference following puberty. This result is in agreement with the result from priya et al. (11).

Similarly, Reesink et al. (184) reported that in children; the mean value of HBH increased with non-significant sexual differences until the age of 12 years, but thereafter in the males, the measurements increased furthermore till the age of 25 years. In the females above 12 years, the measurements slightly increase till the age of 20 years with no further increase. In adults, the mean value of HBH was significantly greater in the males (11.01 mm) than in females (10.48 mm).

On the contrary, Ramagalla et al. (70), who measured HBH in 83 specimens aged between 15-75 years with the help of vernier caliper, reported that the mean value of HBH

was 15 mm in males aged between 21 and 30 years. It then decreased to 10.3 mm between the age of 51 and 60 years. The mean value of HBH was 10mm in females aged between 11 and 20 years, and then finally decreased to 9.16 mm between the age of 51 and 60 years. They reported that estimation of the age was possible in male hyoids only.

In the current study, comparing the mean value of HBH between the age groups for both genders, in the male group; the mean value of HBH was 8.88 mm in the age group 8-12 years, it then increased to 10.94 mm in the age group 28-32 years, and finally decreased to 9.77 mm in the age group 43-48 years. In the female group; the mean value of HBH was 8.37 mm in the age group 8-12 years, it then increased to 9.77 mm in the age group 43-48 years. These are agreement with the study of Naimo et al. (75). However, HBH was non significantly different between the age groups for both genders. On comparing the mean value of these parameters between both genders at different age groups, there was a significant difference between females and males from the age of 18 to 27 years regarding the mean value of HBH.

In the current study, comparing the mean value of HBD between the age groups for both genders, in the male group, the mean value of HBD was 2.87 mm in the age group of 8-12 years, it then increased to 7.66 mm in the age group 38-42 years, and finally decreased to 5.26 mm in the age group 43-48. In the female group, the mean value of HBD was 2.51 mm in age group 8-12 years, it then increased to 5.37 mm in the age group 43-48 years. However, HBD was non significantly different between the age groups for both genders. On comparing the mean value of HBD between both genders at different age groups, there was a significant difference between males and females at the age groups of 23-27 years and 33-37 years regarding the mean value of HBD. Since in the literature, there is no study evaluated the HBD at different age groups. No comparison could be made with the current literature.

4.2.4 Hyoid bone Parameters for males and females:

Several types of researches had recognized the sexual dimorphism of some skeletal components. Recent studies analyzed the metric dimensions of the hyoid bone and confirmed that the hyoid bone was a sexually dimorphic bone and for that reason, it has the ability to help the physical anthropologist in the estimation of sex (20)(72)(175)(184)(185).

In regards to the mean value of HBW, Keten et al. (77) measured HBW in the hyoid bones of 85 cadavers using a computer program subsequently by photography with a camera. They

found that the mean value of HBW in the male hyoid bones (26.28 mm) was significantly larger than female hyoid bones (23.62 mm). This result was in accordance with the result of Ito et al. (73), who evaluated the CT images of 600 cases aged between 20-87 years (HBW for male: 27.6 mm, HBW for female: 22 mm).

A similar conclusion was made by Priya et al. (11), who measured HBW in 100 hyoid bones (66 males and 34 females) aged between 15-75 years by vernier calipers. They found that the mean value of HBW in the male hyoid bones (23.24 mm) was significantly larger than female hyoid bones (20 mm). They suggested that this parameter may be useful in the determination of sex. This result was also in agreement with Vicianoa et al. (10), who measured HBW in specimens belonging to 64 individuals (HBW for male: 20.40 mm, HBW for female: 18.14 mm), also in agreement with previous studies that emphasize the sexual dimorphism of the HBW (12)(152)(180)(184). Moreover, according to kim et al. (20), who analyzed the dimensions of the hyoid bone in 85 digital photographs of cadavers; the mean age was 52 years, found that the mean value of HBW in the male hyoid bones (26 mm) was significantly larger than female hyoid bones (22.4 mm). This result was also consistent with the results of Alghazally et al. (178) study (HBW for males: 23.13 mm, HBW for females: 20.54 mm), and results of the current study (maxHBW and minHBW for males: 22.31 mm, 17.54 mm, and maxHBW and minHBW for females: 19.67 mm, 15.53 mm; respectively).

Fakhry et al. (12) evaluated the hyoid bones on 88 CT images taken from cadavers (group 1) and on 92 CT images taken from living adults (group 2). In group1, all muscles inserted on bones were removed before scanning, whereas in group2, the hyoid bone was under the effect of all the attached muscles. HBW in both groups1 and groups2 was compared to assess the effect of muscle traction on the morphology of the hyoid bone. The result revealed that there was a significant difference between the mean value of HBW in group1 (21.72 mm) and group2 (20.14mm). These results revealed that the muscles had an effect on the morphology of the hyoid bone. There was a significant correlation between HBW and age.

Sexual dimorphism of hyoid bone dimensions may be due to gender differences in the pull of the muscle on the bone. The sternocleidomastoid muscles and muscles of the larynx are more developed in the male than in the female and as a result that, the two greater horns come closer together. In addition, the success of using the hyoid bones for assessing the sex is

influenced by population, and interpopulation shifts in patterns of sex-related differences along with the suitability of the method used to extract predictive models (12).

