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Cephalometric Appraisal of the Sella Turcica- A Literature Review

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Abstract

The sella turcica is considered an important landmark in orthodontics as it is used extensively in various cephalometric analyses be it for diagnosis, evaluation of growth or treatment results. In order to recognize deviations from the norm, one needs to be familiar with normal radiographic anatomy as well as morphologic variability. A review of the literature was conducted regarding the norms and variations in size, shape, morphology and bridging of the sella turcica as evidenced by cephalometric evaluation. Literature search was carried out using the following keywords: Sella Turcica, Sella Bridging, Sella Size and Morphology. Search engines: PubMed and Google Scholar were utilised, followed by hand search. The purpose of the review is to provide an insight into detection of subclinical and potentially pathologic conditions during regular orthodontic pretreatment assessments.

Keywords: Sella Turcica, Sella Bridging, Sella Size, Sella Morphology

1. Context

On the intracranial surface of the body of the sphenoid bone, lies a saddle shaped depression, called the "sella turcica". Literally meaning "Turkish saddle", its anterior border is represented by the tuberculum sellae and posterior border by the dorsum sellae (1). It contains the pituitary gland and has two anterior (formed from lesser wing of sphenoid) and two posterior (end of dorsum sellae) clinoid processes projecting above it.

In radiographic analysis of the neurocranial and craniofacial complex, the sella is generally considered an important structure. Orthodontics, in particular, places great importance on the sella turcica as the midpoint of this structure termed "sella point" is used extensively as a reference point in various cephalometric analyses (2). Bony apposition ceases at a very early age along the inner surface of the anterior wall of the sella whereas resorption continues for a much more longer time along the posterior wall and floor. Consequently, the "sella point" gets displaced downwards and backwards during growth. Thus the anterior wall and Walker point (point where anterior clinoid process intersects the anterior wall) are considered more stable and used extensively in various cephalometric analyses and craniofacial growth assessments (3, 4).

2. Development of Sella Turcica

The sella turcica develops in embryonic period (Carnegie stage 19, approximately 44 days after fertilization) when longest part of embryo is 16 - 18 mm, in the region where notochord ends cranially at rostral end of germ sheet (5). According to Sheng and Westphal, the pituitary gland develops prior to formation of cartilaginous sella turcica (6). Adenopituitary (anterior pituitary) develops from oral ectoderm (Rathke's pouch) and neuropituitary (posterior pituitary) from infundibulum cerebri. Pituitary fossa differentiates from hypophyseal cartilage derived from cranial neural crest cells of chondrocranium. Kjaer concluded that sella turcica forms only after completion of development of the pituitary gland. Obviously, both the developmental processes are closely co-ordinated (5). Hence a anomalies in the development of pituitary gland may result in anomalies of sella turcica as well.

The anterior part of sella turcica develops mainly from neural crest cells that are not directly dependant on the notochord, whereas the posterior part develops from the para-axial mesoderm, which is closely related to notochordal induction (7-10). The SHH (sonic hedgehog gene), plays an important role in the midaxial development along the notochord.

Because of the close association of sella turcica with the pituitary gland, any pathology in the pituitary gland leads to alteration in size, shape and morphology of the sella turcica. This explains the numerous scientific publications associated with measurements of the sella turcica. Lateral cephalograms give us information on shape, morphology, size and bridging of the sella turcica.

3. Sella Shape

Camp classified normal sella shape into three types: Oval, round and flat (Figure 1). The most frequent shape was oval and least was the flat type (11). The same classification was used by Teal in 1977 (12). According to Gordon and Bell, most common shapes of sella encountered in their study were either round or oval (13). Davidoff and Epstein used the term 'J-shaped sella' (14) while 'omega sella' was described by Fournier and Denizet (15). Kier called them radiological myths (16). Such abnormal shapes may be present in 'normal' subjects as well. According to Alkofide, normal shaped sella turcica was seen in 66.7%, while the rest presented with different aberrations (17). This is also in agreement with Axelsson et al. who reported normal shaped sella turcica in 65% girls and 71% boys (18). Yassir et al. also reported normal shape in 80.6% girls and 71.4% boys (19).

