MORPHOMETRIC STUDY OF SELLA TURCICA USING COMPUTED TOMOGRAPHY SCAN OF THE BRAIN IN KANO METROPOLIS, NIGERIA.

BY

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A DISSERTATION SUBMITTED TO THE DEPARTMENT OF ANATOMY, BAYERO UNIVERSITY, KANO, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE DEGREE IN ANATOMY.

OCTOBER, 2019

DECLARATION

I hereby declare that this work is the product of my research efforts undertaken under the supervision of Dr. M. S. Saleh and Dr. M. K. Saleh and has not been presented anywhere for the award of a degree or certificate. All sources have been duly acknowledged.

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CERTIFICATION

This is to certify that the research work for this dissertation and the subsequent write-up by (Mubaraq Abdulsalam Yakubu, SPS/16/MAN/00011) were carried out under my supervision.

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APPROVAL

This dissertation titled "Morphometric Study of Sella Turcica Using Computed Tomography Scan of the Brain in Kano Metropolis, Nigeria" has been examined and approved for the award of Masters of Science Degree in Anatomy.

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ACKNOWLEDGEMENTS

I would like to acknowledge the contributions of the following individuals to the development of this research work:

My supervisors; Dr. M. S. Saleh and Dr. M. K. Saleh, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

My profound and sincere thanks goes to Head of Department, PG-Coordinator, the Hospital and staff that assisted me in the site of the research. Also, Associate Prof. M. A. Suwaid, whose exceptional wisdom instilled the love for Anatomy in me.

I would also like to acknowledge my family & friends, my brothers (Alh. Abubakar Yakubu, Alh. Ibrahim Yakubu, Engr. Aminu Yakubu, Hassan Yakubu, Hussaini Yakubu, Aliyu Yakubu, Late. Muhammad Yakubu and Abdulsalam Yakubu) and my sisters (Associate Prof. Hadiza Usman, Engr. Maimuna Yakubu, Late Hajiya Halima Yakubu, Hajiya Aisha Yakubu, Mairo Yakubu, Amina Yakubu, Rakiya Yakubu, Zainab Jato, Hafsat Yakubu and Hajiya Jameelah Bakari). There is no doubt in my mind that without their continued support and counsel I couldn't have completed this process. To my friends (Mustapha Al-amin, Musa S. Musa, Abdullahi Tijjani, Adam Ibrahim Kafinta, Adil Hamman, Muhammed Sajo, Umar muhammad, Maryam Tafida, Roseanne Udokwu and Aisha Muhammad Ahmad) whose unflinching loyalty and relentless advise kept me in the right direction all these years.

Lastly, I offer my regards and blessings to my wife (Mrs. Farida Ibrahim) who supported me in every way imaginable all through the duration of the project.

DEDICATION

I would like to dedicate this project to my lovely parents (Alh. Yakubu Abdulsalam and Hajiya Saida Bakari) and my late brother (Muhammad Yakubu Abdulsalam).

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ABSTRACT

Morphometric study of the Sella Turcica provides knowledge or insight about the anatomical structure of the sella area that is rooted within the skull. The use of medical imaging modalities, such as computed tomography (CT), provides the opportunity to image and survey live subjects. This study was aimed at describing the linear dimensions of sella turcica among normal Nigerian adults in Kano metropolis. A total of 198 brain CT scans was used for this study. The study population comprised of 127 males (64.1%) and 71 females (35.9%). The study highlighted mean sella dimension values of Sella Length, 10.83±1.68mm, Sella Width, 11.87±1.63mm, Sella Height Anterior, 8.89±1.66mm, Sella Height Posterior, 8.19±1.51mm, Sella Height Median, 8.59±1.67mm, Sella Depth, 7.96±1.47mm and Sella Antero-posterior Diameter, 13.41±1.81mm. A mean Sella Area of 87.14mm^2 was reported. Sexual dimorphism was established for Sella Length as the only Sella turcica linear dimension that showed statistically significant difference with a p-value of 0.034. Statistically significant difference was seen in most of the Sella turcica linear dimensions across age categories. The study found no significant correlation between Sella Area and Age. The present study provides the normal values of sella turcica linear dimensions within this Nigerian population and can help in the objective assessment of Sella turcica enlargement. The study further affirms the potentials of using computed tomography (CT) scan images in surveying and describing the Sella turcica.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Morphometric study of the Sella Turcica provides knowledge or insight about the anatomical structure of the sella area that is rooted within the skull. The use of medical imaging modalities, such as computed tomography (CT), provides the opportunity to image and survey live subjects without having to dissect the human skull. It is possible to survey the sella turcica and describe its morphology with regards to individual variations.

Early anthropologists classified humans largely through geographical origins and recognized physical traits which could be described as ethnicity. The traditional view of ethnicity is that it is “one of the major zoological subdivisions of mankind regarded as having a common origin and exhibiting a relatively constant set of physical traits”. The four traditional races of humans were: Caucasoid, Negroid, Mongoloid and Australoid (Standring *et al.*, 2016). Ethnic origin plays an important role in morphometry of bone. Morphometric studies of different races have almost always revealed variations and this established fact corresponds to ethnic variation and such variations of the bone are of clinical importance (Fathi *et al*., 2017). Anatomical variations are very important for medical education; it is paramount for surgeons to have a thorough understanding of the surgical region as this could alter diagnosis or treatment. The use of proper imaging techniques to detect these variations is essential (Aytaç, 2017).

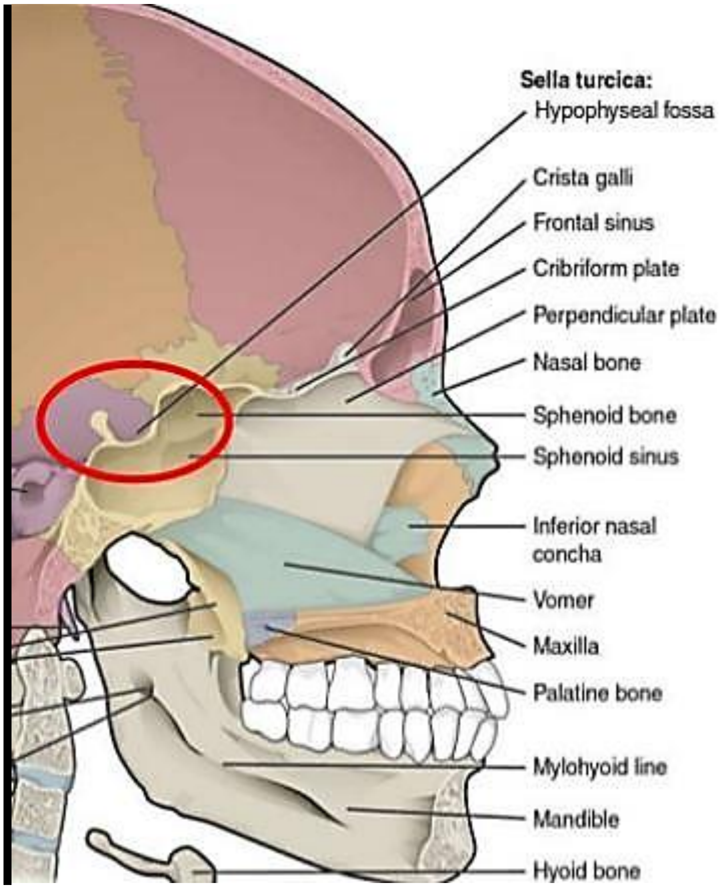


Plate I: Sketch of the Location of Sella Turcica in the Skull (Sathyanarayana *et al.*, 2013).

The sella turcica also known as hypophyseal fossa is a saddle-like depression in the body of the sphenoid bone within the human skull that accommodates the pituitary gland (Saokar, 2014). The pituitary gland is the master endocrine gland of the human body and controls other glands and secretes important hormones (Lamichhane *et al.*, 2015). The exact dimensions of sella turcica are essential in medicine (Chavan *et al.*, 2012). The skull is a useful source of information for the establishment of identity and is probably the most studied region of the skeleton (Standring *et al*., 2016). Computed Tomography (CT) study provides more accurate measurements than other studies that typically use cephalometric measurements (Turamanlar *et al.,* 2017). Data regarding the morphologic standards of people are needed in all communities as every person differs from one another (Valizadeh *et al.*, 2015).

Sella turcica is an important structure in radiographic analysis of the neurocranial and craniofacial complex. One of the pathologies of the sella turcica is the empty sella syndrome which is characterized by shrunken or flattened pituitary gland (Agrawal *et al*., 2001; Halil *et al.*, 2014). The linear dimensions of sella turcica can be used to approximate the pituitary gland size (Sathyanarayana *et al.*, 2013). The deformity of the sella turcica is often a major clue that an abnormality exists within the cranium, hence a familiarity with the sella turcica anatomy and radiological appearance is very important (Ize-Iyamu, 2014).

Researchers in various fields of study such as radiology and orthodontics have an increasing interest on describing the morphology of the sella turcica (Rennert & Doerfler, 2007). Radiographic images of the human body structures with advanced imaging technology such as CT and MRI (Magnetic Resonance Imaging) have now made it possible to study the morphology and characterize the anatomy of the sella turcica. (FitzPatrick *et al.*, 1999; Mazumdar, 2006). Neurologist and neurosurgeons assess pathologies of the sella turcica based on knowledge of anatomy of the sellar area. Understanding normal morphology of the sella turcica is fundamental to describing abnormalities concerning the region (Hassan *et al.*, 2016) and identifying sellar turcica variations helps in planning of surgery and avoiding injuries to the surrounding structures (Turamanlar *et al*., 2017).

Computed Tomography is a non-invasive method of acquiring the images of the inside of the human body without superimposition of distinct anatomical structures, from a mathematical reconstruction of X-ray (ionizing radiation) attenuation measurements made through a thin axial slice of the patient (Yates *et al.*, 2004; Buzug, 2008). Modern computed tomography allows the human body to be accurately visualized in any plane, including three-dimensional (3-D) reconstructions. Image acquisition is done with the patient moving through the beam while the detectors (which are arranged in the arc of a circle) and a stationary X-ray source are in a fixed angular position (Lee *et al.*, 2011). CT imaging is a powerful modality for central nervous system imaging and it has impeccable thorough depiction of bony structures. It offers reduced scanning duration and it is relatively available as compared to other modern imaging modalities (Laughlin & Montanera, 1998; Sgouros *et al*., 1999; Mazonakis *et al*., 2004).