In regards to HBT, Keten et al. (77) found that the mean value of HBT in the male hyoid bones (9.46 mm) was significantly larger than female hyoid bones (8.86 mm). This result was in accordance with the result of Ito et al. (73) (HBT for male: 7.2 mm and HBT for female: 5.9 mm), Priya et al. (11) (HBT for male: 6.14 mm and HBT for female: 5.60 mm), Vicianoa et al. (10) (HBT for male: 5.18 mm and HBT for female: 4.40 mm), and kim et al. (20), and results of current study (HBT for male: 4.51 mm and HBT for female: 3.42 mm). However, According to kim et al. (20), the mean values of HBT were statistically non-significant differences between females (7.1 mm) and males (7.8 mm). This result is also in accordance with Alghazally et al (178) who reported that the mean value of HBT in the male (7.50 mm) was non-statistically significant larger than that of the female (7.18 mm).

In regards to HBH, Priya et al. (11) reported that the mean value of HBH was statistically significant larger in male hyoid bone (11.85 mm) than in the female hyoid bones (10.04 mm). A similar conclusion was made by Vicianoa et al. (10) (HBH for male: 10.96 mm and HBH for female: 9.80 mm), and results of the current study (HBH for male: 10.36 and HBH for female: 9.17 mm).

In the current study, comparing the mean value of HBD between sexes, the mean value of HBD in the male hyoid bones (5.60 mm) were significantly larger than in female hyoid bone (4.75 mm). Since in the literature, there is no study evaluated the difference in the HBD between genders. No comparison could be made with the current literature.

4.2.5 Hyoid bone parameters at different fusion stages:

Regards to HBW, Urbanová et al. (155) evaluated 298 fused and non-fused hyoid bones for subjects aged between age 20 to 89 years. They reported that the mean value of HBW was significantly larger in the males (26.61 mm) than the females (21.96 mm) in fused hyoid bones. Also, the mean value of HBW was significantly larger in the males (24.55 mm) than the females (20.48 mm) in non fused hyoid bones. Comparing fused and non-fused hyoids, HBW in non-fused bones was statistically significant smaller values then fused bone and only HBW correlated with age. This result was in accordance with the result of Kindschuh et al. (152) who evaluated 398 fused and unfused hyoid bones. They reported that the mean value of HBW was significantly larger in the males (23.93 mm) than the females (20.29 mm) in

fused hyoid bones. Also, they reported that the mean value of HBW was significantly larger in the males (23.40 mm) than the females (20.30 mm) in non fused hyoid bones. This result is also consistency with studies of Naimo et al. (75), Keten et al. (77), and Vasavada et al. (186). In contrast, Peckmann et al. (153) evaluated HBW in 134 fused and unfused hyoids from a contemporary white population aged between 20 and 49 years old. They reported that the mean value of HBW was non significantly larger in the males (25.79 mm) than the females (22.18 mm) in fused hyoid bones. Also, they reported that the mean value of HBW was non significantly larger in the males (25.31 mm) than the females (22.11 mm) in non fused hyoid bones. The current study reported that the mean value of maxHBW was non significantly larger in the males (25.07 mm) than the females (24.39 mm) in fused hyoid bones. whereas, the mean value of maxHBW was significantly larger in the males (23.32 mm) than the females (19.97 mm) in non fused hyoid bones. In addition, The current study reported that the mean value of minHBW was non significantly larger in the male (19.94 mm) than the female (18.93 mm) in fused hyoid bones. Whereas, the mean value of minHBW was significantly larger in the males (18.38 mm) than the females (15.92 mm) in non fused hyoid bones.

Regards to HBT, Urbanová et al. (155) reported that the mean value of HBT was significantly larger in the males (6.84 mm) than the females (5.68 mm) in fused hyoid bones. Also, they reported that the mean value of HBT was significantly larger in the males (6.57 mm) than the females (5.49 mm) in non fused hyoid bones. Comparing between fused and non-fused hyoids, HBT in non-fused bones was non statistically significant smaller values then fused bone. Similarly, Peckmann et al. (153) reported that the mean value of HBT was significantly larger in the males (11.93 mm) than the females (10.14 mm) in fused hyoid bones. Also, they reported that the mean value of HBT was significantly larger in the males (12.39 mm) than the females (10.49 mm) in non fused hyoid bones. Kindschuh et al. (152) reported that the mean value of HBT was significantly larger in the males (12.13 mm) than the females (10.79 mm) in fused hyoid bones. Also, they reported that the mean value of HBT was significantly larger in the males (12.93 mm) than the females (10.87 mm) in non fused hyoid bones. This result is in agreement with kim (20) who assessed the hyoid bone of the Korean and Vicianoa et al. (10) who assessed the hyoid bone of Turkish population and stated that there is a significant difference between males and females regarding HBT. However, the current study reported that the mean value of HBT was non significantly larger in the males (4.53 mm) than the females (4.05 mm) in fused hyoid bones. Whereas, the mean

value of HBT was significantly larger in the males (5.37 mm) than the females (3.58 mm) in non fused hyoid bones.

Regards to HBH, Urbanová et al. (155) reported that the mean value of HBH was significantly larger in the males (11.53 mm) than the females (9.88 mm) in fused hyoid bones. Also, they reported that the mean value of HBH was significantly larger in the males (11.64 mm) than the females (10.48 mm) in non fused hyoid bones. Comparing between fused and non-fused hyoids, HBH in non-fused bones was non statistically significant smaller values then fused bone. This result is in agreement with the current study as the mean value of HBH was significantly larger in the males (10.66 mm) than the females (9.52 mm) in fused hyoid bones. Also, the mean value of HBH was significantly larger in the males (10.40 mm) than the females (9.12 mm) in non fused hyoid bones.

