



Sella Turcica Variations in Skeletal Class I, Class II, and Class III Adult Subjects: A CBCT Study

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Abstract

Introduction: Sella turcica is an important landmark for superimposition in orthodontics. The current literature reports a large variation in the size of sella turcica among the three different type's skeletal malocclusion classes. With the advent of 3D CBCT, the purpose of this study is to explore the differences in sella turcica size in all three dimensions between skeletal Class I, II, and III adult subjects.

Methods: This cross-sectional study includes 60 pretreatment 3D Cone Beam Computed Tomography (CBCT) scans with equal distribution of adult males and females. Sella turcica linear dimensions, sagittal areas, and axial areas were measured via Dolphin Imaging™. Sella turcica volume was determined via Checkpoint™ (Stratovan).

Results: Skeletal Class III subjects presented with a significantly larger width, axial area, and volume when compared to Class I ($P < 0.05$) and Class II subjects ($P < 0.001$). There was no significant difference in linear dimension, area, and volume of sella turcica between Class I and Class II. There was no significant difference in linear measurements, area, and volume of sella turcica when comparing between genders. However, sella turcica length in males appeared longer than females ($P < 0.05$).

Conclusion: Skeletal Class III adult subjects displayed larger width, wider axial area, and larger volume of sella turcica when compared to Class I and Class II subjects. This study provides a three-dimensional comprehensive illustration of the size variation of sella turcica among the different skeletal classes.

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Received Date: 30 Sep 2016

Accepted Date: 28 Oct 2016

Published Date: 16 Nov 2016

Citation:

Luong HM, Ahn JH, Bollu P, Chenin D, Chaudry K, Pourhamidi J. Sella Turcica Variations in Skeletal Class I, Class II, and Class III Adult Subjects: A CBCT Study. *J Dent Oral Biol*. 2016; 1(3): 1015.

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Introduction

Sella turcica, also known as the pituitary fossa, lies within the middle cranial fossa and houses the pituitary gland. The pituitary gland occupies 80% of the pituitary fossa [1,2]. Since the pituitary gland forms before the cartilaginous skeleton of the hypophyseal fossa, the literature suggests that the pituitary gland serves as a functional matrix for the skeletal unit of sella turcica [2-4]. Development of sella turcica is associated with development of the pituitary gland; as the gland enlarges, there is corresponding increase in dimension of sella turcica. Chilton et al. [5] postulated that since growth and development of the bony skeleton depends on anterior pituitary hormones, bony development of hypophyseal fossa is correlated to pituitary gland size [5].

Abnormality of the gland or disturbances in hormonal regulation can lead to changes in the size and shape of sella turcica [2-10]. Abnormally large pituitary gland or pituitary tumor leading to over production of anterior pituitary hormones can result in systemic diseases such as acromegaly or gigantism, Cushing's syndrome, hyperthyroidism, and/ or menstrual disturbances that can be associated with a larger sella turcica [5-10]. Furthermore, pituitary adenomas can cause uniform enlargement and deepening of sella turcica floor with thinning and posterior displacement of dorsum sellae [1]. A smaller sella turcica was noted in subjects with pituitary hypo functioning and can also be found in primary hypopituitary and growth hormone deficiency which leads to truncated skeletal growth and maturation [1-4].

Growth and development of sella turcica

Data from the current literature suggest that deposition of bone on the inner contour of the anterior wall of sella turcica ceases and that the morphology of the anterior wall becomes stable after the age of 5-7 years [6-13]. Resorption on the distal aspect of the sella floor and posterior wall continues until 16-18 years of age [11-12]. Therefore, on 2D cephalometrics, sella point is displaced

backward and downward with growth as there is more resorption on the posterior aspect than the anterior aspect of sella turcica [11].

Bjork's [11] study on cranial base development reported that morphology of sella turcica does not change significantly after 12 years of age and that the completion of pubertal growth in female occurs after 15 years [11]. Axelsson et al [14] concluded that the growth curve of the anterior cranial base flattened out at 18 years for both males and females. Similarly to Bjork's findings, they noted that the female growth curves of both anterior and posterior cranial base plateaus after 15 years of age.