The present study would be using multi-detector computed tomography (MDCT), which has been recognized as an excellent method of assessing morphometry and is regarded appropriate for 3D measurements (Kim *et al*., 2012). It would also attempt to deduce more generalized and valid data on sella turcica morphometry among normal adults and some of the major ethnic groups residing in Kano, north-western Nigeria. This can be used for establishing ethnic specific data and would assist in mapping out linear dimensions of the sella turcica among the population.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Most data references on the morphometry of sella turcica were based commonly on Caucasian studies. There was paucity of data on sella turcica studies in the metropolitan Kano Population.

1.3 JUSTIFICATION

Morphometric studies in the Nigerian population on sella turcica were scanty.

There is a rapid rise in the use of CT for diagnostic decision-making (Power *et al.*, 2016). Morphometric studies using CT scan of the brain will add more insight and give objective assessment pattern of Sella turcica dimensions in the Nigerian population.

Such studies on a larger scale are needed to corroborate the findings of other research (Zagga *et al.*, 2008).

1.4. AIM AND OBJECTIVES

1.4.1. Aim

To study the morphometric dimensions of sella turcica among normal Nigerian adults in Kano metropolis using computed tomography scan images.

1.4.2. Specific Objectives

1. To determine sella height, sella width, sella height anterior, sella height posterior, sella depth, sella anterior-posterior diameter in the normal adult population in Kano metropolis.
2. To determine sexual dimorphism on sella dimensions in the normal adult population in Kano metropolis.
3. To determine sella area in the normal adult population in Kano metropolis.
4. To determine dimensional differences in age category.
5. To correlate sella area with age in the normal adult population in Kano metropolis.

1.5 SIGNIFICANCE OF STUDY

To provide baseline reference data on sella turcica in the normal Nigerian adult population of Kano for anatomist, anthropologist, radiographers, radiologists, surgeons, orthodontist and the general academia.

CHAPTER TWO

LITERATURE REVIEW

2.1 ANATOMY OF SELLA TURCICA

2.1.1 Gross Anatomy of Sella Turcica

The skull is the bony skeleton of the head. The skull consists of the cranium, facial skeleton and mandible. The cranium is subdivided into the calvaria (sometimes called the cranial vault) and the basicranium (cranial base). It encloses the brain, cranial nerves, meninges, blood vessels and cerebrospinal fluid within the cerebral ventricles and the extra-axial fluid spaces. Internally, the cranial base can be divided into three regions corresponding to the floor of the anterior, middle and posterior cranial fossae. An alternative subdivision of the skull distinguishes between the neurocranium (calvaria and basicranium) and the viscerocranium (facial skeleton) (Standering *et al*., 2016). The term sella turcica, Latin for ‘‘Turkish saddle,’’ was introduced to the anatomical nomenclature by the anatomist, physician, and botanist Adrian van der Spieghel, in his famous work *De Corpora Humanis Fabrica*, in 1627 (Tekiner *et al.*, 2014). The sella turcica is located in the middle cranial fossa within the body of the sphenoid bone in the centre of the cranial base and is bounded by the two anterior and two posterior clinoid processes. The lesser wing of the sphenoid bone is prolonged posteromedially to form the anterior clinoid processes. The posterior clinoid processes are located at the superolateral angles of the dorsum sellae. Inconstant and variable the middle clinoid processes are located posterolateral to the tuberculum sellae. The sella turcica is composed of three parts: the tuberculum sella, pituitary (or hypophysial) fossa and the dorsum sella (Sakran *et al*., 2015). The anatomy of sella turcica has been described as variable. Sella turcica is divided in to three segments, consisting of an anterior wall, a floor, and a posterior wall (Sathyanarayana *et al*., 2013). The pituitary fossa houses the pituitary gland, and the gland is covered on its superior surface by the diaphragma sellae, which is a fold of dura matter attached to the anterior and posterior clinoid process. Central part of the diaphragma sellae is pierced by an opening for pituitary stalk (Sakran *et al*., 2015). When exposed from above by opening the diaphragma, the superior surface of the posterior lobe of the pituitary gland is lighter in color than the anterior lobe. The anterior lobe wraps around the lower part of the pituitary stalk to form the pars tuberalis (Rhoton, 1987). The posterior lobe is more densely adherent to the sellar wall than the anterior lobe. The gland's width is equal to or greater than either its depth or its length in most individuals. Its inferior surface usually conforms to the shape of the sellar floor, but its lateral and superior margins vary in shape, because these walls are composed of soft tissue rather than bone (Rhoton *et al*., 1979).

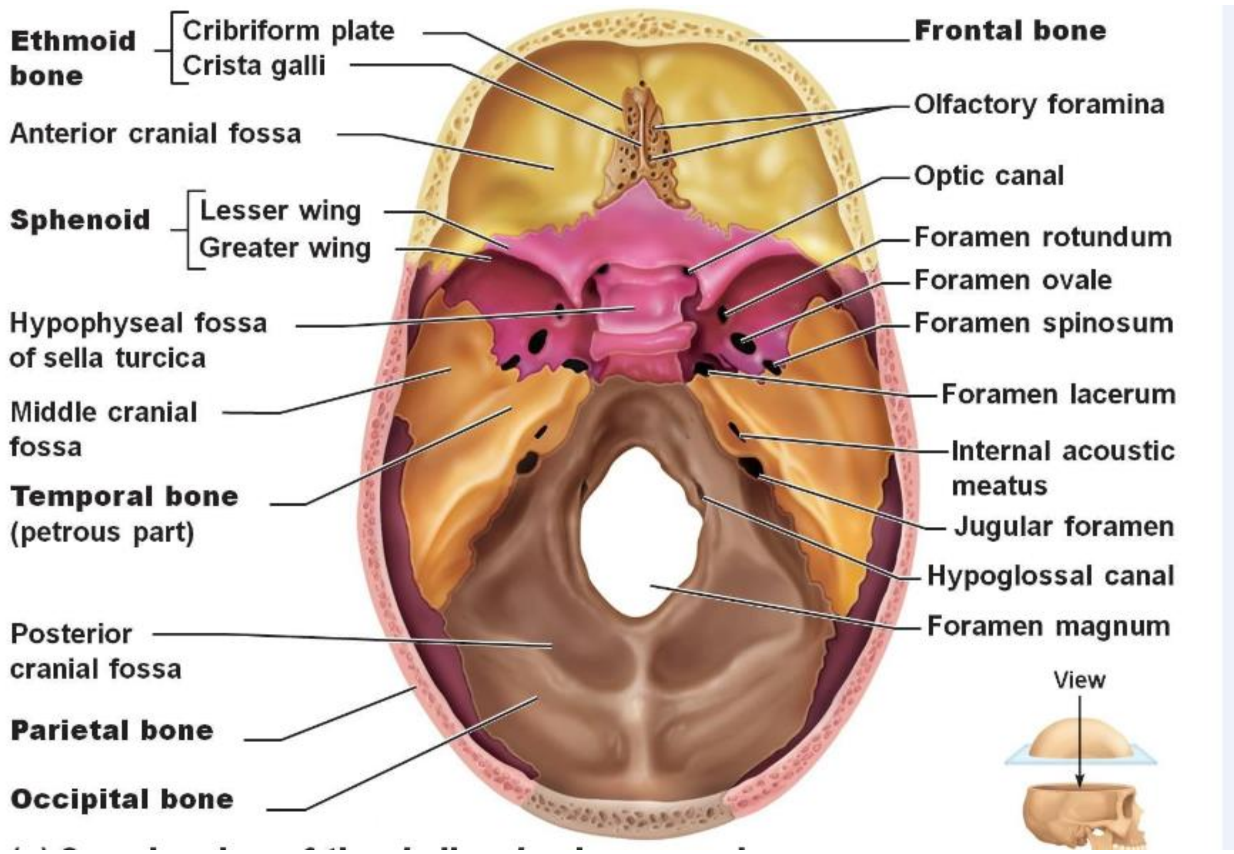


Plate II: Sketch of the Skull Showing the Basicranium (Agarwal, 2017).

Different structures relate differently with the sella region. The diaphragma sellae basically forms the roof of the sella turcica. It covers the pituitary gland, except for a small central opening in its centre, which transmits the pituitary stalk. It is frequently a thin, tenuous structure found to be at least as thick as one layer of dura in 38% over some portion of pituitary gland and extremely thin in the remaining 68% (Renn & Rhoton, 1975). In early life, the sphenoid sinus is present as minute cavities and extends backwards into the parasellar region. During adolescence, degree of pneumatization causes it to expand into the area below and behind the sella turcica, reaching its full size. However, as age advances, the sinus frequently undergoes further enlargement associated with absorption of its bony walls (Rhoton *et al.,* 1979). Pituitary gland and carotid artery are closely related with the distance separating the medial margin of the carotid artery and the lateral surface of the pituitary gland usually varied from 1 to 3 mm. However, in some cases, the artery will protrude through the medial wall of the cavernous sinus to indent the gland. The carotid arteries groove each side of the sphenoid bone and often form a serpiginous prominence in the lateral wall of the sphenoid sinus. The basilar artery rests against its posterior surface. The circle of Willis is located above its central portion and the middle cerebral artery courses parallel to the sphenoid ridge of the lesser wing. The cavernous sinuses rest against the sphenoid bone and intercavernous venous connections line the walls of the pituitary fossa and dorsum sellae (Bergland *et al.*, 1968). The chiasmatic groove, a shallow depression between the optic foramina, is bounded posteriorly by the tuberculum sellae and anteriorly by the planum sphenoidale. The relationship of the sella turcica with the optic chiasm has been classified into 'prefix' in which the optic chiasm is located on top of the tuberculum sellae, 'normal' in which the optic chiasma is located on the top of diaphragma sellae and the 'postfix' variety where the optic chiasma is located on top of the dorsum sellae (Sakran *et al*., 2015). In approximately 70% of cases, the chiasm is in the normal position. Of the remaining 30%, about half are "prefixed" and half "postfixed" (Renn & Rhoton, 1975).

2.1.2 Embryological Development of Sella Turcica

Mesenchyme (embryonic connective tissue) for formation of the head region is derived from paraxial and lateral plate mesoderm, neural crest, and thickened regions of ectoderm known as ectodermal placodes. Paraxial mesoderm (somites and somitomeres) forms the floor of the brain case and a small portion of the occipital region (Sadler & Langman, 2004).

The prenatal and postnatal formation of pituitary gland and sella turcica are complex processes. These two important structures are located in the boundary region, separating tissues of different origin and development. Origin of the pituitary gland is a result of interaction between oral ectoderm which gives rise to anterior pituitary and neural ectoderm gives rise to posterior pituitary.

The pituitary fossa differentiates directly from the hypophyseal cartilage which in turn is derived from the cranial neural crest cells of the early chondrocranium (Sathyanarayana *et al*., 2013).