Furthermore, the current study reported that the mean value of HBD was non significantly larger in the males (7.43 mm) than the females (5.71 mm) in fused hyoid bones. Whereas, the mean value of HBD was significantly larger in the males (6.10 mm) than the females (4.92 mm) in non fused hyoid bones. Since in the literature, there is no study evaluated the difference in the HBD between different fusion sates. No comparison could be made with the current literature.

4.3 Spheno-occipital synchondrosis:

Any skeletal indicator of age that represents biological age and is independent of other indicators will be helpful in estimating the final age in both forensic or archaeological fields (187). The age estimate data from spheno-occipital synchondrosis was found to be particularly helpful in combination with information from other skeletal markers. However, in the lack of additional skeletal evidence, spheno-occipital synchondrosis was used as an independent age indicator for examining unknown human remains (83)(84)(187). It can assess the age of the adolescent and adult based on their fusion state, which starts from the endocranial border and progresses to the ectocranial border (80)(84)(187)(188). As a result of maturation, the gap between the bones; the synchondrosis is completely obliterated (83).

4.3.1 The mean age for the spheno-occipital synchondrosis fusion:

Based on previous literature, researchers had different opinions regarding the time of closure of the spent-occipital synchondrosis. They suggested that the spheno-occipital fusion is affected by hormonal and systemic changes in growing adolescent (96).

The pattern for the ossification of synchondrosis on CT images was evaluated by Mann et al. (189) and they reported that the fuse of spheno-occipital synchondrosis began at the age of 8 years and completed at the age of 16 years in females and 18 years in males. While in the study by El-sheikh (89); the complete fusion of the spheno-occipital synchondrosis was seen earlier at age of 11 years in females and 12 years in males, and in the study by Kahana et al (90); the complete fusion in individuals as young as 11 years of age.

According to Lottering et al. (82), who analyzed CT images of 448 males and 416 females aged between birth and 20 years, reported that fusion started at the age of 6.56 years for females and 7.36 years for males. The complete fusion occurred during adolescence, exactly by the age of 13.8 years for females and 16.3 years for males. Also, they demonstrated that the fusion of the spheno-occipital synchondrosis occurred 3 years earlier for females than for males.

However, Ingervall B and Thilander B (190) studied the spheno-occipital synchondrosis macroscopically and reported that the synchondrosis remained completely open until the age of 13 years for females and 16 years for males. This is compatible with the results of Okamoto et al. (92), who evaluated 253 CT images for patients aged between 1 and 77 years and reported that the synchondrosis remained completely open until the age of 13 years in both sexes. These are also compatible with the results of Kocasarac et al. (83), who evaluated panoramic and CT images for 349 subjects aged between 8 and 25 years. Their results showed that the synchondrosis remained completely open until the age of 13 years for females and 12 years for males and the earliest age of the fusion is at 14 years for females and 11 years for males. These also are in agreement with the results of Powell G and Brodie V (191), who evaluated the spheno-occipital synchondrosis of 205 males aged between 8 and 21 years. They reported that the fusion age of the synchondrosis was between 13 and 16 years for males and between 11 and 14 years for females.

Kocasarac et al. (93) evaluated 116 radiographs for patients aged between 8 and 28 years. Their result showed that the synchondrosis remained open until the age of 12 years for

females and 14 years for males. The spheno-occipital synchondrosis began to fuse at the age of 13 years for females and 14 years for males. By the age of 17 years, the fusion was completed for both genders. This is consistent with the result of Can et al. (188) who evaluated 638 CT images for men and women aged between 10 to 25 years. They reported that spheno-occipital synchondrosis remained open at the mean age of 11.54 years for males and 10.68 years for females. The spheno-occipital bone fusion began approximately 14 years in males and 12.7 years in females. By the age of 17 years, fusion was completed in both sexes. The results showed significant difference between sexes at different age groups except at the age of 10 and 16 years. The mean age for complete fusion in Can et al. (188) study was nearly matched the mean age for complete fusion in B Melsen (192) and El-Sheikh et al. (89) studies who suggested that the fusion completed at the age of 16 years for women and 18 years for men. Similarly, Ford EH et al. (193) reported that the fusion of sphenooccipital synchondrosis was completed between the age of 17 and 25 years. Whereas, Melsen (192) found that the fusion was completed between the age of 12 and 17 years.

Madeline A and Elster D (194) evaluated 189 CT for children age between 0 and 18 years. They found that synchondrosis remained partially open until the teenage years.

Similarly, Bassed et al (91) evaluated 666 CT image for individuals aged between 15 and 25 years, they reported that fusion began by the age of 15 years and completed by the age of 17 years for both sexes. Also, they demonstrated that the fusion of the spheno-occipital synchondrosis occurred 3 years earlier for females than for males this can be attributed to the early growth or maturity of girls.

Alhazmi et al. (96) analyzed the spheno-occipital synchondrosis on 741 CBCT images for individuals aged between 6 to 20 years. They reported that the mean ages of open, partially fused, mostly fused, and completely fused were 11.07, 12.95, 14.44, and 16.41 years; respectively for males, and 9.75, 11.67, 13.25, and 15.25 years; respectively for females.