Sella turcica 2-D measurements among the three skeletal classes

The conventional diagnostic approach of skeletal malocclusion focused on 2-D lateral cephalometric analysis using linear length, depth, and diameter measurements of sella turcica obtained from the Silverman [15] methods and compared the linear measurements with different skeletal types. Length of sella turcica included the greatest anteroposterior dimension of the pituitary fossa [15]. To measure depth, a perpendicular line was drawn from the length line to the deepest point on the floor. A line was drawn from tuberculum sella to the furthest point on the posterior inner wall of the fossa, and this was considered the diameter of sella turcica [13,15-20].

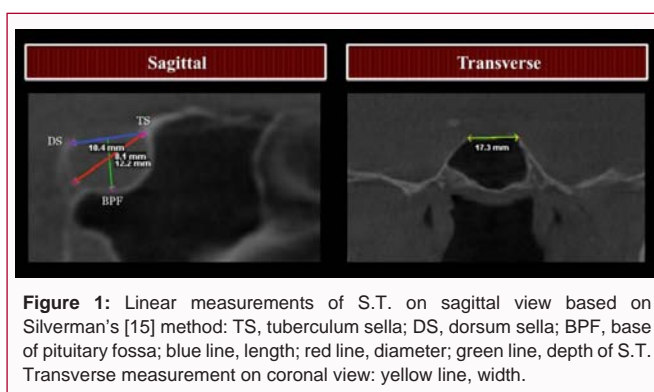
To compare the size of sella turcica in Class I, Class II, and Class III patients, Alkofide [13] explored 180 lateral cephalograms of the three skeletal types in Saudi subjects, and discovered that sella was larger in length, depth, and diameter in subjects that are 15 years or older compared to pre-pubertal, but no significant difference was seen between genders. There was a significant difference in the diameters of the skeletal classes with Class III subjects having larger diameter compared to Class II and Class I subjects. There was no significant difference in length and depth. On contrary, Shah [17] duplicated Alkofide's research design using 180 pretreatment 2D lateral cephalograms, with 60 subjects from each skeletal class of Islamic subjects and discovered no significant differences in size of sella among males or females and no significant differences amongst the different skeletal types.

Furthermore, Meyer-Macotty et al. [19] studied 400 adult Caucasian subjects and saw similar results to Shah et al study in that there was no significant difference between the sella turcica linear measurements between males and females and no significant difference between sella turcica size between Class I and Class III adult subjects. Soakar and Nawale [20] reported similar findings to Alkofide's [13] study in that Class III subjects had larger diameter compared to Class I. However, no significant difference was found for Class I & II or Class II & III.

The literature reports a wide variations in sella's size and shape [1,2,5-20]. There is also a lack of consensus when it comes to the size of sella turcica among the three skeletal classes [13,17,19,20]. This ambiguity presents a problem as cephalometric analysis is contingent on the size and shape of sella turcica and the downward and backward displacement of sella point with growth. Thus, the aim of this study is to compare the size of sella turcica in skeletal Class I, II, and III adult subjects in all three dimensions.

Materials and Methods

This was a cross-sectional CBCT study comprised of 60 pretreatment 3D Cone Beam Computed Tomography (CBCT) scans



from the i-CAT® Cone Beam 3D machine at Roseman University of Health Sciences (RUHS) Orthodontic Clinic. CBCT settings were set at 23cmx17cm, 17.8 seconds, 0.3 voxels, 120kVP, and 37.10mA. Samples consisted of equal representations of skeletal Class I, Class II, and Class III and equal representation of genders with an age range of 18 years or older for female and 20 years or older for males. Skeletal classification was based on ANB angle and was categorized as follows: skeletal Class I ($0 \leq \text{ANB} \leq 4$); Class II ($\text{ANB} > 4$); and Class III ($\text{ANB} < 0$). Exclusion criteria consisted of subjects with craniofacial syndromes, prior orthodontic treatment or orthognathic surgery, history of head and neck trauma, gross skeletal asymmetry, and cleft lip and/or palate. Additionally, CBCTs with motion artifacts, sellas that are not fully captured, and DICOMS with poor image quality were excluded.