During embryological development, sella turcica area is the key point for the migration of the neural crest cells to the fronto nasal and maxillary developmental fields. Formation and development of the anterior part of the pituitary gland, sella turcica, and teeth share in common, the involvement of neural crest cells, and dental epithelial progenitor cells differentiate through sequential and reciprocal interaction with neural crest-derived mesenchyme (Morotomi *et al.*, 2005). Posterior part of the pituitary gland develops from the paraxial mesoderm which is closely related to notochordal induction (Kjaer & Fischer-Hansen, 1995). The cranial skeleton develops in three stages: the membranous stage (desmocranium), the cartilaginous stage (chondrocranium), and the stage of ossification (osteocranium). The bones forming the base of the skull develop mainly via endochondral ossification, and also play an important part in the overall growth of the face and the neurocranium (Standering *et al*., 2016).

2.1.3 The Postnatal Development of Sella Turcica

Deposition of bone on the anterior part of the interior surface of the sella turcica ceases at an early age, whereas resorption on the distal part of the sella floor and on the posterior wall continues for a longer period of time. Deposition of bone is seen on the tuberculum sellae and resorption at the posterior boundary of sella turcica up to 16-18 years of age. The sella point is displaced backward and downward during growth and development (Bjork & Skieller, 1983). During puberty, growth changes occur which may alter the shape and size of the sella turcica and affect diagnosis and treatment (Zagga *et al*., 2008).

2.1.4 Sella Turcica Linear Dimensions

The size of sella turcica assessed from radiographs can be either linear or various methods of area and volume measurements. It typically ranges from 4 to 12 mm for the vertical and from 5 to 16 mm for the anteroposterior dimension (Silverman, 1957; Chilton *et al.,* 1983; Choi *et al.,* 2001).

Olubunmi *et al.,* (2016) studied the size of 297 normal adult Nigerians resident in Lagos using computed tomography scans. This was carried out to provide normal, standard reference for the indigenous population in Nigeria. This study assessed: the length, the depth and the anteroposterior diameter of the sella turcica. The results showed the mean length of 9.81±0.094mm; the mean antero-posterior diameter of 11.37±0.090mm and the mean depth of 8.49±0.08mm. The values from the study were lower than those reported in Caucasian studies. Ejike *et al.,* (2017), in a similar study, evaluated the normal adult sella turcica dimensions from computed tomography head images of 197 patients that presented at a foremost public tertiary hospital in Lagos State. The study reported that the sella turcica has mean length of 9.8 mm, AP diameter of 11.5 mm, and depth of 8.6 mm. A positive correlation was established between sella turcica dimensions and height of the subjects.

Chavan *et al.,* (2012) studied lateral radiographs of skulls of 447 subjects in Maharashtra. The various parameters of sella turcica were studied, these were greatest anteroposterior diameter, depth & area of sella turcica. A morphological study of sella turcica in Gujarat state involving 263 cadaver skulls and 37 individual dried sphenoid bones (total 300 bones) reported that the mean length of sella turcica was 10.72mm and maximum length was 14.98mm and minimum was 6.46 mm. The mean width of sella turcica was 12.45mm and maximum width was 16.89mm and minimum was 8.01mm. The mean depth of sella turcica was 6.61mm and maximum depth was 11.98mm and minimum was 2.16mm. The mean volume of sella turcica was 442mm^3 and maximum volume was 990mm^3 and minimum was 122mm^3. The mean area of sella turcica was 70mm^2 and maximum area was 133 mm^2 and minimum was 4mm^2 (Tandel & Kanjiya, 2015). Nagaraj *et al*., (2015) studied Lateral cephalometric radiographs of 200 subjects of which 100 males and 100 females in the age group of 8-30 years. Linear dimensions which include the length, depth, and anteroposterior diameter were measured. The morphological size and shape of the sella turcica in Bangladeshi populace was carried out by Islam *et al.*, (2017), the study included 166 (108 men and 58 women) Bangladeshi subjects and reported the mean values for the following linear dimension of sella diameter, sella length, sella height anterior, sella height posterior, sella height median, sella width and sella area as 9.902mm and 9.784mm, 8.637mm and 8.219mm, 7.214mm and 6.974mm, 6.937mm and 6.729mm, 6.614mm and 6.485mm, 8.426mm and 8.641mm, 54.934mm^2 and 55.919mm^2 for male and female respectively. Hasan *et al.*, (2016) studied linear and area dimensions and morphological shape of sella turcica to determine age related differences and sexual dimorphism. A total of 183 (113 men and 70 women) Malay subjects were included in the study. The mean values for sella length, sella width, sella diameter, sella height anterior, sella height posterior, sella height median and sella area were 8.46mm, 8.21mm, 10.79mm, 7.41mm, 7.40mm, 7.44 and 65.29mm^2 respectively.

Alkofide (2007) studied the lateral cephalograms of 180 Saudi subjects with an age range of 11-26 years with different skeletal types. Linear dimensions of length, depth, and diameter of sella turcica was measured. Diameter of sella turcica was larger in class III subjects and smaller in class II subjects. Sakran *et al.*, (2015) studied effect of gender on the sella turcica using 36 formalin fixed adult cadaver skulls in Saudi Arabia. The study reported the mean linear dimension for male and female sella turcica length, depth and anteroposterior diameters as 10.77mm and 11.57mm, 10.05mm and 9.5mm, 11.23 and 11.57mm, respectively. Turamanlar *et al*., (2017) included 101 brain CT scans of subjects aged 17 to 70 years in a Turkish population. Sella length, sella width, sella height anterior, sella height median, sella height posterior, sella area, sella depth and sella anteroposterior (AP) diameter were measured. The study showed sella length was measured as 9.18±1.91 mm, sella width 10.41±1.74 mm, sella height anterior 8.09±1.65 mm, sella height median 7.71±1.24 mm, sella height posterior 7.48±1.34 mm, sella area 69.15±17.45 mm^2, sella depth 7.87± 1.37 mm and antero-posterior sella diameter as 11.48±1.82 mm. The dimensions of the sella turcica vary greatly in normal individuals and are influenced by genetic and local factors. Abu Ghaida *et al.*, (2017) studied 509 computed cephalograms of 252 male and 257 female healthy Jordanians aged 10–40 years, groups were divided into two adolescent and adult age-groups for both genders. The results showed that the overall values for width, length, height, area, and aperture (interclinoid distance) were 8.72 mm, 7.68 mm, 6.25 mm, 40.80 mm^2, 3.92 mm, and 8.67 mm, 7.42 mm, 6.38 mm, 41.26 mm^2, 3.68 mm for males and females, respectively. Mustafa *et al*., (2018) studied the shape of the sella turcica in the Jordanian population with reference to age and gender in terms of width and height. For this purpose, 509 computed cephalograms: 252 males and 257 females, aged 10 to 40 years old healthy Jordanians were collected and divided into adolescent and adult age groups in both genders. The mean values for the width and height in the adult group were 9.81 ± 1.48 mm, 7.05 ± 1.24 mm and 9.00 ± 1.10 mm, 6.75 ± 0.90 mm for the male and female respectively.

A microsurgical anatomical study on 250 sphenoidal blocks from cadavers of different ages was performed by Quakinine and Hardy (1987) and found that the average transverse width of sella turcica was 12 mm, length was 8 mm, and the average height was 6 mm. Elster *et al*., (1990) in a magnetic resonance imaging study of 169 patients aged 1-30 years, Pituitary gland was 7-10 mm in females while in males it was 7 mm, both being larger than in childhood or young adult hood.

Andredaki *et al.* (2007) in 184 subjects reported the mean values for sella length and width as 7.1mm and 8.9mm respectively. Ruiz *et al.* (2008) studied a Brazilian populace and reported the mean value for sella length as 10.31mm and sella height median as 8.03mm

2.1.5 Age and Sella Turcica Dimensions

According to Preston (1979) pituitary fossa increased in size with age and found a positive correlation of the area of the sella to age. Choi *et al.* (2001) reported that the dimensional changes in the sella turcica had a significant positive linear trend to length, depth, and diameter until 25 years of age. After 26 years of age, no significant increase was found in sella turcica dimensions. Alkofide (2007) compared linear dimensions and reported that with age, the size of sella turcica was larger in older age group than in the younger age group. Nagaraj *et al*. (2015) reported that there was statistically significant increase in the depth and anteroposterior diameter of sella turcica with advance in age. Olubunmi *et al.* (2016) observed that the age group of the patients is a determinant of the sella turcica dimensions. Ejike *et al.* (2017), highlighted that there is no relationship between age and sella turcica dimensions. Hasan *et al.* (2016) reported significant differences among all age groups. Turamanlar *et al*. (2017) reported the only statistically significant difference among age groups, was in the sella area. Abu Ghaida *et al.* (2017) highlighted the highest increase the area parameter, the results support the classical notion of general trend of increase in parameters with age, irrespective of gender. Mustafa *et al*. (2018) reported significant differences were evident between adult male group on one hand and adolescent female group and adult female group on the other hand.

2.1.6 Sex and Sella Turcica Dimensions

Silverman (1957) in his extensive longitudinal radiographic investigation of 320 subjects from 1 month to 18 years of age reported that sella turcica was larger in males than in females except during puberty as this occurred about 2 years earlier and more pronounced in females than in males. Elster *et al*. (1990) found that there was no difference in the size between males and females in childhood and dramatic change occurs at puberty with swelling of the gland. They also concluded that young adults had slightly but significantly smaller glands than adolescents of the same gender. Axelsson *et al*. (2004) studied the size of Norwegian males and females longitudinally from 6 to 21 years of age with normal facial appearance and normal occlusion. The depth and diameter in males and females were similar but the length was larger in males. Alkofide (2007) found that there were no statistically significant differences between males and females in all the three linear dimensions. Chavan *et al*. (2012), found that greatest anteroposterior diameter of sella turcica, depth of sella turcica showed statistically no significant difference in their mean values of males and females indicating no sexual dimorphism. The area also showed no sexual dimorphism. Sakran *et al.* (2015) reported no significant difference between males and females concerning linear dimensions of sella turcica. Nagaraj *et al*. (2015) reported no significant difference in the linear measurements of sella turcica between males and females. Olubunmi *et al.* (2016) observed that males tend to have slightly larger sella turcica dimensions than the females. Ejike *et al.* (2017), results highlighted no difference between sella turcica dimension and the gender of the patient. Islam *et al.*, (2017), revealed no statistically significant sexual dimorphism for all linear dimensions and area estimations of sella turcica. Hasan *et al.*, (2016) reported no significant differences in size of the sella except at sella height anterior between genders with mean value of 6.05mm and 6.60mm (p <0.001.) for male and female respectively. Turamanlar *et al*. (2017) observed that only sella length and width differed significantly among males and females.