4. Sella Morphology

The cartilaginous morphology of sella before birth is similar to its bony postnatal morphology. Therefore, information obtained from foetal pathological studies revealing aberrations in the sella turcica helps in understanding deviations in sella turcica seen postnatally. Morphological variations of the sella turcica have been described by many authors. Teal while using camp's classification of sella shape, described morphology of sella turcica as divided into three segments: anterior wall, floor and posterior wall including dorsum sellae (11, 12). Tetradis and Kantor divided morphological variants into J shape, shallow, double contour of floor and presence of a middle clinoid process (20). Morphological variations of the anterior wall was reported by Kjaer et al. in lumbosacral myelomeningocele as well as an oblique anterior wall in Seckel syndrome (21, 22). The anterior wall of the sella turcica is formed prenatally by the influence of hormone production in the adenopituitary gland (23).

Other morphological aberrations like notching and pyramidal shape of dorsum sellae was first described by Axelsson et al. (18). He categorized sella turcica morphological aberrations into five different types: Normal, oblique anterior wall, double contour of the floor, notching and pyramidal shape of the dorsum sellae (Figure 2).

Reported alterations in morphology of sella turcica due to certain pathological conditions both prenatally and postnatally have been summarized in Tables 1 and 2.

5. Sella Size

Radiological assessment of sella are generally based on linear (11, 13, 31, 32), area (32-34) and volume measurements (35-38). Different methods are used for calculating the area. One is to multiply the length and breadth as shown in Figure 3. Another method is to trace the outline of the sella on a transparent sheet, superimpose the tracing on a calibrated graph and count the number of squares contained.

Most of the studies on sella size are in accordance with the method proposed by Silverman (32). Variables measured are length (tuberculum sella to tip of dorsum sella), depth (perpendicular line from length to deepest point on floor) and diameter (distance from tuberculum sella to the furthest point on the posterior inner wall).

5.1. Sella Size in Normal Population

Size of sella turcica is reported to vary in different populations. In a Saudi population, the dimensions reported are 11 (+2.62) mm in length, 9.1 (+1.2) mm in depth and 13.9 (2.09) mm in diameter (17). This was found to be 2.02 to 2.73 mm larger than the Norwegian sample of Axelsson et al. (18). A recent study on sella size in Dravidian population of South India reports mean length of 10.91 (+1.98) mm, depth of 9.03 (+1.18) mm and diameter of 13.17 (1.89) mm (39). This is similar to the Saudi (17) and Caucasian populations (40) but larger than the Norwegian (18), Iraqi (41) and Greek populations (1).

5.2. Sella Size in Pathological Conditions

Dimensional variations of the sella turcica have been reported in various pathologies. Table 3 summarizes various pathological conditions in which dimensional variations of the sella turcica have been reported. A recent study reported decreased dimensions of the sella turcica in a statistically significant number of unilateral cleft lip and palate cases. This has been attributed to the fact that neural crest cells, which arise from the final stages of formation of the embryonic neural tube, migrate from the neural tube towards facial and pharyngeal areas. The neural crest cells form the anterior wall of the sella. The migration of these neural crest cells is influenced by the external environment through which they migrate (39). For example, craniofacial defects like clefts can be formed due