Linear Measurements: Dolphin Imaging™ (Dolphin, Chatsworth, CA)

CBCT DICOMS were each consistently re-orientated to eliminate errors in measurements. Each skull oriented to best fit the right and left side and have Frankfort Horizontal (FH) parallel to the floor, for which both orbitals and right porion was used. Orientation was set to the zygomatic arch and the orbit, which was close to the neurocranium bilaterally. The midsagittal plane was placed perpendicular to FH plane, passing through nasion. The coronal plane was perpendicular to both horizontal and mid-sagittal planes. Digital calipers were dropped on the screen and all images were measured with magnification ranges from 18-20 mmx2 magnification. This was determined by the investigator to be the most optimal range of magnification as any higher magnification creates a blurry radiographic image. Next, Dolphin multiplanar view was used to aid in the measurements of length, diameter, height, width, sagittal area, and cross sectional axial area of sella turcica.

Length, Diameter, Height, Transverse Width

The midsagittal plane was used to measure the length, diameter, and height of sella turcica using Silverman's [15] method (Figure 1). Furthermore, at the same level of the midsagittal plane on coronal view, the transverse width measurement or the base of the pituitary fossa was measured (Figure 1).

Sagittal and Axial Area

The sagittal area was obtained on the mid-sagittal plane by following the contour of sella turcica. The anterior limit was the junction of the anterior wall of sella and tuberculum sella, and the posterior limit was the highest tip of posterior clinoid processes. Before measuring areas, the sagittal view has been rotated such that anterior and posterior limits of sella turcica were aligned, and the

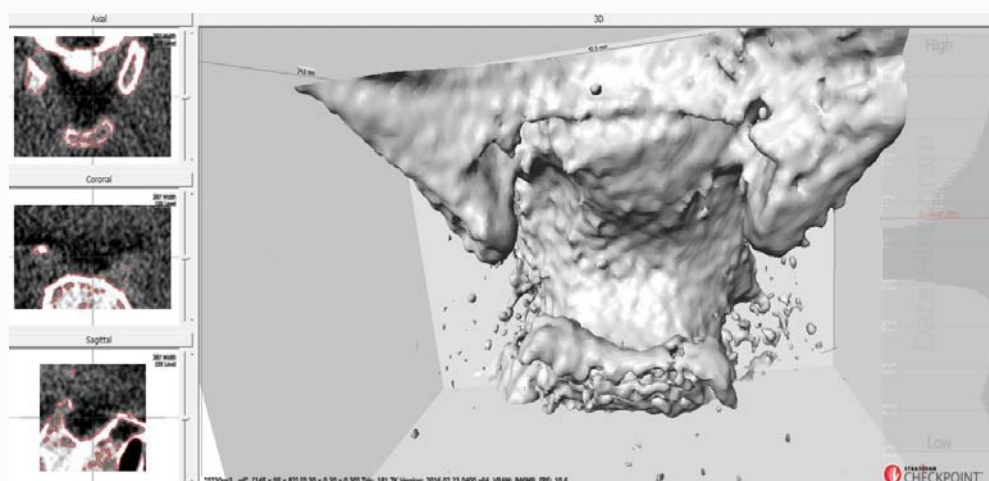


Figure 2: Multiplanar view of sella turcica on Checkpoint (Stratovan).