2.1.7 <u>Shape of Sella Turcica</u>

Morphological appearance of sella turcica is established in early embryonic structure. Variations in the shape of sella urcica have long been reported by many researchers. The shape of sella turcica was classified in to circular, oval, and flattened or saucer-shaped and majority of the subjects had either a circular or oval shaped sella. Other classifications were based on the contours of the sella floor, the angles formed by the contours of anterior and posterior clinoid processes and tuberculum sellae and the fusion of both clinoid processes as sella turcica bridge (Choi *et al.,* 2001).

A retrospective study of lateral skull radiographs was carried out by Zagga *et al*., (2008) in Sokoto, Nigeria. A total of 228 subjects were involved to describe the normal variants of the anatomical shapes of the sella turcica. Of this figure, 171 (75%) were males, and 57 (25%) were females (m: f ratio=3:1). The predominant shape of sella in the African subjects studied is oval, and the difference in frequency of oval shaped sella and that of round or flat types is highly statistically significant. (P<.001). The commonest type of sella floor in the African subjects studied is concave. In both the various anatomical shapes of the sella turcica and the types of floor of the sella turcica in relation to sex of the subjects studied, the difference in frequency of males and females is highly statistically significant. (P<.001).

Becktor *et al*. (2000) studied 177 lateral cephalometric radiographs and found that 18.6% of subjects had sella turcica bridging. Axelsson *et al*., (2004) categorized the shape of sella turcica into six main types - Normal sella turcica, oblique anterior wall, double contoured sella, irregularity (notching) in the posterior part of the sella, pyramidal shape of the dorsum sellae, and sella turcica bridge. The study, normal morphology was found in 71% of males and 65% of females. He concluded that sella turcica bridge was evident as early as 6 years of age. Anatomical and radiographic studies showed that the occurrence of sella turcica bridging ranges from 5.5% to 22% in normal population. A study on Bangladeshi population found that sella turcica gave three unique shapes which were considered flat (28.3%), ovoid (48.1%) and circle (23.4%) (Islam *et al.*, 2017). In another morphological classification sella turcica represent 6 different variations. Those were normal sella (69.2%), oblique anterior wall (4.8%), double contour of sella floor (6.6%), sella turcica bridge (0 %), irregularity (notching) in the posterior part of the dorsum sella (16.2%) and pyramidal shape of dorsum sella (3.0%) (Islam *et al.*, 2017). Hasan *et al*. (2016) described the shape of sella turcica in a Malay population presented with three different shapes. U shape (57.9 %), J shape (24.5 %) and shallow (17.5 %).

2.1.8 <u>Pathology of Sella Turcica</u>

The importance of size and shape of the sella turcica in connection with the occurrence of symptoms of pituitary diseases has long been recognized (Alkofide, 2007). Any abnormality or pathology in the pituitary gland could manifest from an altered size and shape of the sella turcica, to a disturbance in the regulation of secretion of glandular hormones; prolactin, growth hormones, thyroid-stimulating hormone, follicular stimulating hormone, etc. (Pisaneschi *et al.,* 2005). Around 13% of brain tumors are found in the sella turcica (Gammal *et al.*, 1972). Pathologies related to the sella turcica are usually associated with increased size. An enlargement in size not accompanied by bony erosion is usually found in intrasellar adenomas and the empty sella sendrome (Dostalova *et al*., 2003; Giustina *et al.*, 2005). An uncommon small sella turcica may be seen in primary hypopituitarism, growth hormone deficiency, and William's syndrome (Axelsson *et al*., 2004).

A close interrelationship exists between the development of brain tissue and the bones surrounding the Brain-neurocranium. Any congenital malformations in the development of brain may be detected by analyses of bones in the neurocranium. Abnormal morphology of the cranial base and the sella turcica should be included in the postnatal evaluation of craniofacial malformations. The term neuroosteology is a scientific discipline which links the osseous and neurological analyses (Kjaer, 1998). Kjaer *et al*. (2002) found that in a fetus with holoprosencephaly, the area of sella turcica displayed malformations. Literature indicates the occurrence of sella turcica bridge as a radiographic feature in basal cell carcinoma, Reigers syndrome (Koshino *et al*., 1989). Kjaer *et al*., (1998) studied the lateral cephalometric radiographs of 16 patients with myelomeningocele and found that alteration in the shape of sella was seen during fetal life in all the patients. Meyer-Marcotty *et al*. (2008) found that in all investigated patients with Axenfeld-Rieger syndrome; presence of abnormal sella turcica morphology in association with sella turcica bridge was seen. They concluded that these abnormal features could be primary indicators for diagnosis of Axenfeld-Rieger syndrome. Variations in the shape of sella turcica can be misleading since it may be present in normal subjects and in medically compromised conditions such as in spina bifida (Kantor & Norton, 1987). A change in the shape of sella turcica was evident prenatally and continued postnatally in patients with Fragile X syndrome and Down syndrome (Tetradis & Kantor, 1999; Russell & Kjaer, 1999).

The most common causes of enlargement of sella turcica are the presence of intrasellar adenomas (e.g., prolactinoma) and empty sella syndrome (intrasellar herniation of the suprasellar subarachnoid space) (Dostolova et al., 2003).] Other rare conditions like Rathke's cleft cysts and aneurysms can also cause enlargement. The size of sella turcica is smaller in primary hypopituitarism, growth hormone deficiency, Williams' syndrome (Axelsson *et al.,* 2004). Sheehan's syndrome, the necrosis of the pituitary from infarction after a complicated delivery. Most of these conditions are not immediately life-threatening but some can lead to pituitary apoplexy (necrosis and haemorrhage), which requires urgent management (Kelestimur, 2003).

Table 2.1: Sella Turcica Linear and Area Measurements Reported in Previous Studies.

STUDY	SL(mm)	SW(mm)	SHA(mm)	SHP(mm)	SHM(mm)	SD(mm)	APD(mm)	SA(mm^2)
Ruiz, *et al*., (2008)	10.1	-	-	-	6.33	-	-	41.21
Shah, *et al*., (2011)	11.3	-	-	-	-	9.9	13.9	-
Najim and Al-Nakib (2011)	9.22	-	-	-	-	7.56	11.56	-
Olubunmi et al., (2016)	9.81	-	-	-	-	8.49	11.37	-

Nagaraj et al., (2015)	9.52	-	-	-	-	8.21	11.83	-
Tandel and Kanjiya (2015)	10.72	-	-	-	-	6.61	-	70
Hasan, *et al*., (2016)	8.46	8.21	7.41	7.40	7.44	-	10.79	65.29
Islam et al., (2017)	8.63	7.21	6.93	6.61	8.42	-	9.9	54.93
Ejike et al., 2017	9.8	-	-	-	-	8.6	11.5	-
Turamanlar et al., 2017.	9.18	10.41	11.83	10.54	10.83	7.87	11.48	69.15

CHAPTER THREE

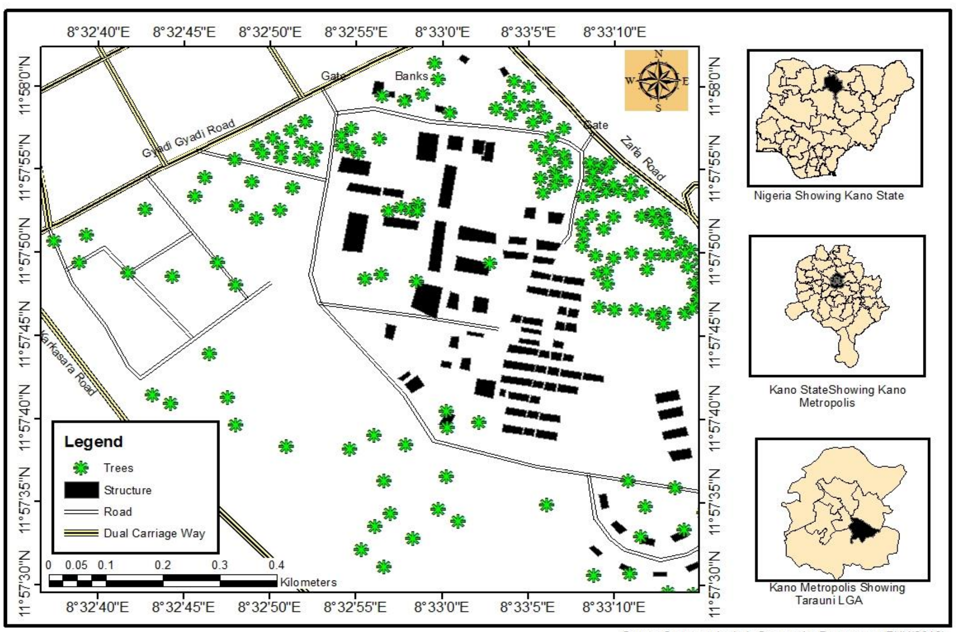
MATERIALS AND METHODS

3.1 STUDY AREA

Aminu Kano Teaching Hospital (AKTH), located in Tarauni local government area of Kano State, northwest region of Nigeria. The hospital serves as a referral hospital from both private and government health institutions.

3.2 STUDY SITE

The study was carried out at Muhammadu Sunusi (II) Radio-Diagnostic centre of the Radiology department of Aminu Kano Teaching Hospital (AKTH), located in Kano Metropolis, Nigeria.



Source:Cartography Lab Geography Department BUK(2018)

Plate III: Cartograph of Aminu Kano Teaching Hospital in Kano Metropolis. (Geography Department, Bayero University Kano. 2018).

3.3 STUDY POPULATION

The study population comprised of any Nigerian male and female adult brain scan aged 18 to 75 years which fulfilled the selection criteria.

3.4 STUDY DESIGN

A prospective, quantitative cross sectional study design was adopted for the study.

3.5 STUDY DURATION

The study was carried out between July to November 2018

3.6. SAMPLE SIZE DETERMINATION

The minimum sample size for the study was calculated using Fisher's statistical formula (Kuti *et al.*, 2017) for sample size determination as follows:

$n = z^2 P(1 - P) / d^2$ [46]

Where:

n = Minimum sample size

Z = Standard deviation (constant of 1.96 corresponding to 95% confidence interval).

P = Proportion in target population estimated to have particular characteristics. If no reasonable estimate 50% (0.5) will be used.

d = precision of study (in proportion of one; if 5%, d = 0.05).

Therefore, $n = 1.96^2 \times 0.5 \times 0.5 / 0.05^2$

$= 384.16$

Rounded up to 385.

Using the finite population correction formula to estimate the sample size (used for sampling from a population less than 10,000 without replacement)

$$N_0 = \frac{n \times N}{n+(N-1)}$$ ((Daniel, 1999).