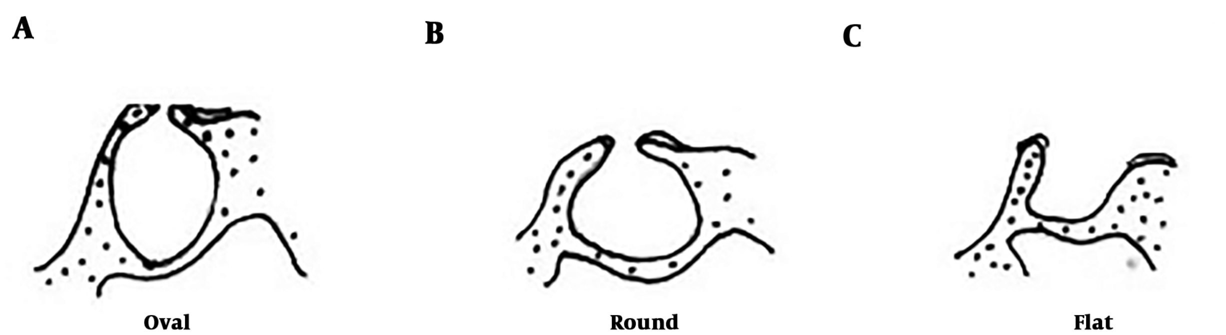

Figure 1. Sella shape

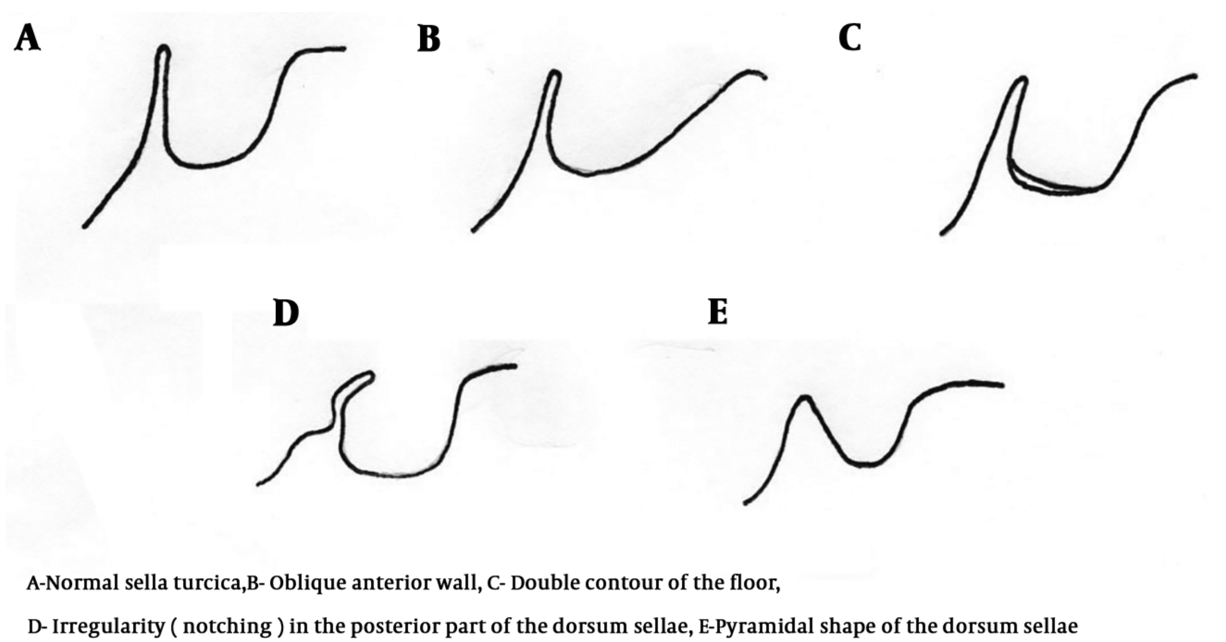

Figure 2. Sella morphology

to either excess or deficiency of retinoids (42). Such defective differentiation, proliferation and migration of neural crest cells has been linked to developmental defects called "neurocristopathies". Another recent study has reported decreased dimensions and increased morphological variations of sella turcica in type 1 diabetic patients. This has been attributed to the fact that the neural crest cells, which form the anterior wall, are also responsible for the proliferation and survival of beta cells, which are necessary for insulin secretion (43).

During craniofacial development, sella turcica is a very important area from where neural crest cells migrate to frontonasal, maxillary and mandibular fields. Kjaer has described six craniofacial fields; the thecal, frontonasal, maxillary, palatine, mandibular and occipital (Figure 4). All these craniofacial fields are developmentally linked to the sella turcica region (5). So it can be sensibly concluded that any deviations in these craniofacial fields may extend to the sella turcica or vice versa. The anterior wall of sella turcica lies at the most posterior part of the frontonasal field, in which malformations like single median maxillary central incisor (SMMCI) and cleft lip are located. These have a

Table 1. Reported Alterations in the Morphology of Sella Turcica Associated with Prenatal Pathological Conditions

Pathology	Authors, Reference	Reported Morphological Alterations
Holoprosencephaly	Kjaer and Fischer-Hansen (24)	Small sella, anterior wall partly absent, posterior wall normal
Trisomy 21	Kjaer (5)	Anterior wall may be depressed or may be completely separated from posterior wall
Myelomeningocele	Kjaer et al. (25)	Anterior wall undermined, thin bottom
Meckel-Gruber syndrome	Kjaer et al. (9)	Wide dorsum sella, uneven anterior wall
Anencephaly	Kjaer and Fischer-Hansen (24)	Anterior wall normal, Posterior wall is short, broad, and malformed
Trisomy 18	Kjaer et al. (26)	Posterior wall may be malformed, with a broad base and posterior region having several notches
Chondrodystrophy	Kjaer (5)	n. Enlarged sella with uneven inner contours
Hydrocephalus	Kjaer (5)	Broad and abnormal posterior wall, no connection between anterior and posterior wall.
Cleft lip	Kjaer (5)	Normal to short, uneven
Cleft lip and palate	Kjaer (5)	Abnormal anterior and posterior walls with a narrow bottom of sella
Fragile-X syndrome	Kjaer (5)	A deep depression in anterior wall
Turner syndrome	Kjaer (5)	Large sella, more open cranially than normal with a notch at the posterior border.

