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Mid-Skull Anatomy on Orthopantomogram- A Simplified Visual Guide

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ABSTRACT

Orthopantomogram is the routinely used radiograph that allows visualization of maxillomandibular structures. The maxillary region along with the small surrounding bones is depicted superimposed over each other. This leads to difficulty in clear visualization of each structure's extent and margins. Thus, this study was done to clearly demarcate the complex midfacial structures and to understand their anatomy on the OPG so that complex investigations can be minimized.

Keywords: *Anatomy; Mid-Skull; Maxilla; Orthopantomogram*

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INTRODUCTION

Orthopantomogram (OPG) is a two dimensional radiograph that allows comprehensive and simultaneous evaluation of the oral hard tissues of both the jaws. It is a widely used radiograph because it is very convenient and comfortable for the patient and it allows visualization of the dental as well as maxillofacial region in a reduced amount of time with a reduced radiation dose as well. The complex situations where intraoral radiography is difficult to tolerate like in trismus, gagging etc, OPG proves to be a very useful alternative. OPG is a type of tomographic procedure involving simultaneous and synchronized but opposite rotation of x-ray source and image receptor around a stationary patient's head. The 180degreerotation of X-ray source captures the entire volume of maxillofacial region but the structures that lies within the image layer or focal trough are particularly clearly demonstrated whereas the ones lying outside the image layer are either blurred, magnified or minified. Since, the entire volume content gathered is displayed on a two dimensional image receptor, multiple superimpositions and shadows of structures are noted in OPG and this is one of the biggest disadvantages of this radiograph [1].

The structures of the midskull region are particularly difficult to appreciate on a panoramic radiograph because it is made up of a number of small and thin bony segments, air cavities and soft tissues all of which creates multiple shadows that are difficult to delineate [2]. The mid skull region constitutes the maxillary bone and its antrum, zygomatic bone, orbital rims and plates, palatine bone, nasal bone, ethmoid bone, nasal turbinates, sphenoid bone with its pterygoid plates, and temporal bones on each side. Some of the characteristic landmarks that are formed by the intersection of these bones serve as important identification points of involvement of a particular structure in a pathology. In fact, the absence of a landmark, is sometimes the only identification point for the diagnosis of a pathology on a panoramic radiograph.[1] Since the advent of3-D imaging modalities, the reliability and dependency on OPG for diagnosis of disorders affecting the midface or midskull is reduced considerably but its usage in dental clinics and dental institutions for low socio-economic groups is not overruled. It still remains the first choice and sometimes the only radiograph to evaluate the extent of disorder and decide the treatment plan or further imaging that may be required. Hence, it is important to understand the interpretation and radiologic anatomy of the midskull structures that are appreciable on OPG but not studied extensively so that the information available to us in conventional 2D radiography can be studied completely and unnecessary exposures to 3D imaging can be minimized [3-6].

Thus, this study was attempted to understand the radiologic anatomy of the complex midskull structures on an OPG by highlighting the key structures through a radiopaque material. This aims to create a visual guide for the students and radiologists for the easy interpretation of midskull structures in day to day practice.

MATERIAL AND METHODS

A macerated adult skull was used to demonstrate the following key midskull landmarks:

1) *Pterygomaxillary fissure (PMF)* is the triangular shaped opening of the pterygopalatine fossa. It is a vertical gap between the lateral pterygoid plate of the pterygoid process and the maxilla. It is an important midskull landmark and appears as tear drop shaped radiolucency bilaterally on OPG.[1] The loss of PMF or disturbance in its integrity is seen in the disorders affecting the posterior border of the maxillary sinus as in sinus mucoceles, carcinomas and in traumatic conditions.
2) The *superior orbital fissure (SOF)* is a 22-mm cleft that separates the greater and lesser wings of the sphenoid and lies between the optic foramen and the foramen rotundum. It provides passage to the three motor cranial nerves III, IV and VI that supply the extraocular muscles of the orbit.[2] Its involvement in traumatic disorders of midface and in other pathologies highlights the significance of its radiographic interpretation. Generally, it is not easily discernible on OPG rather attempts have not been made to appreciate its interpretation on OPG as can be judged by the sparse description in the radiology reference textbooks.
3) The *inferior orbital fissure (IOF)* lies inferior to SOF and separates the lateral wall and the floor of the orbit. It joins medially with the pterygomaxillary fissure at a right angle. It transmits the infraorbital nerves and vessels, zygomatic nerves and branches from the pterygopalatine ganglion. This structure is particularly involved in the fractures of the orbital floor [3].
4) The *orbital floor and medial wall (OFM)* are joined at maxilloethmoid suture [5]. The medial wall anteriorly is composed of lamina papyracea, a thin plate of bone overlying the ethmoid sinuses. The posterior aspect is made of sphenoid bone adjoining the optic canal. The orbital floor is triangular in shape and gradually slopes upwards conforming to the pyramidal shape of orbit. It is formed mainly by the orbital plate of the maxilla and is the roof of the maxillary sinus. In its posterolateral two-thirds, the floor is separated from the lateral wall by IOF. The inferior orbital rim is easily visualizable on OPG but the orbital floor is a thin bony plate which is generally involved in Lefort and Zygomatic complex fractures and not readily discernible on OPG. The medial orbital wall is particularly obscured on OPG due to superimposition by central spine and the ethmoidal air sinuses.
5) The *Maxillary sinus (MS)* is the air cavity in maxillary bone that is readily appreciated on OPG. It appears as radiolucency with distinctly appreciable anterior wall, floor and posterior wall. The radiopaque septae if present within the maxillary sinus makes an appearance of physiological multilocular radiolucency of the jaws. The discontinuity in the integrity of the borders of maxillary sinus or radiopacities in the air cavity of sinus suggests pathologies affecting the MS and this is one of the useful indications for prescribing an OPG. The panoramic innominate line is also seen superimposed in the posterior aspect of MS on OPG formed by the cortical outlines of zygomatic process of maxilla inferiorly and frontal process of zygoma superiorly [5].
6) The *Posterior surface of Maxilla (PSM)* is formed by a fusion of several bones: the maxillary bone, the palatine bone, the zygomatic bone, and the pterygoid plates of the sphenoid bone.[6]It forms the anterior wall of the infratemporal fossa.[7] The significance of its delineation in radiographs lies in its involvement in midfacial fractures particularly Lefort II and in MS disorders [5].
7) The *Medial and Lateral Pterygoid plates(MLPP)* are paired postero-inferior projections of the sphenoid bone. They give attachments to the pterygoid muscles of mastication. A small hook shaped process extends from the medial pterygoid plate called as the pterygoid hamulus which serves as attachment for tensor veli palatini and pterygomandibular raphe. The pterygoid plates are specifically affected in the complex midfacial structures like Lefort I, II and III and hence their identification is significant.
8) The *petrous ridge of temporal bone(PRT)* is the superior aspect of the petrous temporal bone(PTB). PTB is pyramidal in shape and forms a part of skull base between sphenoid and occipital bones. It houses vital cranial nerves, sinuses, canals and vessels. The superior aspect of PTB known as PRT is visualized in various extraoral projections. Its appearance of OPG has not been studied thoroughly.

Radiopaque lead foil was used to highlight these structures except MS. The thin lead foil that is a component of intraoral film packet and is easily available after development of radiographs was used. The advantage of using the lead foil was that it could be adapted to the bony surfaces easily like in case of OF, PRT, PSM, MLPP and secured in place using a transparent tape.

For PMF, SOF, IOF, multiple lead foils were manually manipulated and moulded to conform to the fissures. For MS, the foil could not be conformed to the irregular borders of the maxillary sinus cavity as the access was present only through the nasal cavity in the skull. So first, the cotton was inserted and adapted to the walls of the maxillary sinus cavity using a tweezer and probe and then the contrast agent was injected into the cotton filling the air cavity of maxillary bone.

The skull was then placed in Planmeca Promax Panoramic Machine manufactured by Planmeca Oy, 00880 Helsinki, Finland. The skull was positioned in the OPG machine in standardized position such that its sagittal plane is perpendicular to floor and placed in the centre of image layer and the Frankfort horizontal plane parallel to the horizontal plane and perpendicular to the sagittal plane. Because the anterior teeth of the skull were missing, the exact positioning of anterior teeth in the image layer could not be obtained and was done approximately. An exposure was made without any radiopaque highlighter.(Figure 1) The positioning was then repeated for exposure of each landmark highlighted by radiopaque material.