D. Franklin and A. Flavel (86) evaluated 312 CT images for individuals aged between 5 to 25 years. They reported that synchondrosis remained completely open until the mean age of 10.28 years for males and 8.62 years for the females. The earliest age of fusion was at 14.30 years for males and 12.65 years for females. The mean age for complete fusion was 19.83 years for males and 18.62 years for females. Also, they observed that the fusion of synchondrosis occurred proximately 2 years earlier for females than in males. This is in

agreement with the result of Ingervall B and Thilander B (190) and Thilander B and Ingervall B (195).

However, all of these previously mentioned results were lesser than that found by Sinanoglu et al. (13) who found that the mean age for completing the fusion was greater than 20 years for both genders. Also, Akhlaghi et al. (88) analyzed the degree of spheno-occipital suture closure in 376 autopsies from both sexes aged between 8 and 26 years. They found that the mean ages of males with open, semi-closed, and closed sutures were 12.27, 16.12, and 21.17 years; respectively. However, the mean ages of females with open, semi-closed, and closed sutures were 9.04, 12.38, and 19.44 years; respectively.

Similarly, Akhlaghi et al. (196) directly inspected Iranian male cadavers aged between 8 to 26 years and concluded that the mean age for open, semi closed, and closed were 12.78, 16.86, and 21.36 years; respectively.

Moreover, Barran El and Ibrahim M (15) made a cross-sectional study on 217 CT images for subjects aged between 15 and 25 years. They reported that the mean ages of open, semi-closed, closed sutures with a scar and closed sutures without scar were 16, 18, 21.32, and 21.78 years; respectively for males, and 15, 20, 21.56 and 20.41 years; respectively for females. Similarly, in Krogman WM and Iscan YM study (197), the complete fusion was seen between 18 and 23 years.

Sahni et al. (85) and Mann et al. (189) made a direct inspection of the ectocranial site of the synchondrosis and found that there were significant differences between genders in the time of fusion as all stages for the female groups appeared earlier than the corresponding stages for the male groups. This is consistency with the results of Powell G and Brodie V (191), Ingervall B and Thilander B (190), Madeline LA, Elster AD (194), and Alhazmi et al. (96). This is because that the Puberty period initiates earlier in females than in males and as a result of the effect of life quality and the endocrine system on ossification (188).

In the current study, the synchondrosis remained completely open (SOSS1) until the mean age of 9.33 years for females and 10 years for males. The superior border fusion of synchondrosis (SOSS2) was seen at the mean age of 11.50 years for both genders. The half length fusion of synchondrosis (SOSS3) was seen approximately 6 years earlier in females (13 years) than the males (19.80 years). The fusion scar (SOSS4) was seen approximately 3 years earlier in females (25.30 years) than males (28.13 years). The complete fusion of

synchondrosis (SOSS5) was seen approximately 1 year earlier in females (28.76 years) than in males (29.60 years). However, there is a non-significant difference between males and females regarding to the mean age of fusion in all stages.

4.3.2 The percentage of Spheno-Occipital Maturation Stages (SOSS) at different age groups:

The percentage of spheno-occipital maturation stages at different age groups was evaluated by many researches. They found that there is a trend towards increasing the incidence of fusion between sphenoid and occipital bone with the increase in age. Tingne et al. (187), who evaluated 198 cadavers aged between 8 and 26 years reported that regarding the female group, the fusion was not seen in 8 (9%) of females aged 9.25 years old, the partial fusion was seen in 5 (6%) of females aged 12.6 years old, and the complete fusion was seen in 68 (83%) of females aged 20.27 years old. Regarding the male group, the fusion was not seen in 13 (11 %) of males aged 11.11 years old, the partial fusion was seen in 21 (17%) of males aged 16.80 years old, and the complete fusion was seen in 83 (70%) of males aged 21.48 years old.

Additionally, D. Sahnia (85) who studied 73 Indian subjects aged between 10 and 19 years, reported that regarding the female group; the fusion was not seen in any female aged ≥ 11 years, the partial fusion was seen in 1 (14.28%) of females aged 12 years, the complete fusion was seen in 1 (16.6%) of females aged 13 years, and at the age of 16 years, the incidence of fusion increased to 71.4%. Regarding the male group; the fusion was not seen in any males aged ≥ 12 years old, the partial fusion was seen in 2 (33.3%) of males aged 13 years old, and the complete fusion was seen in 2 (25%) of males aged 15 years old. At the age of ≤ 19 years, the complete fusion was seen in all males.

Moreover, Powell, TV and Allan G (99) examined CT images of 205 male subjects aged between 8 and 21 years; and 193 females subjects aged between 6 to 18 years. Their results showed that regarding the female group; the fusion was not seen in any female aged ≥ 8 years old, the partial fusion was seen in 2 (5.40%) of females aged 12 years old, and the complete fusion was seen in 17 (100%) of females aged 14 years old. Regarding the male group; the fusion was not seen in any male aged ≥ 9 years old, the partial fusion was seen in 2 (5.88%) of males aged 12 years old, and the complete fusion was seen in 9 (28.12%) of males aged 14 years old.

Furthermore, Sinanoglu et al. (13) who examined 238 CBCT images patients aged between 7-25 years old, reported that the fusion was not seen in 8 (20.5%) of subjects aged 7 years, the partial fusion was seen in 14 (26.9%) of subjects aged 11 years, and the complete fusion was seen in 13 (11.5%) of subjects aged 13 years.