Table 2. Reported Alterations in the Morphology of Sella Turcica Associated with Postnatal Pathological Conditions

Pathology	Authors, Reference	Reported Morphological Alterations
Holoprosencephaly	Kjaer and Fischer-Hansen (24)	Sella may be small with abnormal anterior wall. Bottom may have a pointed shape.
Trisomy 21	Kjaer (5)	Anterior wall may be slightly depressed, or completely separated from posterior wall. Posterior wall may have minor alterations.
Myelomeningocele	Kjaer et al. (25)	Sloped anterior wall
Cleft lip	Nielsen et al. (27)	Normal sella or anterior wall short/sloped
Cleft lip and palate	Neilsen et al. (27)	Anterior wall sloped/curved
Fragile X syndrome	Kjaer et al. (21)	Anterior wall very high compared with the length of posterior wall, curved anterior wall, short posterior wall
Cri-du-Chat syndrome	Kjaer and Niebuhr (28)	Dorsum sella broad, short, plump, notch in the posterior aspect.
Williams syndrome	Axelsson et al. (29)	Normal/notched posterior wall
Arnold-Chiari Syndrome	Kjaer (5)	Short posterior wall
Velocardiofacial syndrome	Molsted et al. (30)	Dorsum sella narrow and short
Kallman syndrome	Kjaer and Hansen (23)	Abnormal contour of anterior wall

different genetic background. Malformations in maxillary and palatine fields are related to cleft palate and velocardiofacial syndrome (5, 30, 49).

5.3. Sella Size and Age

Longitudinal studies show that sella grows rapidly during the first few years of life, after which it decreases. A second phase of increased growth occurs at the time of puberty, after which growth slows down and completes by early adulthood (4, 29). On the other hand, Alkofide reported that all three linear dimensions were found to be consistently larger in an older group compared to the younger (17). Preston reported that as age advanced, so did the area of sella until about 26 years of age. There was no significant increase after that (50).

5.4. Sella Size and Gender

Males had larger sella than females at all times except during the pubertal stages. This was because puberty occurred at least two years earlier in females (32, 35). This is in contrast to the report of Francis who reported that the size of sella was larger in females than males (51). Alkofide did not find any gender difference for all the three dimensions (17).

5.5. Sella Size and Skeletal Pattern

Class III individuals are reported to have larger diameters and class II subjects smaller, as compared to class I (17). However, significant differences in length or depth has not been reported.

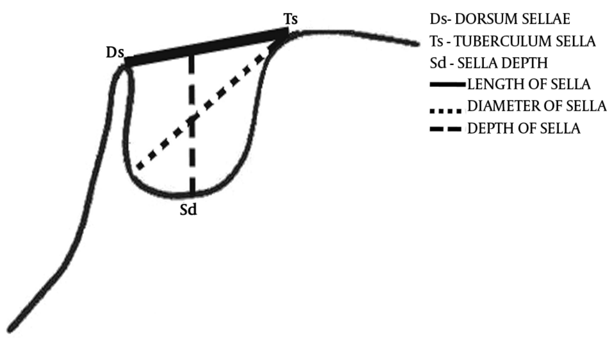

Figure 3. Sella measurements

Table 3. Dimensional Variations of Sella Turcica in Various Pathologies

Pathology	Reference
Increase in the size of the sella turcica	
Acromegaly	(5)
Turner syndrome	(5)
Chondrodystrophy	(5)
Intrasellar adenomas	(44)
Empty sella syndrome	(45)
Rathke's cleft cysts and aneurysms	(46)
Decrease in the size of the sella turcica	
Williams syndrome	(29)
Holoprosencephaly	(7)
Sheehan's syndrome	(47)
Primary hypopituitarism	(48)
Unilateral cleft lip and palate	(38)
Type 1 diabetes	(43)