Where N is the population size which is 325 [this was calculated from number of patients' attendees per day multiplied by number of days of data collection (within 13weeks i.e. 5 days) = 5 x 65= 325].

n is d sample size as calculated using the 95% CI = 385.

Therefore,

$$N_0 = \frac{385 \times 325}{385+(325-1)}$$

$= 176.4$

Rounded up to = 180

The finite corrected minimum sample size is 180.

3.7 INCLUSION CRITERIA

Age limit was set because during childhood, the pituitary fossa enlarges with the pituitary gland and becomes smaller if the gland decreases in size. The pituitary gland enlarges during the period of active growth, causing sella to enlarge with it. As age advances, atrophy of dorsum sellae may occur (Chavan *et al.,* 2012).

1. Any subject with age between 18 to 75 years old that present for brain CT scan at Muhammadu Sunusi (II) Radio-Diagnostic Centre, AKTH
2. Any subject of Nigerian Nationality,
3. Any scan that was reported by the reporting Radiologist
4. High quality CT volumetric data of the sella turcica with utmost clarity.

3.8 EXCLUSION CRITERIA

1. Any subject that present for CT scans of other parts of the body or with age below 18years and above 75years,
2. Subjects with previous history of plastic or reconstructive surgeries involving craniofacial or maxillofacial regions,
3. Any subject with history of previous orthodontic or prosthodontic treatment,
4. Any subject with craniofacial deformities such as cleft lip or palate,
5. Any subject with findings of trauma or tumor (growth) involving the base of skull, craniofacial or maxillofacial regions,

3.9 ETHICAL CONSIDERATION

1. Ethical clearance was obtained from the Research & Ethics Committee of AKTH (Appendix I)
2. Informed consent was obtained from all study participants with the aid of a consent form (Appendix II).
3. Participation in the study was voluntary and participant's refusal to consent did not in any way affect the services rendered to them.
4. Confidentiality and anonymity were observed strictly.
5. Data collected were used strictly for research purpose only.

3.10 METHODS OF DETERMINATION OF SELLA TURCICA DIMENSIONS

3.10.1 Study Tools and Instruments

1. Helical Computed Tomography machine – 164 slice CT scanner Aquillion prime Model TSX-303A, Toshiba Medical Systems Corporation, 1385, Shimoshigami, Otawara-Shi,

Tochigi-Ken 324-8550, Japan. Stationed at Muhammadu Sunusi II Radio-Diagnostic centre, AKTH. Manufactured by Toshiba American Medical Systems, Inc. 2012.

2. Vitrea® 2.0 (Version 6.6.3) work station. Stationed at Muhammadu Sunusi II Radio-Diagnostic centre, AKTH. A product of Vital Images, Inc., a Toshiba Medical Systems Group Company, 2014.

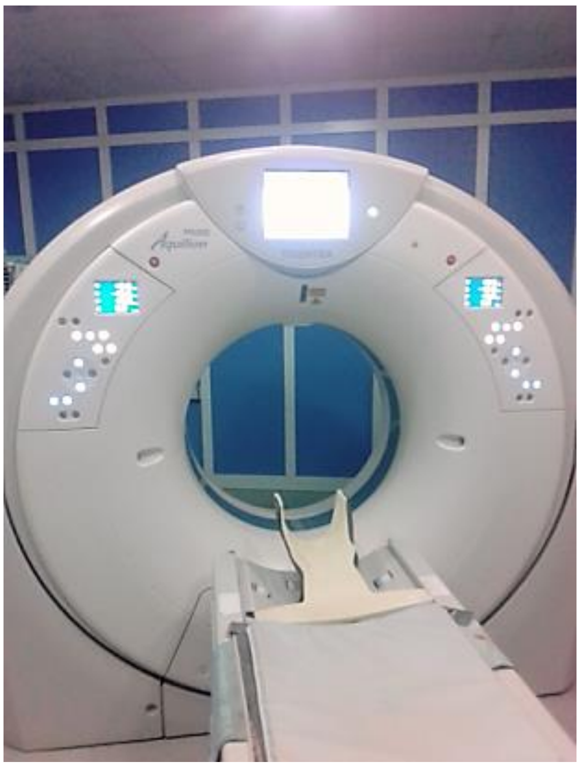


Plate IV: 164 Slice CT Scanner at Muhammadu Sunusi II Radio-Diagnostic Center, AKTH.

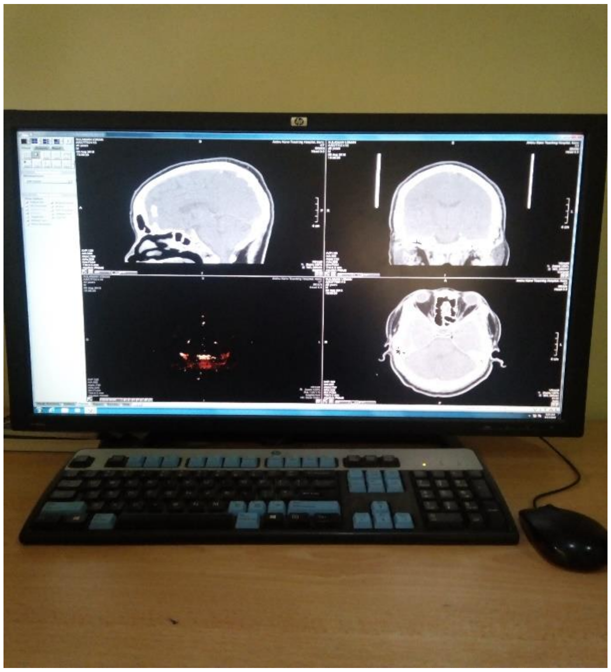


Plate V: Vitrea Work Station at Muhammadu Sunusi II Radio-Diagnostic Center, AKTH.

3.10.2 Computed Tomography Technique

All the Brain CT-scans were performed by an experienced and qualified radiographer, in a standardized conditions and manner, as described by the American Association of Physicists in Medicine (AAPM, 2016):

I. Patient should be supine, head first into the gantry, with the head in the head-holder whenever possible.

II. Center the table height such that the external auditory meatus (EAM) is at the center of the gantry.

III. To reduce or avoid ocular lens exposure, the scan angle should be parallel to a line created by the supraorbital ridge and the inner table of the posterior margin of the foramen magnum. This may be accomplished by either tilting the patient’s chin toward the chest (“tucked” position) or tilting the gantry. While there may be some situations where this is not possible due to scanner or patient positioning limitations, it is considered good practice to perform one or both of these manoeuvres whenever possible.

However, a modified approach to the technique was performed. After explaining examination/procedure to the research participants/patients the following steps were taken:

I. Subject/Patients was asked to wear comfortable clothing with loose fittings and removed all jewelleries/metals around the area to be examined for the period of the examination to avoid artefacts in the resultant images.

II. The patient/subject was placed on the CT couch in supine position with the head placed in the head rest (cradle). Patient was placed with orientation of "Head first".

III. Head was centralized and supported for correct alignment with head pads thus reducing blurring of images. Ear plugs are placed on patient ears to reduce the sound of the moving X-ray tube.

IV. The neck was flexed so that the orbito-meatal base line is perpendicular to the horizontal laser light. The vertical laser light is then coincident with the mid-saggital plane of the patient. The horizontal laser light is coincident with the coronal plane at the external auditory meatus (EAM) with the Frankfurt horizontal plane perpendicular to the gantry.

V. Initial scanning point (laser centering point) was set at the Philtrum (corresponding to the base of skull). Scanning commences, moving cephalad, beginning from base of skull to end at the vertex.

3.10.3 <u>CT Scan Protocol for Routine Adult Brain</u>

The protocol for routine adult brain CT was designed to be in helical mode. The scan parameters were set at 120 kilovoltage (kV) and 250 Milliampere (mA). In most cases automatic mA is prescribed due to its dose saving effect. The slice thickness in the scanner was set at 0.5mm for adult brain. An average total of 400 images were gotten from base of the skull to the vertex. These scan images are generated and stored in DICOM (Digital Imaging and Communications in Medicine) format on the Aquillion prime work station and then transferred to Vitrea work station for reporting.

3.10.4 Image Analysis

CT images generated and saved in DICOM format on Vitrea software, that have been reported by the Consultant Radiologist in the Radiology Department, AKTH was used. The software utilizes the existing axial view to create cross-sections in the sagittal and coronal views.

The analysis was made on the sagittal view of the bone window, using the coronal and axial view to manipulate and align for the sagittal section that is nearest to the mid-saggital plane as described by Turamanlar *et al.*, (2017) and Abu Ghaida *et al.*, (2017).

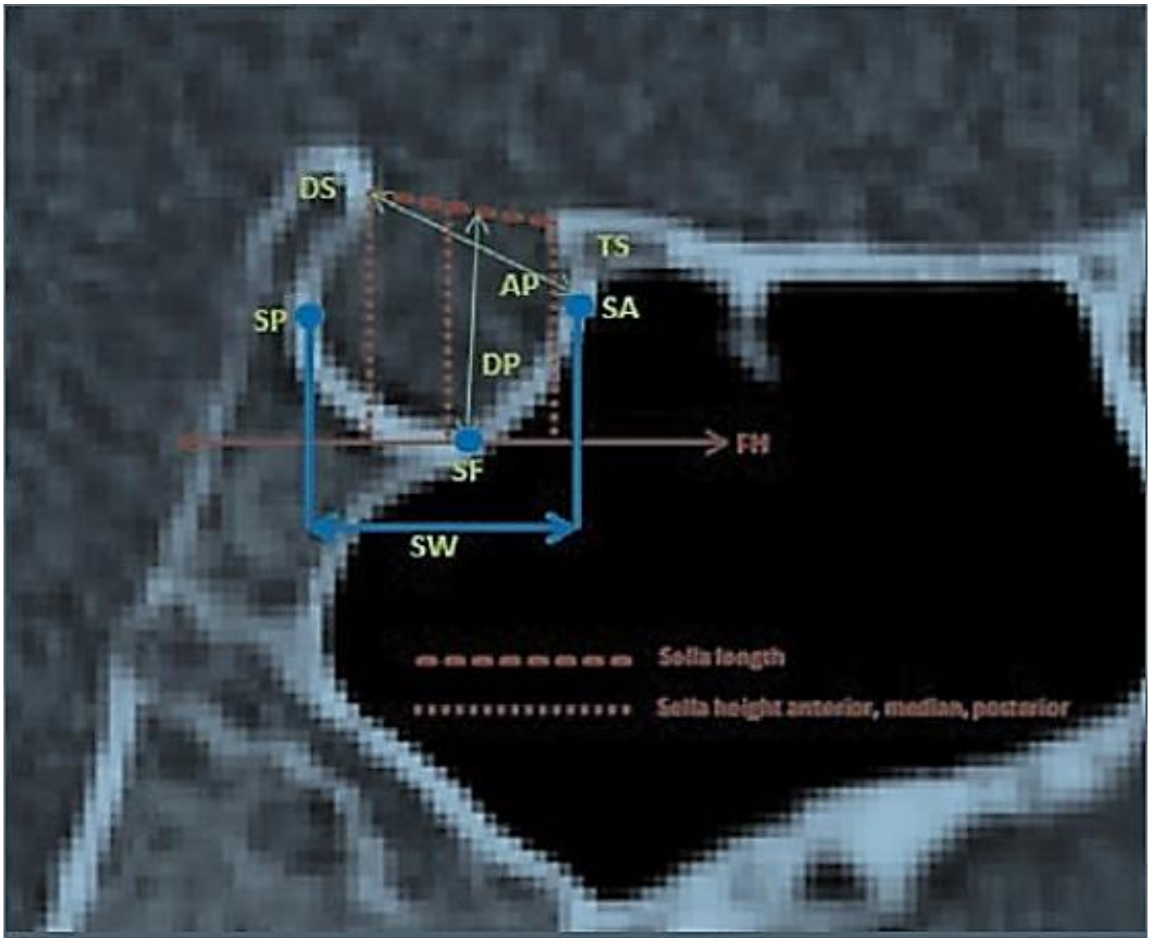


Plate VI: Mid-sagittal Section of the Sella Area Showing Linear Measurements of Sella Turcica (Turamanlar *et al*. 2017).