In the current study, the results revealed that completely open synchondrosis (SOSS1) and the superior border fusion of synchondrosis (SOSS2) were not evident in male and female groups after the age of 17 years. Half the length fusion of synchondrosis (SOSS3) was found in 1(9.1%) of females between the age of 13-17 years, and 3 (33.3%) of males between the age of 18-2 years. The fusion of synchondrosis tends to increase with age to be a complete fusion in 2 (50%) of females and 2 (100%) males between age 43-48 years. There are non-significant sexual differences regarding the distribution of fusion stages in almost all the age groups except between the age of 33-37 years.

The variation in results between earlier studies regarding the closure of spheno-occipital synchondrosis may be due to the different techniques used for analysis by different researchers. The analysis of autopsy specimens, histologic sections, dry skulls, and radiography images may be interpreted differently by different researchers (84)(96). In addition, the sample size, age ranges of the sample, the use of different statistical analyses (84), environmental factors as socioeconomic status and nutritional intake in the study population are other possible reasons for variation in the time of the fusion (82).

4.3.3 Basion to Sella Length (BSL) at different age groups for both sexes:

Since in the literature, there is only two studies evaluated BSL at different age groups for both sexes. No suffusion comparison could be made with the current literature.

Regarding the basion to sella length (BSL), Powell TV and Allan G (99) measured it in 205 males aged between 8 and 21 years, and 193 females aged between 6 and 18 years. The result reveals that the BSL increased with age. The mean increase for BSL with age was smaller and slower in the females (4.57 mm) than that in the males (6.76 mm).

However, Brodie A G (198) could not find any increase in the BSL after one and a half years in longitudinal studies for population aged between the third month to the eighth year of life. They could prove that there was a continuous and slow growth between sella and basion until maturity, but such an increase could not be attributed to the synchondrosis.

In the current study, regarding the male group, the mean value of BSL was 43.10 mm at the age group 8-12 years, it then increased to reach 48.40 mm at the age group 38-42 years, and then finally decreased to 42.28 mm at the age group 43-48 years.

Regarding the female group, the mean value of BSL was 39.51mm at the age group 8-12 years, it then increased to reach 44.18 mm at the age group 43-48 years. The results showed that there was no significant difference in the mean value of BSL between all age groups for both sexes. Comparing the mean value of BSL between sex at different age groups, there were significant sexual differences at the age groups 18-22 years, 23-27 years, and 33-37 years. Comparing the mean value of BSL between sexes, the BSL in the males (45.59 mm) was significantly larger than in the females (42.53 mm). Comparing the mean value of BSL between different fusion stages (SOSS1 to SOSS5), the mean value of BSL ranged between 38.91 mm in SOSS1 to 43.49 mm in SOSS5 with non-significant differences in the mean value of BSL between different fusion stages. BSL correlated with all hyoid and cervical vertebrae parameters and fusion stages. However, SOSS should not be used as a single indicator for age estimation. Additional biological indicators are needed to reach more accurate age prediction (96).

4.4 The correlation Between Cervical Vertebrae, Hyoid Bone, and Spheno-occipital Parameters:

Since in the literature, there is no study evaluated correlation between cervical vertebrae, hyoid bone and spheno-occipital parameters. No comparison could be made with the current literature.

Roman et al. (66) evaluated lateral cephalometric radiographs of 958 Spanish children from age 5 to 18 years. The results showed that the concavity of the lower border tended to have a good correlation with the height of cervical vertebrae (female: $r=0.70$; male: $r=0.60$).

The result of the current study showed that there were significant correlations between all these parameters measured on CBCT images ($p < 0.05$) except the correlation between:

- Age with VBW3 and HBH

- CVMS with SVBT2, IVBT2, VBW2, SVBT3, IVBT3, VBW3, SVBT4, IVBT4, VBW4, HBT, and HBH.

- SVBT2 with CVMS, VBW2, VBCD3, VBCD4, and HMS.
- BSL with VBCD2, VBCD3, and VBCD4.
- HBH with VBW2, VBCD3, HMS, and HBT.
- HMS with SVBT2, IVBT2, VBW2, VBCD2, VBW4, HBH, and VBW3.
- SOSS with VBW2, IVBT2, VBW3, VBW4, BSL, and HBT.
- HBT with VBCD2, and VBCD3.

4.5 The correlation between chronologic age, Cervical Vertebral Maturation Stages (CVMS), Hyoid Bone Maturation Stages (HMS), and Spheno-Occipital Synchronosis Stages (SOSS):

Previous studies assessed the correlation between the CVMS and chronological age. This correlation was significantly in Stiehl J et al. (26) study (males: $r=0.60$; females: $r=0.68$), in Uysal et al. (163) study (males: $r=0.68$; females: $r=0.82$), in Kocasaraca et al. (93) study (males: $r=0.81$; females: $r=0.44$), in Sukhia R and Fida M (199) study (males: $r=0.78$; females: $r=0.78$), and in Bonfim et al. (98) study ($r=0.81$).

The result of all previously mentioned studies are in agreement with result of current study as there is significant correlation between CVMS and age (for all groups: $r=0.00$, for females: $r = 0.32$; for males: $r = 0.57$; $p < 0.05$).

However, today there is an agreement that chronologic age and skeletal age do not always correlate (94). These results support the other studies in which chronological age was a weak biological indicator of skeletal maturity. Caldas et al. (28) proved that there was a statistically insignificant correlation between CVMS and chronological age when they assessed the lateral cephalometric radiographs of 238 individuals aged 7-15.9 years old. These results were in accordance with a study performed earlier by Alkhal et al. (200) who also demonstrated insignificant correlation between these variables in both females and males.