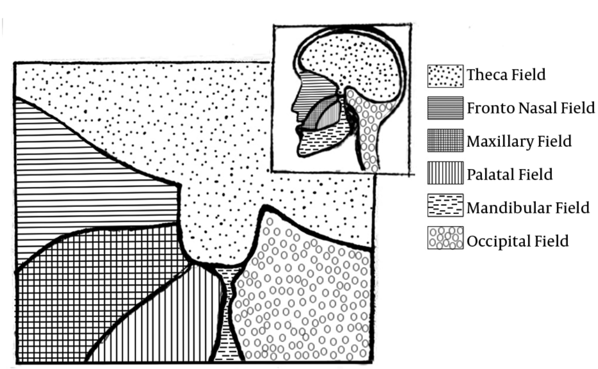

Figure 4. Sella turcica and craniofacial patterning

6. Clinical Implications

Sella turcica is a very important structure and the lateral cephalogram is a routine diagnostic tool used by every orthodontist. It is therefore important for an astute clinician to be well aware of normal variations of the anatomical structure to be better equipped to identify abnormal deviations.

7. Bridging of Sella Turcica

The anterior, middle and posterior clinoid processes are basically bony structures. Any abnormal development in these structures could lead to fusion, leading to formation of osseous bridges. The bony fusion of anterior and posterior clinoid processes is referred to as interclinoid taenia (52-55), sella bridging or roofing of sella (56) or interclinoid osseous bridge (57).

Intracranial calcification is a condition in which mineral calcium and sometimes other chemical compounds are deposited on the soft tissue structures, causing it to harden. Initially the sella bridges are formed in cartilage, during the time of sphenoid development. Ossification occurs in early childhood. Studies show embryological basis for sella bridges (53, 56, 58). In the absence of clinical signs and symptoms, "bridging" is considered a normal variation.

Several classifications of sella have been proposed. According to Becktor et al., sellas can be divided into two groups; those with and without fusion/bridging (59). Depending upon the type of bridging, sellas with ribbon like fusion of the clinoid processes belong to type A. In type B, the fusion of the processes is thinner and they are seen to meet anteriorly, posteriorly or in the middle.

Yet another anatomic classification has been proposed by Ossenberg (60):

A. No bridging;

B. Trace: Existence of spinous bony protrusions or bony tubercles on both sides of the clinoid processes;

C. Incomplete: Bony projections on both sides of the clinoid processes separated by a fissure;

D. Complete: Completely fused bony projections.

7.1. Prevalence

Increased prevalence of sella bridging has been reported in skeletal class III malocclusions. Meyer-Marcotty reported a prevalence of 16.8% in skeletal class III as compared to 9.45% in skeletal class I (61). A still higher prevalence of 18% has been reported by Marsan and Oztas in skeletal class III malocclusions (62). It is also reported that fusions generally are more frequent in males than in females (63, 64). In contrast, there was no gender difference reportedby Peker et al. (65). The frequency of this bony formation is given as 49% (56, 57). Incidence varies in different populations, such as South African Blacks (male: 19.2%, female: 14.8%) (64), Japanese (male: 3.9%, female: 6%) (63), Ontario Iroquois (male: 34.9%, female: 31.7%) (63) and Alaskan Eskimos (male: 17.3%, female: 17%) (63). Increased prevalence of sella bridges have been reported in idiots (25%), criminals (20%), epileptics (15%) and mental disorders (38%) (66). The presence of osseous interclinoid ligament on dry skulls was stated as variable (56, 57, 67). Skeletal class III individuals were reported to have greater prevalence of sella bridging compared to Skeletal class I (61, 62, 68). A recent study reported significant higher prevalence of sella bridging (type A 4.6% and type B 21.7%) in unilateral cleft lip and palate patients (39).

7.2. Sella Bridges and Pathology

Many pathological processes can be associated with sella bridging as well as enlargement of sella turcica. The prevalence of sella turcica bridging in various pathologies are given in Table 4.

In a study conducted by Leonardi et al., the prevalence of complete interclinoid ligament (ICL) calcification was found to be high (17.6%) in individuals with dental anomalies like mandibular second premolar aplasia and palatally displaced canines (PDC) as compared to the controls (9.9%) with no anomalies (71). They concluded that the very early appearance of a sella turcica bridge during development should alert clinicians to possible tooth anomalies in life later. He also studied the association between sella turcica bridging and dental transposition. 33% of transposition cases also had complete calcification as compared to only 5% among the controls.