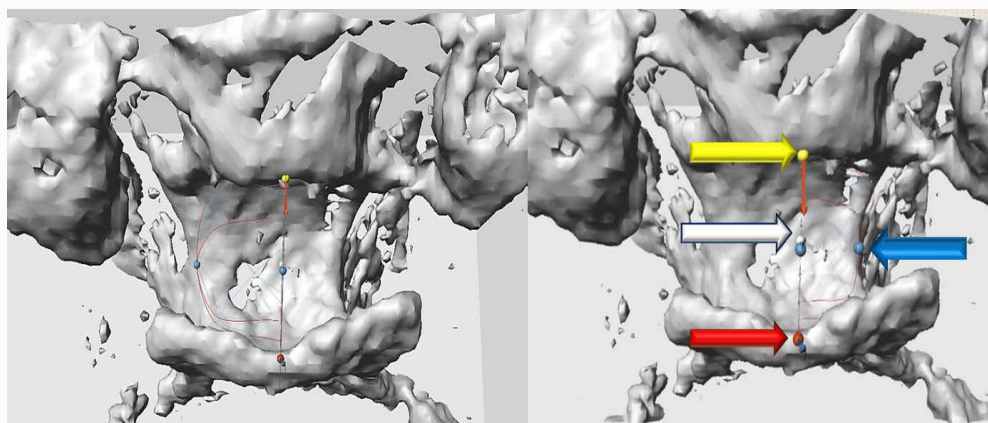


Figure 3: Sella turcica in Checkpoint. Volume of S.T. was obtained via 5x5 semi-automated landmark mesh on Checkpoint (Stratovan) with three anchor points displayed in yellow, white, and red arrows. Lateral and superior borders were defined by blue arrows and points, respectively.

cross-sectional image to measure axial area was passing through anterior and posterior borders of sella turcica.

On the axial view, the axial area was measured by setting the superior limit at the cortical wall on the junction of tuberculum sella with anterior wall of sella turcica. Due to the concavity of the most superior border of dorsum sellae, a straight line was drawn from the most lateral borders.

3-D Rendering Volume: Check point™ (Stratovan, Sacramento, CA)

To obtain the volume of sella turcica, data from the CBCT were exported in DICOM format and imported into Check point™ (Stratovan, Sacramento, CA), a land marking software that allows for the measurement of sella turcica volume through location of various points and landmarks. Semi-landmarks of 5x5 patch density were placed over the areas surrounding sella turcica (Figure 2). Three anchor points were dropped on sella turcica borders with the yellow point at the equidistant of tuberculum sella, white point at the most inferior point or the base of sella turcica, and the red point at the equidistant of dorsum sella. One blue point is placed at the most lateral border of sella turcica, and the last blue point is placed at the most superior border of sella turcica. These form the three anchor points in which a mesh was constructed using the multiplanar and 3-D rendered image to create a semi-landmark patch that will yield

the volume and area of half of sella turcica (Figure 3). The same steps were performed to capture the volume and area on the opposite side. The two volumes and area were then added together, respectively, to yield the total volume and area of sella turcica. Therefore, a total of 47 points were used in this study to identify sella turcica volume and area, 25 points per side minus three anchor points.

Statistical analysis

IBM SPSS version 23 was used for statistical analysis. Analysis of variance (ANOVA) and Tukey post hoc tests were used to explore the relationship between skeletal classifications and sella turcica linear measurements, area, and volume. Independent sample T-test was used to assess differences in mean sella turcica linear measurements, area, and volume between males and females.

Results and Discussion

Reliability of measurements

To assess intra-operator variability, nine subjects with equal class distribution were randomly selected to re-digitized and measured after two weeks interval under identical methodologies. Intraclass correlation coefficient (ICC) was completed, and the data were deemed reliable and reproducible.

Results

The mean ANB angle and age for all three skeletal classes and

Table 1: Study Sample Characteristics.

Skeletal Class			
	Sample Size	Mean ANB± SD (degrees)	Mean Age ± SD (years)
Class I	20	3.0± 1.00 [*]	32.40 ± 8.07
Class II	20	7.2±1.44 [*]	36.6 ± 9.80
Class III	20	-2.7±1.81 [*]	35.75 ± 13.07
Statistically significant; Tukey Post-hoc test: [*] Class I vs. Class II, p<0.001; [*] Class I vs. Class III, p<0.001; [*] Class II vs. Class III, p<0.001			
Gender			
	Sample Size	Mean ANB± SD (degrees)	Mean Age ± SD (years)
Male	30	2.15± 4.17 ^{**}	37.06 ± 10.64
Female	30	3.0± 5.00 ^{**}	32.78 ± 10.09
Statistically significant; t-test: ^{**} Male vs. Female, p < 0.001			

Table 2: Linear Measurements of Sella Turcica.