Ellis Fisher (69) evaluated the correlation between age and HMS. Their result reflected a strong correlation between fusion and age group ($r=0.75$, $p=0.001$).

Other studies assessed the correlation between the degree of closure of spheno-occipital suture (SOSS) and the chronologic age. This correlation is important to explain the variability in the time of spheno-occipital suture closure between different studies with different populations, for better understanding of spheno-occipital development, and for expected age of closure (96).

Many studies over the previous century had confirmed that there was correlation between the age of an individual and SOSS for both sexes. This correlation was significantly in Tingne et al. (187) study (males: $r=0.64$; females: $r=0.78$), in Akhlaghi et al. (88) study (males: $r=0.78$; females: $r=0.85$), in kocasarac et al. (83) study (males: $r=0.59$; females: $r=0.81$), in Kocasarac et al. (93) study (males: $r=0.81$; females: $r=0.64$), in Sinanoglu et al. (13) study (males: $r=0.84$; females: $r=0.56$), in Akhlaghi et al. (196) study ($r=0.68$), in D. Franklin and A. Flavel (86) study (males: $r=0.85$; females: $r=0.82$), in Alhazmi et al. (96) study (males: $r=0.84$; females: $r=0.83$), in Shirley Natalie R (87) study (males: $r=0.62$; females: $r=0.62$), and in Can et al. (188) study (male, $r=0.71$; female, $r=0.69$).

However, Kahana et al. (90) assessed the correlation between these two variables and concluded that the fusion of spheno-occipital was not a good age indicator in male cadavers, but it could be useful for the estimation of age in females.

The current study demonstrated that a significant correlation existed between the chronological age and SOSS for both the sexes (females: $r=0.50$; males: $r=0.57$; $p < 0.05$). this is agreement with the results of previously mentioned studies (13)(86)(87)(88)(93)(96)(187)(188). So, the fusion of spheno-occipital suture can be used as a biological indicator for the onset of puberty and can be used as an indicator for chronological age.

The correlation between SOSS and CVMS was assessed in Alarcón et al. (41) study by evaluating 315 CBCT images for subjects aged between 6 and 23 years. They found a strong significant correlation between these variables (females: $r = 0.88$; males: $r = 0.89$). They also concluded that CVMS could be accurately predicted from SOSS. Also, the age significantly correlated with CVMS ($r = 0.66$) and SOSS ($r = 0.66$).

Similarly, results of recent study by Kocasarac et al. (93) who evaluated 116 radiographs for patients aged between 8 and 28 years revealed that there is a very strong correlation between age and CVMS for males ($r=0.81$) and moderate for females ($r=0.44$). There is a

strong correlation between age and SOSS (males: $r=0.81$; females: $r=0.64$), and a strong correlation between CVMS and SOSS (males: $r=0.85$; females: $r=0.61$).

The results of the current study showed that there was significant correlation between CVMS and SOSS (females: $r=0.38$; males: $r = 0.61$; $p < 0.05$).

Since in the literature, there is no study evaluated the correlation between spheno-occipital synchondrosis (SOSS) fusion, chronologic age, and cervical vertebrae maturation (CVMS) and hyoid bone maturation (HMS). No comparison could be made with the current literature.

The results of the present study showed that there was significant correlation between CVMS and HMS (females: $r=0.33$; males: $r=0.49$; $p < 0.05$), significant correlation between SOSS and HMS (females: $r = 0.27$; males: $r = 0.52$; $p < 0.05$), and significant correlation between HMS and age (females: $r = 0.66$; males: $r = 0.75$; $p < 0.05$).

To completely explain the underlying reason for variation in the correlation coefficient between chronological age and cervical maturational status between different studies, it should be emphasized that the maximum craniofacial growth velocity is a complicated process and is affected by genetic factors. In addition, racial, obesity, and several environmental factors including nutrition, civilization, physical activity, and climate affect significantly in skeletal maturity. So these factors significantly affect the correlation between chronological age and cervical maturational status of the individuals (17)(38)(94)(200).

The wide age range of the individuals in the sample of various studies might effect on this correlation because it is difficult to identify the changes in skeletal maturity accurately when the individuals are either too young or too old (18).

According to the distribution of SOSS at CVMS:

According to the distribution of SOSS from CVMS1 to CVMS6 in Alarcón et al. (41) study, SOSS1 was not seen after CVMS3, SOSS2, and SOSS3 was seen after CVMS5. SOSS 4 started seen at CVMS4. The closing of the synchondrosis was finished at the CVMS5. Also, CVMS6 started seen when spheno-occipital synchondrosis was closed (SOSS5 and SOSS6).

According to the distribution of SOSS from CVMS1 to CVMS6 in Kocasarac et al. (93) study, SOSS0 and SOSS1 were not detected after CVMS4. The closing of the synchondrosis

(SOSS2) was finished in CVMS5. In CVMS6, spheno-occipital synchondrosis was closed (SOSS3).

According to the distribution of SOSS from CVMS1 to CVMS6 in the current study, SOSS1 was seen only at CVMS1 and CVMS2. SOSS2 was not seen after CVMS5. SOSS3 was seen only at CVMS4 and CVMS5. In CVMS5, spheno-occipital synchondrosis was nearly completely closed with a fusion scar (SOSS4). In CVMS6, spheno-occipital synchondrosis was completely closed (SOSS5). There was a significant difference in the distribution of SOSS at each CVMS for both genders.