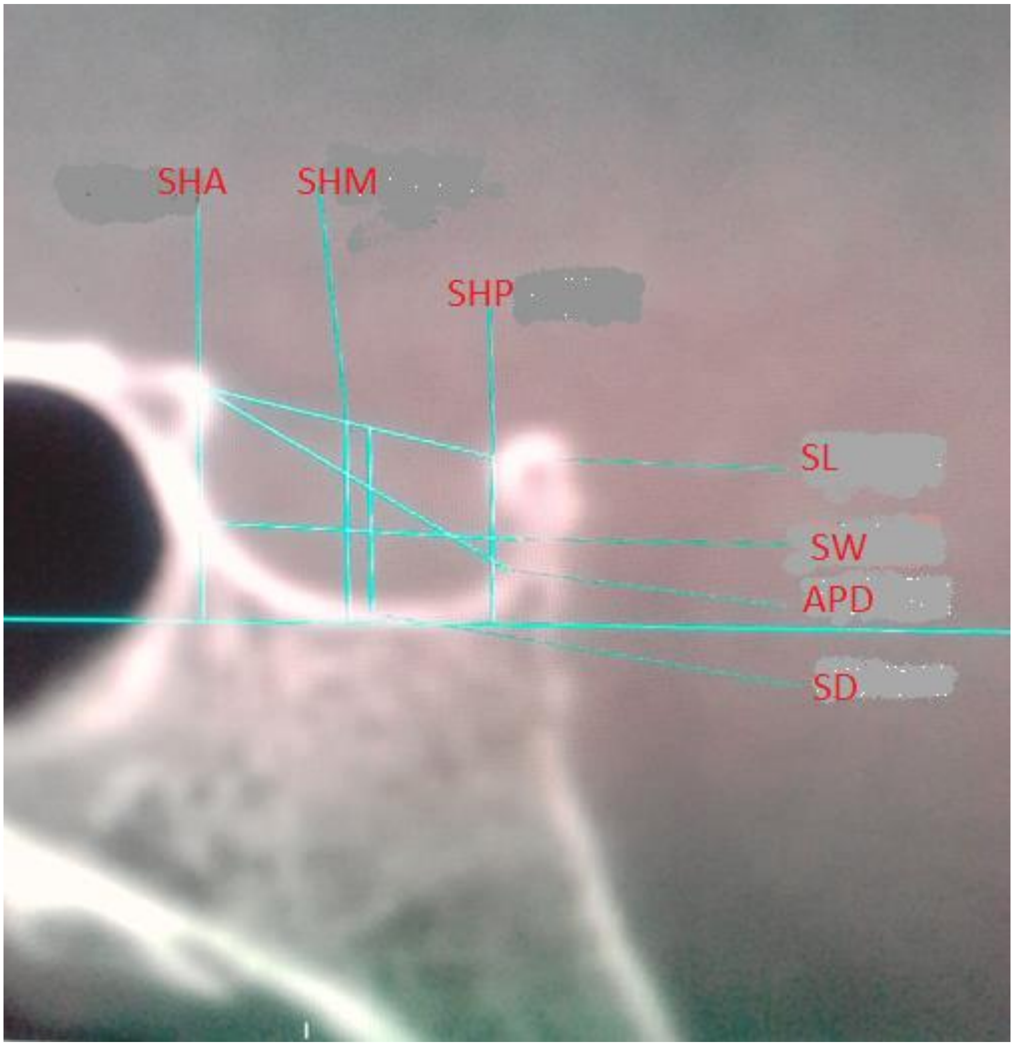


Plate VII: Mid-sagittal Section of the Sella Area Showing Linear Measurements of Sella Turcica (Present Study)

3.11 ANTHROPOMETRIC STUDIES

3.11.1 Safety Measures

Morphometric measurements were done using selected parameters on the sagittal section that is nearest to the mid-sagittal plane. The averages of three readings of each measurement was considered for the statistical analysis in order to minimize the intra-examiner variation.

3.11.2 Measurement of Sella Length (SL)

Equipment for measuring SL: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper

Technique for measuring (SL): Line measuring the distance between tuberculum sellae (TS) and dorsum sellae (DS) points.

3.11.3 Measurement of Sella Width (SW)

Equipment for measuring SL: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper

Technique for measuring SW: Line measuring the longest antero-posterior length measured parallel from the most anterior and posterior points of sella turcica to the Frankfort horizontal plane (FH).

3.11.4 Measurement of Sella Height Anterior (SHA)

Equipment for measuring SHA: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper

Technique for measuring SHA: Line measuring the vertical distance measured from TS through sella turcica base to the FH plane.

3.11.5 Measurement of Sella Height Posterior (SHP)

Equipment for measuring SHP: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper.

Technique for measuring SHP: Line measuring the vertical distance measured from DS through sella turcica base to the FH plane.

3.11.6 Measurement of Sella Height Median (SHM)

Equipment for measuring SHM: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper.

Technique for measuring SHM: Line measuring the vertical distance measured from the midpoint between TS and DS to the FH plane.

3.11.7 Measurement of Sella Turcica Antero-posterior Diameter (APD)

Equipment for measuring APD: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper.

Technique for measuring APD: Line measuring the distance measured from the tuberculum sellae to the backmost point in the interior surface of the posterior wall of the pituitary fossa.

3.11.8 Measurement of Sella Turcica Depth (SD)

Equipment for measuring SD: DICOM image at mid-saggital plane on Vitrea work station that is equipped with electronic caliper.

Technique for measuring SD: The length of the line measuring drawn vertically from the deepest BPF in the direction of the sella turcica length

3.11.9 Determination of Sella Area (SA)

This was determined by obtaining the value, in mm^2, of the product of length and depth.

Where; TS = Turberculum Sellae, DS = Dorsum Sellae, FH = Frankfort Horizontal plane

3.12 STATISTICAL ANALYSES

Data were recorded using a computer spreadsheet program (Microsoft Office 2010 EXCEL; Microsoft Corporation; Redmond, WA. USA). Discrepancies was queried and corrected. Data analysis were performed using a statistical software package SPSS, version 20 for Windows. Data were presented in tables and charts.

Data were analyzed for descriptive statistics and represented as mean and standard deviations for continuous variables and as proportions/percentages for categorical data. Independent sample test and Mann-Whitney were used to analyze for differences between gender while one-way ANOVA and Kruskal Wallis were used to check for association between age of subjects and the parameters recorded. Statistical significance was set at $P<0.05$.

Data were kept in computer pass worded file, and hard copies of documents was locked in cabinet, access to which was only available to the researcher, to ensure confidentiality and safety of data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 DESCRIPTIVE STATISTICS

4.1.1 Distribution of Participants in the study

A total of 198 brain CT scans was used for this study. CT scans were certified normal and signed by a Consultant Radiologist. The study comprised of 127 males (64.1%) with mean age of 41.39±15.16 years and 71 females (35.9%) with mean age of 40.10±15.63 years. Overall mean age was 40.92±15.30 (Table 4.1).

Table 4.1: Distribution of Participants in the Study

Sex	N (no. of Subjects)	Age (yrs) (Mean±SD)
Males	127	41.39±15.16
Females	71	40.10±15.63
Mean	198	40.92±15.30

4.1.2 Distribution of Participants Based on Age Category in the Study

Participants between 18-25 years (first age category) had the highest frequency of n=48 with a percentage of approximately 24%. The least frequency was the participants between 66-75 years (sixth age category) with a frequency of n=6 and a percentage of 6% (Table 4.2).

Table 4.2: Distribution of Participants in Age Categories

Age Cat. (Yrs.)	Frequency	Percentage	Minimum	Maximum
1 (18-25)	48	24.2	18	25
2 (26-35)	37	18.7	26	35
3 (36-45)	36	18.2	36	45
4 (46-55)	34	17.2	46	55
5 (56-65)	37	18.7	56	65
6 (66-75)	6	3.0	66	75

4.1.3 Total Mean Values for Sella Dimensions and Sella Area in the Study

In the present study, the overall mean Sella Length, Sella Width, Sella Height Anterior, Sella Height Posterior, Sella Height Median, Sella Depth, Sella Antero-posterior Diameter and Sella Area were estimated to be 10.83±1.68mm, 11.87±1.63mm, 8.89±1.66mm, 8.19±1.51mm, 8.59±1.67mm, 7.96±1.47mm, 13.41±1.81mm and 87.14±24.81mm^2 (Table 4.3).

Table 4.3: Total Mean Values for Sella Dimensions and Sella Area.