Linear Measurements (mm)	Class I (n=20) Mean ± SD	Class II (n=20) Mean ± SD	Class III (n=20) Mean ± SD	All Classes (n=60) Mean ± SD	P-value (ANOVA)
Length	9.90 ± 0.98	9.87 ± 1.50	10.68 ± 0.38	10.15 ± 1.44	0.135
Diameter	11.55 ± 1.81	11.50 ± 1.26	12.56 ± 1.51	11.87 ± 1.60	0.059
Height	8.02 ± 1.53	7.44 ± 1.13	8.20 ± 1.32	7.89 ± 1.36	0.184
Width	10.32 ± 1.40	10.46 ± 1.24	12.12 ± 1.18	10.96 ± 1.50	0.001 [*]
Statistically significant between-group differences; Tukey Post-hoc test: [*] Class III vs Class II; Class III vs Class I p<0.001.					

Table 3: Area and Volume of Sella Turcica.

2D & 3D Parameters	Class I (n=20) Mean ± SD	Class II (n=20) Mean ± SD	Class III (n=20) Mean ± SD	All Classes (n=60) Mean ± SD	P-value (ANOVA)
Axial Area (mm ²)	82.53 ± 9.33	77.29 ± 14.98	93 ± 11.49	84.27 ± 13.65	0.001 [*]
Sagittal Area (mm ²)	75.60 ± 20.92	70.71 ± 14.49	79.00 ± 14.02	75.10 ± 16.84	0.298
Volume (mm ³)	414.30 ± 45.18	406.42 ± 44.64	553.07 ± 32.26	457.93 ± 79.04	0.001 ^{**}
Statistically significant between-group differences; Tukey Post-hoc test: [*] Class III vs Class II, p<0.001; Class III vs Class I, p<0.05. ^{**} Class III vs Class II, p<0.001; Class III vs Class I, p<0.001.					

genders are presented in (Table 1). A one- way ANOVA with Tukey post hoc test was performed to determine if adult subjects with different skeletal patterns presented with different linear dimensions, area, and volume of sella turcica (Table 2 and 3).

Within the four linear dimension measurements, sella turcica's transverse width in skeletal Class I vs. III and Class II vs. III was statistically significant ($P < 0.001$; Table 2). Class III subjects displayed larger transverse width compared to Class I and Class II. There was no significant difference in transverse width of Class I and Class II. Furthermore, there was no statistically significant difference in sella turcica's length, diameter, and height in all three skeletal classes. Table 3 displays no significant difference in the sagittal area of sella turcica among the different skeletal classes. However, there was a significant difference in the mean axial area of sella turcica in Class I vs. Class III and Class II vs. III subjects ($P < 0.001$; Table 3). Class III subjects displayed significantly larger axial area compared to Class I and Class II, and there was no significant difference between Class I and Class II subjects. Moreover, a significance difference in sella turcica volume was displayed between Class I vs. III and Class II vs. III ($P < 0.001$; Table 3). Class III subjects had significantly larger volume compared to Class I and Class II. There was no significant difference in volume of Class I and Class II.

The mean linear dimensions, sagittal area, axial area, and volume for males and females are presented in Table 4. When comparing

between males and females in all three skeletal classes, there was no significant difference in volume, surface area, sagittal area, and cross sectional axial area. Also, there was no significant difference in linear dimensions except for length. There was a significant difference in sella turcica length between males and females, with males having a larger length ($P < 0.05$; Table 4).