According to the distribution of HMS at CVMS:

Since in the literature, there is no study regarding the distribution of HMS at CVMS1 to CVMS6. No comparison could be made with the current literature.

In the current study; at CVMS1, CVMS2, and CVMS3, the body and greater cornu of hyoid bone were still unfused, while at stage CVM4, a partial or non-uniform fusion between the body and greater cornu has begun (HMS2). In CVM5, between the body and greater cornu of hyoid has was completely fused (HMS3). There was significant difference in the distribution of HMS at each CVMS.

5. CONCLUSION

A small FOV during CBCT scan and the usage of previously taken CBCT images obtained for different clinical indications are recommended for age and sex estimation. Therefore, CBCT images mostly include the spheno-occipital and hyoid bone area, but not the cervical vertebrae. As well, in some cases, the cervical vertebrae are partially covered by the lead apron. Due to the correlation between cervical vertebrae, spheno-occipital and hyoid bone parameters and maturation stages, the maturation of growing subjects could be estimated by evaluating the spheno-occipital or the hyoid bone, instead of the cervical vertebrae in these cases.



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7. APPENDICE

7.1 Acceptaness latter from Ethic Committe Of Yeditepe University



Sayı : 37068608-6100-15- 1571
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

03/01/2019

İlgili Makama (Eman A.B. Aguon)

Yeditepe Üniversitesi Diş Hekimliği Fakültesi Ağız, Diş ve Çene Radyolojisi Anabilim Dalı Doç. Dr. Zehra Semanur Dölekoğlu'nun koordinatör olduğu **“Konik Işınlı Bilgisayarlı Tomografide Sfenookspital Sinkondrozis, Servikal Vertebra ve Hyoid Kemik Olgunlaşma Aşamalarının Belirlenmesi ve Ölçümlerinin Yapılması ile Aralarındaki Korelasyonun Yaş ve Cinsiyete Göre Retrospektif Olarak Değerlendirilmesi”** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası (1543 kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **02.01.2019** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 925**).

Prof. Dr. Turgay ÇELİK
Yeditepe Üniversitesi
Klinik Araştırmalar Etik Kurulu Başkanı

7.2 General consent form

Hastalarınızla aranızda doğacak sorunların önüne geçilmesi açısından da büyük önem taşıyan form Yeditepe Üniversitesi Dişhekimliği Fakültesi tarafından hazırlanmıştır. Katkılarından dolayı Yeditepe Üniversitesi Diş Hekimliği Fakültesine teşekkür ederiz. İstanbul Diş Hekimleri Odası Yönetim Kurulu.

GENEL BİLGİLENDİRME VE GENEL ONAM FORMU

Sayın Hastamız,

Aşağıda size verilen bilgileri okuyunuz. Bu bilgileri okuyup imzalayarak size ya da çocuğunuza uygulanacak tedavileri hakkında bilgi sahibi olacaksınız. Tedavi planlamasının fayda ve risklerini öğrenmek sizin tedavi sonunda memnun olmanızı sağlayacaktır. Sağlıklı ve mutlu bir yaşam dileğiyle.

Tedaviler esnasında ağrı kontrolünü sağlamak amacıyla sınırlı uyuşturma uygulanmaktadır. Gerekli hallerde öncelikle topikal anestezi (sprey) ile dişeti veya yanağın iç kısmı uyuşturulur. Bölge uyuşturduğunda anestezi sıvı enjektör ile enjekte edilerek, diş ve bulunduğu bölge bir süreliğine hissizleştirilir. Lokal anestezi uygulaması sonrası nadir de olsa hastalarda alerjik reaksiyonlar, his kaybı, kanama, geçici kas spazmları, geçici yüz felci görülebilir. Lokal anestezi uygulaması, bölgede anatomic farklılıklar veya akut enfeksiyonlar olmadığı sürece başarılı bir uygulamadır. Lokal anestezi uygulanan bölge yaklaşık 2–4 saat boyunca hissizdir. Bu nedenle, ısırma ve yanak içi ve dudakta yara oluşmaması için hissizlik geçene kadar yeme içme önerilmez. 2–4 saat sonrasında anestezinin etkisi ortadan kalkar.

Tedavileriniz esnasında ileri tetkik için biyopsi alınması gerekebilir.

Sağlık kuruluşumuzun, düzeninin ve tedavi programının aksamaması için randevularınıza sadık olmaya ve zamanında gelmeye özen gösteriniz. Gelmeniz mümkün olmadığında, randevunuzu 24 saat öncesinden iptal ettiriniz.

Hasta veya Hastanın Yasal Temsilcisi* - Yakınlık Derecesi

Adı-Soyadı:

T.C. Kimlik No'su:

Adresi:

Telefon:.....

İmza:

7.3 Genel onam formu

Aşağıda imzası olan ben/hastanın vasisi/hastanın velisi, dişhekimi tarafından hastalığın teşhisi, tedavi planı ve alternatif tedaviler hakkında bilgilendirildim. Bana önerilen tedavileri kabul ettim. Şüpheli tedavilerde planlamanın değişebileceği anlatıldı, anladım ve kabul ettim.

Tedavilerimle ya da çocuğumun/..... tedavisi hakkında merak ettiğim tüm sorulara cevap verildi.