There have been many instances where pathological problems such as prolactinoma were discovered on lateral cephalograms during orthodontic therapy (72). Therefore, the lateral cephalometric radiograph must be carefully evaluated for possible pathologies as it may prove to be an initial evidence to an underlying problem a chronic infections also can have an effect on the pituitary gland and consequently the sella, in the form of enlargements or sella bridges. This would signify the presence of a problem before it's clinical manifestation (72).

7.3. Partial Bridging of Sella Turcica

Incomplete bridging of the anterior, middle and posterior clinoid processes is referred to as partial sella bridging. In the literature, partial sella bridging is more prevalent than complete (63, 64). According to Leonardi et al., if the length of the sella is less than or equal to 3/4th of its diameter, it is referred to as partially calcified (71). As this method measured length from tuberculum sellae to dorsum sellae and does not take into account the variable calcifications of clinoid processes, a second method has been proposed by Sundareswaran and Nipun (39). In this method, if the interclinoid distance is less than 1/3rd of the length of sella turcica, it is considered to be partially calcified. Partial sella bridging was found to be significantly higher among unilateral cleft lip and palate patients as evidenced by both these methods in their study.

7.4. Clinical Implications

Knowledge about sella bridges are important from both clinical and surgical standpoint as they have important vascular and neuronal relations. It may cause dysfunction of the muscles of eye due to the compression of the occulomotor nerve. It also presents difficulties in surgeries of aneurysms of intracavernous portion of the internal carotid artery and knowledge of their presence can increase the success of diagnostic evaluation and surgical approaches to the region It can cause compression of the occulomotor nerve and dysfunction of eye muscles. Surgeries involving the intracavernous portion of internal carotid would be difficult. Obviously, a thorough knowledge of sella bridges can increase both diagnostic and therapeutic efficiency (73).

8. 3D Findings of Sella Turcica

Recently shape and dimensions of sella turcica have been evaluated using cone beam computed tomography (CBCT) in cleft subjects. Their results confirm previous findings regarding shortened length of sella turcica in cleft patients (74).

Identification of sella point in 3D maxillofacial software is done after generating 2D cephalometric images from 3D data, which could be either CT or CBCT. Another highly precise and reproducible method for sella identification using 3D models has now been proposed, using a newly developed reference system, which is not based on 2D dimensional images derived from 3D data (75). However it may not be possible to use this method on a day to day basis.

Though CBCT and digital volume tomography could give more information about sella size, they are prone to higher radiation exposure. Being routine diagnostic tools in orthodontics, the astute clinician should regularly evaluate cephalograms for various pathologies.

Table 4. Reported Prevalence of Sella Turcica Bridging in Various Syndromes

Syndrome/Anomalies	Prevalence of Sella Bridging (%)	Authors, Reference
Severe craniofacial deviations	18.6%	Becktor et al. (59)
Axenfeld-Rieger syndrome with PITX2 mutation	-	Meyer-Marcotty et al. (40)
Skeletal class III patients		
	16.8%	Meyer-Marcotty et al. (61)
	10.71%	Abdel-Kader (68)
Severe craniofacial deviations	18.6%	Becktor et al. (59)
Solitary median maxillary central incisor	-	Kjaer et al. (69)
Williams syndrome	13%	Axelsson et al. (29)
Dentofacial deformities	16.7%	Jones et al. (70)
Unilateral cleft lip and palate	Type A (4%); Type B (21.7%)	Sundareswaran and Nipun (39)

9. Conclusions

Sella point is one of the most commonly used cranial landmarks for cephalometric tracing. The benefits gained from studying these structures are many. It can be used in longitudinal studies for studying growth by superimposition, to diagnose subclinical conditions during regular orthodontic pretreatment assessments and for evaluation of orthodontic treatment results. The accuracy of cephalograms in detecting pituitary pathologies needs to be assessed in further studies. Incidental findings noted by the orthodontist may lead to further investigation of undiagnosed or subclinical conditions.

Footnotes

Authors' Contribution: Shobha Sundareswaran developed the concept of reviewing various aspects of sella turcica, critically reviewed and supervised the manuscript and is guarantee. Ravisankar Vijayan contributed to the development of the review, searched literature and drafted the manuscript. Praveen Santhakumaran Nair, Latheef Vadakkepediyakkal and Sreehari Sathyanadhan contributed to searching literature regarding different aspects of sella turcica, and also drafting of the manuscript. All the authors had read and approved the final version of the manuscript.

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