DIMENSIONS	MEAN±SD	MINIMUM	MAXIMUM
Sella Length	10.8±1.68mm	7.0mm	16.6mm
Sella Width	11.87±1.63mm	7.4mm	17.4mm
Sella Height Anterior	8.89±1.66mm	5.2mm	13.9mm
Sella Height Posterior	8.19±1.51mm	4.9mm	12.4mm
Sella Height Median	8.59±1.67mm	5.1mm	18.5mm
Sella Depth	7.96±1.47mm	5.0mm	13.0mm
Sella Antero-posterior Diameter	13.41±1.81mm	7.3mm	18.0mm
Sella Area	87.1±24.8mm^2	39.1mm^2	185.9mm^2

4.1.4 Mean Values of Sella Dimensions and Sella Area for Male and Female in the Study

Also mean values of Sella Length, Sella Width, Sella Height Anterior, Sella Height Posterior, Sella Height Median, Sella Depth, Sella Antero-posterior Diameter and Sella Area for male were determined to be 11.01±1.56mm, 11.99±1.52mm, 8.80±1.68mm, 8.09±1.47mm, 8.52±1.75mm, 7.89±1.43mm, 13.47±1.82mm, 87.53±22.49mm^2 and for female were 10.51±1.86mm, 11.66±1.80mm, 9.06±1.61mm, 8.35±1.58mm, 8.70±1.53mm, 8.08±1.54mm, 13.30±1.81mm, 86.43±28.66mm^2 (Table 4.4).

Table 4.4: Mean Values of Sella Dimensions and Sella Area for Male and Female in the Study.

DIMENSIONS	MEAN±SD	
	MALE	FEMALE
Sella Length	11.01±1.56mm	10.51±1.86mm
Sella Width	11.99±1.52mm	11.66±1.80mm
Sella Height Anterior	8.80±1.68mm	9.06±1.61mm
Sella Height Posterior	8.09±1.47mm	8.35±1.58mm
Sella Height Median	8.52±1.75mm	8.70±1.53mm
Sella Depth	7.89±1.43mm	8.08±1.54mm
Sella Antero-posterior Diameter	13.47±1.82mm	13.30±1.81mm
Sella Area	87.53±22.49mm^2	86.43±28.66mm^2

4.1.5 Levene's Test for Sella Width and Sella Antero-posterior Diameter

Table 4.6 shows the relationship between male and female with the independent sample test for Levene's test (parametric test) for equality of variances for SW and APD having a value of 0.157 and 0.951 ($p>0.05$)

Table 4.5: Levene's Test for Sella Width and Sella Antero-posterior Diameter

VARIANCE	SIGNIFICANCE
SW	0.157**
APD	0.951

P-value <0.05 are statistically significant.

4.1.6 Mann-Whitney U Test for Sella length, Sella Height Anterior, Sella Height Posterior, Sella Height Median, Sella Depth and Sella Area

Table 4.7 shows Mann-Whitney test (non-parametric test) for SHA, SHP, SHM, SD and SA with asymptotic significance (2-tailed) as 0.348, 0.301, 0.348, 0.400 and 0.347 ($p>0.05$). The SL is at 0.034 ($p<0.05$) which is the only dimension that shows statistically significant difference.

Table 4.6: Mann-Whitney U Test Values for Sella length, Sella Height Anterior, Sella Height Posterior, Sella Height Median, Sella Depth and Sella Area

	SL	SHA	SHP	SHM	SD	SA
Mann-Whitney U	3691.000	4145.500	4108.500	4146.000	4186.000	4144.500
Asymp. Sig. (2-tailed)	.034**	.348	.301	.348	.400	.347

P-value <0.05 are statistically significant.

4.1.7 Mean Values of Sella Dimensions and Sella Area in Age Categories

This study used parametric tests for the normally distributed parameters and non-parametric tests for not normally distributed parameters. The present study highlighted different mean values for patients within different age categories (Table 4.4).

Table 4.7: Mean Values of Sella Dimensions and Sella Area in Age Categories

Age Cat. (Yrs.)	SL(mm)	SW(mm)	SHA(mm)	SHP(mm)	SHM(mm)	SD(mm)	APD(mm)	SA(mm^2)
1 (18-25)	10.19±1.71	11.39±1.64	9.36±1.90	8.72±1.48	9.05±1.61	8.45±1.59	13.26±1.92	87.63±26.66
2 (26-35)	10.90±1.78	11.39±1.51	8.52±1.65	7.81±1.71	8.17±1.64	7.52±1.61	13.51±1.60	83.12±27.38
3 (36-45)	10.79±1.51	11.56±1.58	9.03±1.51	8.12±1.52	8.84±2.23	7.87±1.39	13.12±2.01	85.27±24.04
4 (46-55)	10.84±1.68	11.98±1.85	8.20±1.43	7.85±1.18	8.00±1.19	7.59±1.09	13.23±1.85	83.67±20.47
5 (56-65)	11.66±1.43	12.64±1.43	8.98±1.33	8.04±1.36	8.52±1.26	8.06±1.37	13.88±1.52	94.22±22.46
6 (66-75)	10.63±1.76	11.76±0.94	9.95±2.08	9.40±1.72	9.66±1.81	8.66±1.52	13.85±2.31	95.10±32.00

4.1.8 One-way ANOVA with Dimensional Differences in Age Categories

The results showed an asymmetrical pattern of distribution for linear dimensional values. Differences between linear dimensions and area using age categories factor was established using one-way ANOVA (parametric test) for SW and APD. SW showed statistical significant difference ($p<0.05$) while APD did not show any statistical significant difference ($p>0.05$) with F-value of 0.014, and 1.27 respectively (Table 4.8).

Table 4.8: One-way ANOVA with Dimensional Differences in Age Categories

VARIABLE	SOURCE	F	p-value
SW	Age group	2.925	0.014**
APD	Age group	0.910	0.476

P-value <0.05 are statistically significant.

4.1.9 Post-hoc Analysis of Dimensional Differences across Age Category Using One-Way ANOVA.

However, a post-hoc test using Bonferroni method across the various age categories revealed that in the SW, significant difference exist between the first and fifth age categories. While no significant difference exists across other age categories (Table 4.9).

Table 4.9: Post-hoc Analysis of Dimensional Differences across Age Category Using One-Way ANOVA.

VARIABLE	(I)AGE CAT.	(J)AGE CAT.	SIGNIFICANCE
SW	1	2	1.000
		3	1.000
		4	1.000
		5	0.006**
		6	1.000
	2	3	1.000
		4	1.000
		5	0.852
		6	1.000
	3	4	1.000
		5	0.063
		6	1.000
	4	5	1.000
		6	1.000
	5	6	1.000

P-value <0.05 are statistically significant.

4.1.10 Kruskal Wallis Test for Dimensional Differences across Age Groups

Kruskal Wallis Test (non-parametric test) was used to determine differences between dimensions of SL, SHA, SHP, SHM, SD and SA. Statistically significant difference ($p<0.05$) was noted for SL, SHA, SHP, SHM and SD. While no statistically significant difference ($p>0.05$) was noted for SA (Table 4.10).

Table 4.10: Kruskal Wallis Test for Dimensional Differences across Age Groups

	SL	SHA	SHP	SHM	SD	SA
Chi-Square	17.650	12.385	14.517	14.673	13.398	8.071
df	5	5	5	5	5	5
Asymp. Sig.	0.003**	0.030**	0.013**	0.012**	0.020**	0.152

P-value <0.05 are statistically significant.

4.1.11 Spearman Correlations of Sella Area with Age

The study revealed the Sella Area to be not normally distributed. The Spearman correlation (non-parametric test) was used to check the correlation of Sella Area with Age. However, no significant correlation was established as the p-value was >0.05 (Table 4.11).

Table 4.11: Spearman Correlations of Sella Area with Age

VARIABLE	CORRELATION COEFFICIENT	SIGNIFICANCE
Age	0.117	0.099

P-value <0.05 are statistically significant.

4.2 DISCUSSION

The present study estimated mean sella dimension values of Sella Length, 10.83±1.68mm, Sella Width, 11.87±1.63mm, Sella Height Anterior, 8.89±1.66mm, Sella Height Posterior, 8.19±1.51mm, Sella Height Median, 8.59±1.67mm, Sella Depth, 7.96±1.47mm and Sella Antero-posterior Diameter, 13.41±1.81mm. Other literatures, from nearby regions, have conducted similar studies and reported on Sella Length, Sella Depth and Sella Antero-posterior Diameter.

Research on sella turcica linear dimensions has been conducted using various approach by different researchers across the world. Olubunmi, *et al.* (2016) estimated the mean length of 9.81mm. Also, another study reported mean length of 9.8mm (Ejike, *et al*., 2017). Ruiz, *et al*., (2008) reported Sella length as 10.31mm. Shah, *et al*., (2011) reported 11.3mm. Similarly, Najim and Al-Nakib (2011) reported 9.22mm. Nagaraj, *et al*., (2015) reported 9.52mm. These large differences in reported values with the present study can be explained due to the methodological approach as different measurements methods were adopted by different researchers.

The Sella Depth reported by Olubunmi, *et al.* (2016) was 8.49. Ejike, *et al*., 2017 reported 8.6mm. Najim and Al-Nakib (2011) reported 7.56mm. Likewise, Nagaraj, *et al*., (2015) reported 8.21mm. All these aforementioned reported values were similar to the present study as compared to 9.9mm reported by Shah, *et al*., (2011). However, the dimensional differences of the findings could be attributed to predictable differences in normal subjects included in the present study and abnormal subjects included in the study by Shah, *et al*., (2011).

Also, Olubunmi, *et al.* (2016) reported Sella Antero-posterior Diameter as 11.37mm. Ejike, *et al*., 2017 reported 11.5mm. Najim and Al-Nakib (2011) reported 11.56mm. Nagaraj, *et al*., (2015) reported 11.48mm. These reported values are lower than that reported in the present study.

Whereas, Shah, *et al*., (2011) reported 13.9mm which is similar to that of the present study. Again, the similarities and dissimilarities could be due to different measurements methods.

Few studies were found on Sella Height Anterior, Sella Height Posterior and Sella Height Median. Nevertheless, of the studies performed, Hasan, *et al*., (2016) reported 7.41mm, 7.40 and 7.44 for Sella Height Anterior, Sella Height Posterior and Sella Height Median respectively. Islam, *et al*., (2017) reported 6.93mm, 6.61mm and 8.42. Also, Turamanlar *et al*., (2017) reported values of 11.83mm, 10.83mm and 10.54mm for Sella Height Anterior, Sella Height Posterior and Sella Height Median respectively. These values reported do not correlate with the present study. However, a matching pattern of distribution is noted between the present study and that of Turamanlar *et al*., (2017). Evidently, this similarity could be as a result of similar methodology adopted in both studies.

The present study reported mean sella dimension values for males as 11.01±1.56mm for Sella Length, 11.99±1.52mm for Sella Width, 8.80±1.68mm for Sella Height Anterior, 8.09±1.47mm for Sella Height Posterior, 8.52±1.75mm for Sella Height Median, 7.89±1.68mm for Sella Depth and 13.47±1.82mm for Antero-posterior Diameter. While the dimensions for females is reported as 10.51±1.86mm for Sella Length, 11.66±1.80mm for Sella Width, 9.06±1.61mm for Sella Height Anterior, 8.35±1.58mm for Sella Height Posterior, 8.70±1.53mm for Sella Height Median, 8.08±1.54mm for Sella Depth and 13.30±1.81mm for Antero-posterior diameter.