Yapılacak tedavilerin başarısının bana da bağlı olduğu, evde üzerime düşen ağız temizliği ve diyet önerilerine uymam gerektiği anlatıldı, kabul ettim.

Benim/çocuğumun/..... vazgeçmemiz gereken zararlı alışkanlıklarla ilgili önerileri

yerine getirmem ve bana/çocuğuma/..... yazılacak reçetelerdeki ilaçları tarife uygun

doz ve sürelerde kullanmam gerekliliği anlatıldı ve kabul ettim.

Bana/çocuğuma/..... uygulanacak tedavilerin uzun süreli garanti edilemeyeceği anlatıldı, anladım ve kabul ettim.

Tedaviyi kabul ettikten sonra bana/çocuğuma/..... ait bilgi, radyografi, fotoğraf, video ve diğer dokümanların eğitim ve/veya bilimsel amaçlı çalışmalarda kullanılmasını kabul edip izin verdim.

Tedavim sırasında kişisel eşyalarımın(para, mücevher, takı, giyecek, cep telefonu vb.) sorumluluğu ve güvenliğinin bana ait olduğu bildirildi, anladım ve kabul ettim.

Yukarıda belirtildiği gibi tedavi planlaması sırasında bana/çocuğuma/.....anlatılan ve benim tarafımdan kabul edilen diş tedavilerini onayladım ve kabul ettim.

Hasta haklarıyla ilgili olarak bilgilendirildi.

Hasta veya Hastanın Yasal Temsilcisi* - Yakınlık Derecesi

Adı-Soyadı :

T.C. Kimlik No'su :

Adresi :

Telefon :

İmza :

Hekimin

Adı-Soyadı :

Tarih :

İmza :

* Yasal Temsilci: Vesayet altındakiler için vasi, reşit olmayanlar için anne- baba, bunların bulunmadığı durumlarda 1. derece kanuni mirasçılardır.(Hasta yakınının isminin yanında yakınlık derecesini belirtiniz.

8. CURRICULUM VITAE (C.V)

Personal Informations

Name	EMAN.A.B	Surname	AGUORI
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Education

Degree	Department	The name of the Institution Graduated From	Graduation year
Doctorate	Oral Diagnosis and Oral Radiology	Yeditepe University, Faculty of Dentistry, Istanbul- Turkey	2022
Master	Oral Diagnosis and Oral Radiology	Yeditepe University, Faculty of Dentistry, Istanbul- Turkey	2015
University	-	Benghazi University, Faculty of Dentistry, Benghazi - Libya	2006
High school	-	Al-Fatah Center For Distinguished Students School	2000

Languages	Grades / Levels
Arabic Language	Mother language
English Language	GRE (150), TOFEL (580), and IELTS (6)
Turkish Language	C1
French Language	A1 and A2

Work Experience (Sort from present to past)

Position	Institute	Duration (Year - Year)
General dentist	Private dental clinic (Aldeya Clinic and Al Bostan Clinic) in Benghazi - Libya	2006-2013
Assistant	Benghazi University, Faculty of Dentistry, department of Oral Biology, Benghazi - Libya	2006-2013
Assistant	Yeditepe University, Faculty of Dentistry, department of Oral Diagnosis and Oral Radiology, Istanbul-Turkey	2014-2022

Computer Skills

Program	Level
ICDL: international computer driving license	Excellent
CBCT: Vision 3D, version 1.0.2.5, Imtec Image software for Iluma CBCT	Excellent
CBCT: InVivoDental5 Version 5.2 Anatomage software for iCAT units	Excellent
CBCT: Planmeca ProMax Digital Orthopantomograph using the ProMax software	Excellent
Photoshop program	Very good

Scientific works (Projects / Certificates / Rewards)

2009: Scholarship for Master Degree: Ministry of Higher Education and Scientific Research, Libyan Government.
2015: Basic life supporting course: faculty of dentistry, university of yeditepe, turkey
2015: Cross infection control course: Faculty of Dentistry, University Of Yeditepe, Turkey
2016: High Honors from oral Diagnosis and Dentomaxillofacial Dept. Faculty of Dentistry, Yditepe University. Turkey
2018: Scholarship for PhD Degree: Ministry of Higher Education and Scientific Research, Libyan Government
September 2018: Age estimation course, Cappadocia-Turkey
October 2018: Gratist (16) international congress of dentistry, Istanbul –Turkey
February 2019: Turkish-japanese dental workshop, Istanbul-Turkey
April 2019: Full on four course, Istanbul-Turkey
April 2019: Estetic restorative course, Istanbul-Turkey
April 2019: Use of lazer for treatment of oral disese course, Istanbul-Turkey
April 2019: Dental tribune sempozyum (Idex), Istanbul-Turkey
October 2019: Fast and fixed technique for immediate loading implant course, Istanbul-Turkey
October 2019: Symposium of 21st century talents in dentistry clinic, Beykent University, Istanbul - Turkey
October 2019: Gratist (17) international congress of dentistry, Istanbul-Turkey
November 2019: Rehabilitation of the excessively resorbed maxillary with zygomatic implants live surgery course, Istanbul -Turkey
January 2020: Porcelain laminate veneer training course, Istanbul - Turkey
September 2021: ITI World Symposium 2020NE - Evidence and Trends for Patient-Centered Solutions: The Challenge of Choice
September 2021: Straumann scientific corporatr forum at the ITI world symposium 2020NE
May 2022: 5 th Dental tribune sempozyum (Idex), Istanbul-Turkey

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