Discussion

This cross-sectional study describes the variation of sella size in three dimensions in the different skeletal malocclusion classes. The current study presents no significant difference in the length, diameter, and height, but the mean values appeared similar to the literatures' [10,13,17-20]. Soakar and Nawale [20] reported the mean diameter of sella turcica is 11.18 ± 1.34 mm, which is consistent with the mean diameter in all three classes of 11.87 ± 1.60 mm found in this study. Moreover, Alkofide [13] reported a difference in the diameters of the skeletal classes with Class III subjects having larger diameter of sella compared to Class II and Class I subjects. Similarly, the current study showed a trend such that there is a decreases in diameter from Class III > Class I > Class II. However, the difference was so small that there was no significant difference.

Tetradis and Kantor [18] discovered the mean length and height of the hypophyseal fossa was $10.9 \text{ mm} \pm 1.8$ and $7.6 \text{ mm} \pm 1.7$ mm, respectively. These values were consistent with Kantor and Norton's [10] study, which reported the normal length and height values to be

Table 4: Sella Turcica Size According to Gender.

Male (n = 30)		Female (n = 30)	P value (T-test)
Length (mm)	10.52 ± 1.72	9.77 ± 0.99	0.043*
Diameter (mm)	12.15 ± 1.56	11.59 ± 1.61	0.176
Height (mm)	8.08 ± 1.17	7.69 ± 1.52	0.261
Width (mm)	10.86 ± 1.37	11.05 ± 1.64	0.628
Sagittal Area (mm ²)	78.03 ± 14.79	72.17 ± 18.46	0.180
Axial Area (mm ²)	84.64 ± 16.10	83.90 ± 10.91	0.835
Volume (mm ³)	471.76 ± 78.55	444.10 ± 78.38	0.177

*Statistically significant difference.

10.6 mm and 8.1 mm respectively. The current study yielded similar length and height for all three classes of 10.15 mm ± 1.44 and 7.89 mm ± 1.36, respectively, which was consistent with both Tetradis and Kantor's [18] and Kantor and Norton's [10] findings.

Furthermore, when comparing the linear dimensions of sella turcica's length, diameter, and height of the three skeletal malocclusions, the current study found no significant difference in the length, diameter, and height as consistent with the literature [17,19]. Additionally, when comparing between genders, Shah et al [17] found no significant differences in size of sella among males or females and no significant differences amongst the different skeletal types. Meyer-Macotty et al. [19] looked at total of 250 skeletal Class III subjects and found similar results to Shah et al. [17] study in that there was no significant difference between the sella turcica linear measurements between males and females among the three skeletal classes and no significant difference between sella turcica length, diameter, and height between Class I and Class III adult subjects. Similar to Shah et al. [17] and Macotty et al. [19], this study found no significant difference between linear measurements.

When examining sella turcica transverse width, Quakinine and Hardy's [3] microsurgical study revealed the mean sella turcica width transverse was 12 mm. In this study, the mean transverse width of sella turcica among the three skeletal classes was 10.96 ± 1.50 mm, which was similar to Quakinine and Hardy's [3] findings. However, subjects in Quakinine and Hardy's [3] study included patients with various ages and systemic diseases such as diabetic retinopathy, pregnancy, and pituitary gland anomalies that could double the size of the pituitary gland and may be associated with an enlargement of the size of sella turcica [3]. In this study, sella turcica's transverse width in skeletal Class I and Class III and Class II and Class III was statistically significant ($P < .001$). The mean width of Class I, Class II, and Class III subjects were 10.32 mm, 10.46 mm, and 12.12 mm respectively. Class III subjects had larger transverse width than Class I and Class II. There was no significant difference in transverse width of Class I and Class II.

The mean sagittal area of three skeletal classes was 75.10 mm², and the mean sagittal area for males and females were 78.03 ± 14.79 mm² and 72.17 ± 18.46 mm², respectively. No significant difference was found among the three skeletal classes nor gender, but the mean values were consistent with the literature [15,21]. Comparatively, Silverman [15] discovered that the mean area at 15 years old for female was slightly larger than males at 78.6 ± 16 mm² and 76.9 ± 10 mm² respectively [15]. However, Silverman [15] also did not compare between different skeletal malocclusions and did not include any *p* values.