An expansive earlier study by Silverman (1957) reported larger sella turcica in males than in females. However, Silverman (1957) stated that during puberty, sella turcica in females is more prominent than in males. Likewise, Elster *et al*., (1990) described that during puberty, certain changes occur which causes swelling of the gland. Conversely, the study established no significant difference between male and female. Axelsson *et al*., (2004), reported larger Sella Length in

Norwegian males than females with similar Sella Depth and Sella Diameter between males and females. Chavan *et al*., (2012) and Nagaraj *et al*., (2015), reported no significant difference in their studies involving an Indian populace. On the other hand, Turamanlar *et al*., (2017) studied a Turkish population and observed significantly higher values for both Sella Length and Sella Width in males.

Olubunmi *et al.,* (2016) observed a general higher values in all linear dimensions for males as compared to females in a Nigerian population. Similarly, the present study reported Sella Length as the only dimension that shows statistically significant difference. However, no statistical difference exist in other dimensions of the present study. This similar outcome could be described as a result of geographical proximity and comparable populace used in both studies. On the other hand, Ejike, *et al.,* (2017) demonstrated no significant difference between sella turcica of male and female subjects but nevertheless, a slight difference between the sella dimensions of males and females was observed in the study. The trivial contrary finding may be due to geographical differences, racial or ethnic factors.

Although, both Ejike, *et al.,* (2017) and the present study revealed a similar outcome of males subjects having considerably higher values for Sella Length and Sella Antero-posterior diameter than females whereas females have higher values for Sella Depth. This could also be explained as a proximity factor of subjects included in the study.

An earlier study conducted by Preston (1979) revealed that pituitary fossa increased in size with age. Longitudinal studies of sella turcica have illustrated positive results of age related increase in size, mainly because of its contents, i.e. the pituitary gland (Chilton, *et al*., 1983). The present study revealed a significant difference in all the sella dimensions with the exception of Antero-posterior Diameter. The post-hoc analysis on Sella Width showed statistically significant difference between the first (18-25) age category and the fifth (56-65) age category.

Axelsson *et al*. (2004) described that during growth a steady increase in size for both genders is expected. Rennert and Doerfler (2007) in their cross-sectional study of orthodontic patients, revealed an increase in sella dimensions with age, mainly the 6 – 10 to the 21 – 25 age category. In the study by Najim and Al-Nakib, (2011), the only significant difference was noted in Sella Depth. Chauhan *et al*., (2014) reported higher values for higher age group and lower values for lower age group in Sella turcica linear dimensions. Similarly, Nagaraj *et al*. (2015) described a positive correlation of Sella Depth and Antero-posterior Diameter with age. Similarly, Olubunmi *et al.,* (2016) reported that the age group of the patients is a determinant of the sella turcica dimensions. Hasan *et al*., (2016) reported significant difference across age groups with Sella turcica linear dimensions. Turamanlar, *et al.* (2017) noted a significant increase in some Sella turcica linear dimensions with age, namely; Sella Length, Sella Width, Sella Height Median and Sella Height Posterior. Furthermore, the present study revealed findings that shows agreement with most other studies. Although, most literatures have limited number of dimensions to Sella Length, Sella Width and Sella Antero-posterior Diameter.

Different methods have been adopted by researchers to make an estimate of Sella area, such as simple methods of product of length and depth or planimetry to more complex methods of tracing the outline of the sella from the X-ray film or digital image (Chavan *et al*., 2012). The present study adopted the method of multiplying the length by the depth and an estimated mean Sella Area of 87.1±24.8mm^2 was obtained. The mean value reported for male was 87.53mm^2 and for female was 86.4mm^2 with no statistically significant difference recorded in the present study.

According to Silverman (1957) who conducted an extensive study on Sella turcica, reported that gradual increase with age of Sella Area is expected which could be attributed to the function of the anterior lobe. However, this is contradictory to the present study, as no statistically significant difference is recorded. These conflicting findings can be explained possibly by differences in approach and methodology used by different researchers. As the present study involved only adult subjects between the ages of 18 and 75. Whereas Silverman (1957) included much younger subjects. Nevertheless, trivial larger values was seen in older age groups as compared to younger age groups in the present study.

Chavan *et al*., (2012) found no significant difference in the mean values of males and females. Likewise, Islam *et al.*, (2017) determined no sexual dimorphism, revealing no statistically significant difference for area estimations of sella turcica. The findings of these studies are in agreement with the present study.

Ruiz, *et al*., (2008) reported Sella Area as 41.21mm^2. Tandel and Kajiya (2015) studied dried sphenoid bones and reported a value of 70 mm^2. Hassan, *et al*., (2016) did a 3D CT study on Sella turcica and reported a value of 65.29 mm^2. . Islam, *et al*., (2017) reported a value of 54.9mm2. Turamanlar, *et al*., (2017) evaluated the Sella turcica and reported a value of 69.15mm^2 and noted that the only statistically significant difference in the Sella Area was among age groups. However, the present study found no significant correlation between Sella Area and Age. The values reported by Tandel and Kanjiya (2015), Hassan, *et al*., (2016) and Turamanlar, *et al*., (2017) are relatively similar to value reported in the present study as compared to Ruiz, *et al*., (2008) and Islam, *et al*., (2017).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY OF FINDINGS

1. Mean Sella Length of 10.8±1.68mm was determined
2. Mean Sella Width of 11.87±1.63mm was determined
3. Mean Sella Height Anterior of 8.89±1.66mm was determined
4. Mean Sella Height Posterior of 8.19±1.51mm was determined
5. Mean Sella Height Median of 8.59±1.67mm was determined
6. Mean Sella Depth of 7.96±1.47mm was determined
7. Mean Sella Antero-posterior Diameter of 13.41±1.81mm was determined
8. Estimated Mean Sella Area of 87.1±24.8mm^2 was determined
9. Overall mean ± SD of male and female Sella turcica linear dimensions and area were determined as well.
10. Higher and lower mean values recorded for male and female subjects were randomly distributed among the sella turcica linear dimensions.
11. The study established Sella Length as the only Sella turcica linear dimension that shows statistically significant difference with a value of 11.01±1.56mm for male and a value of 10.51±1.86mm for female.
12. Differences exists in Sella turcica linear dimensions across age categories except in Sella Antero-posterior Diameter.
13. The sella Area revealed no statistically significant difference between male and female or across age categories.

5.2 CONCLUSION

This study has highlighted values for Sella height Anterior, Sella Height Posterior and Sella Height Median for the locality. More so, the values reported in this study are relatively higher than most previous studies in nearby region. Mean values for male and female subjects were relatively similar as the Sella length is the only linear dimension that showed significant difference. Thus, typical sella length sexual dimorphism for this population has been highlighted. Different age categories revealed different values with significant differences observed in the Sella turcica linear dimensions with the exception of Sella Antero-posterior diameter. The Sella Area shows no sexual dimorphism or significant correlation with age.

This study gives the normal values of sella turcica linear dimensions within this Nigerian population and can help in the objective assessment of Sella turcica pathologies. The study further affirms the potentials of using CT scan images in surveying and describing the Sella turcica. Also, the findings of this study might be utilized as reference measures for Nigerian subjects when examining sella turcica morphometry.

5.3 RECOMMENDATIONS

1. Future studies should be carried out using 3D imaging software such as Mimics 11.02 Materialise, Leuven, Belgium.

2. Similar studies should also be conducted using other imaging modalities such as magnetic resonance imaging (MRI) to better describe and assess the pituitary gland itself and compare findings of Nigerian populace with global populace.

3. Findings of this study should be regarded as a reference point for Sella turcica evaluation for anatomist, anthropologist, radiographers, radiologists, surgeons, orthodontist and the general public.

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APPENDIX I

AMINU KANO TEACHING HOSPITAL

P.M.B. 3452, ZARIA ROAD, KANO.

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NHREC/21/08/2008/AKTH/EC/2401

AKTH/MAC/SUB/12A/P-3/VI/2501 **25th October, 2018**

Mubaraq Yakubu Abdulsalam
Department of Anatomy
BUK, Kano.

Ufs:

The Head of Department
Anatomy
BUK, Kano.

ETHICS APPROVAL

Further to your application in respect of your research proposal titled "Morphometric Study of Sella Turcica Using Computed Tomography Scans of the Brain in Kano Metropolis, Nigeria", The Committee reviewed the proposal and noted same as a retrospective study.

In view of the above, Ethics approval is hereby granted to conduct the research.

However, the approval is subject to periodic reporting of the progress of the study and its completion to the Research Ethics Committee.

Regards,

Abubakar S. Mahmud
Secretary, Research Ethics Committee
For: Chairman

APPENDIX II

INFORMED CONSENT FORM

My name is MUBARAQ ABDULSALAM YAKUBU, M.Sc. student, Anatomy Department, Bayero University Kano and I am conducting a study on **MORPHOMETRIC STUDY OF SELLA TURCICA USING COMPUTED TOMOGRAPHY SCAN OF THE BRAIN IN KANO METROPOLIS, NIGERIA,** and would like you to participate in the Research.

This study will involve you being asked some questions (age and ethnicity) and also physical recordings of your height with measurements of some dimensions on the CT-Scan images of your Brain.

Please note that all information and findings shall be treated and kept with outmost confidentiality. Even if the study is reported in scientific literature or gathering, your anonymity will be maintained. Also all costs incurred outside the standard cost of care will be borne by me.

The final outcome of the study will provide a reference baseline for assessing the morphometry of sella turcica using CT images in this environment. CT scan uses Ionizing radiation in a controlled environment; it's non-invasive and relatively safe.

Your participation in the study is **voluntary**, and you are free to decline consent or willingness to participate at any stage in the study, with no negative consequences to the care you receive. For further enquiries about this study please contact:

MUBARAQ ABDULSALAM YAKUBU (08063743926),

Department of Anatomy, Bayero University Kano.

I have understood the study as directly explained to me and I am willing to participate.

Participant's Sign/Thumb print………………

APPENDIX III

DATA COLLECTION SHEET

(LINEAR DIMENSION MEASUREMENTS)

S/N	Age (Yrs.)	Sex	Ethn.	Ht

SL	SW	SHA	SHP	SHM	APD	SD	SA

***KEY*:**

S/N = Serial Number;

Ethn. = Ethnicity;

Ht = Height;

SL = Sella Length;

SW = Sella Width;

SHA = Sella Height Anterior;

SHP = Sella Height Posterior;

SHM = Sella Height Median;

APD = Anteroposterior Diameter;

SD = Sella Depth;

SA = Sella Area.