Because the samples in the current study are adults, the sagittal

area of sella turcica appeared to be larger in males than females, as opposed to the data from Silverman's study which included adolescent children in which the area might be affected by the peak velocity growth of females. Female sella turcica area was larger than male during pre-adolescent years due to an accelerated growth of the anterior pituitary lobe [15].

Moreover, Preston [21] presented findings that were consistent with Silverman's findings which stated that the mean area of sella turcica for 15 years old boy with average depth of 7 mm was 71.3 mm², and for 15 years old girls with an average depth of 7 mm was 78.6 mm². However, Preston [21] included subjects with unspecified malocclusion types.

The current study pioneered the cross-sectional axial area of sella turcica and compared it to the three skeletal malocclusion classes. The mean cross-sectional axial area of the three skeletal classes is 84.27 ± 13.65 mm². There was a significant difference in the mean cross sectional axial area of sella turcica in Class I and Class III subjects and Class II and Class III subjects ($p < .001$). Axial area was larger in Class III than Class I and Class II subjects. There was no significant difference between Class I and Class II subjects.

Chilton et al. [5] reported that 14 years old males and females presented with a 2-D extrapolated mean volume of 447 mm³ and 431 mm³ respectively. For 15 years old boys, the extrapolated mean volume was 640 mm³, and due to limitations in females subjects, the mean volume for females ages 15 years and older were not given. However, the limitations of Chilton et al. [5] study were subject's availability and identification of landmarks. Due to superimposition of structures on frontal radiograph, it was difficult to identify the floor of sella turcica to obtain the transverse width measurement. In the current study, the mean volume of all three skeletal classes in the current study was similar with Chilton et al. [5] mean volume for 14 years old males and females. No significant difference was found between males and females volume within the three skeletal classes. However, a significant difference ($P < .001$) in sellar volume was found between Class I vs. III and Class II vs. III subjects. Class III subjects had larger sellar volume compared to Class I and Class II.

Limitations and Future Research

When data were imported into Check point™ for volumetric analysis, it was difficult to isolate sella turcica because sella is surrounded by both soft and hard tissues. On the 3D window in the software, the principle investigator encountered many challenges with obtaining the is surfacing (ISO) value on the histogram and obtaining a clean 3D rendering image of the hypophyseal fossa. Often, images would have excessive noise and/or missing the hypophyseal floor. As a result, many samples were eliminated due to

poor rendering of sella turcica image, which limited the sample size to 20 samples per skeletal class. The data from this 3-D study suggest a trend in linear measurements and sagittal area between the different skeletal malocclusions and males and female subjects, but a larger sample will be needed to confirm statistical significance. Moreover, as sella turcica has various morphology that can affect the measurement of size, a 3-D morphological analysis on sella turcica, in conjunction with size, should be considered.

Future research can offer a more detail 3-D investigation of sella turcica bridging, the calcification of the interclinoid ligament or diaphragma sellae, and may contribute to one of sella turcica's various morphologies. Bridging can be found as a normal variant or can be associated with findings such as Class III and dental anomalies such as palatally displaced canines (PDC) or tooth agenesis, particularly mandibular second premolars [9,16,19,22-25].

Conclusion

No statistically significant difference when length, diameter, height and sagittal area was compared between the three skeletal classes. A significant difference in transverse width, axial area, and volume of sella turcica. Skeletal Class III subjects presented with a larger width, axial area, and volume when compared to Class I and Class II.

No significant difference in transverse width, axial area, and volume of sella turcica between Class I and Class II

No significant difference in linear measurements when males are compared to females, except for length. Males presented with a slightly larger length than females, 0.75 mm.

This study provided a three dimensional comprehensive illustration of sella turcica size and variations among the three skeletal classes. The results in this study support the literature on sella turcica dimensions, provide new 3-D transverse dimensions and volumetric insights for the clinician, and may contribute to the orthodontist's understanding of sella turcica size among the three different skeletal classes.

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