The landmarks were compared on normal skull image without highlighter and one with radiopaque highlighter as per the following parameters:

a) Position
b) Outline/border
c) Extent of landmark
d) Internal structure
e) Relation with surrounding structures
f) Presence of ghost shadow

The OPG radiographs were viewed in a quiet interpretation room with low ambient light after masking the light from the surroundings of the viewing light box and light passing only through the radiographs. The parameters were recorded by two oral and maxillofacial radiologists with more than 8 years of experience(Table 1).Any divergences or conflicting views between the examiners were resolved by discussion and reaching a consensus.

A ghost image is seen in OPG when a densely radiopaque object or anatomical structure lies between the x-ray source and its centre of rotation. It is vertically magnified and projected superior to the actual position due to positive angulation of x-ray beam. Since the highlighter used was densely radiopaque, the formation of ghost shadows was expected. Hence, an attempt was made to identify the ghost shadow for each highlighted landmark.

RESULTS AND DISCUSSION

The PMF is generally discernible on normal OPG and its highlighting with radiopaque lead also shows it to be an oblique tear drop shape with a concave anterior surface and convexity directed posteriorly towards the TMJ region. The superior border of PMF which was not clear on normal OPG was easily visualizable using RO highlighter. Overall the margins of PMF were well defined and no ghost image was seen.(Figure 2)

The OPG actually demonstrates three images in a single flattened view due to its curved/parabolic image layer conforming to the shape of jaws. The anterior portion between the bilateral canines represents the postero-anterior (PA) view of the skull and the portion posterior to canines bilaterally represents the lateral view of the jaws. The anterior position typically shows the maximum distortion and superimposition artefacts due to central spine. However, in skull OPG, there was no superimposition of spine but this area is composed of multiple bony cavities, small bones and fragments. Therefore, the interpretation of 3 landmarks- SOF,IOF, OF was particularly difficult on normal skull OPG. The OPG displays the superior, lateral and the infraorbital rim clearly but the SOF and IOF were not discernible.

On highlighting the fissures, the SOF appeared to be positioned lateral and posterior to the lateral orbital rim as it is situated at the orbital apex and is imaged during the lateral projection of the posterior aspect. The IOF also was captured during the lateral projection of both the sides and not in the PA view of the anterior sextant resulting in a winged appearance(simulating the wings of a flying bird) with the anterior border located close to the lateral orbital rim and the postero-lateral border forming the superior aspect of the PMF. (Figure 3)The margins of SOF were blurred and it appeared magnified whereas for IOF, the margins were well defined. There were 2 images for each IOF, one real image and 1 ghost image located on the contralateral side. This could be explained as per the mapping of maxillomandibular zones by Reuter et al [8] where SOF lies in zone 1A and IOF lies in Zone 2 due to its oblique location.

The OFM was covered with lead foil extending posteriorly from the curved borders of optic canal, covering the medial wall and floor uptill the borders of IOF laterally. The resultant OPG revealed a thin semilunar shaped radiopacities bilaterally. The lateral border of foil near to IOF was represented as the curved inferior border of the radiopacity at the level of inferior orbital rim but the posterior aspect of the foil near the optic canal was projected much laterally. This again is explained by the capture of orbital apex during the lateral projection of the posterior aspect of jaws. The medial border of foil was projected superiorly and directed posterolaterally. A ghost shadow of right OFM was also noted projected superior to the left OFM with blurred borders. (Figure 4)

The MS was highlighted by injecting contrast agent in the previously adapted cotton in the air cavity. The radiolucent space occupied by MS was seen as dense radiopacity with smooth posterior border that conforms to the posterior border of maxillary bone and the anterior concave border of PMF. The superior border of MS was clearly appreciated and seen extending in the orbital cavity as orbital floor. The anteriomedial aspect was underfilled due to constraints in adapting the cotton from the small access from the nasal cavity. (Figure 5). The in nominate line that is discernible as radiopacity over the radiolucent sinus was obscured due to the more radiopaque sinus.

Table 1: Comparison of Landmarks on normal skull OPG and with highlighter.

Landmark		PMF	SOF	IOF	OFM
	Normal	Lateral to PSM	Not Visualized	Not Visualized	Not discernible
Position on OPG	Highlighted	Lateral to PSM	Lateral to lateral orbital rim	Near the lateral point of infraorbital margin	Clearly visualized
Outline/ border	Normal	Superior border not defined	Not Defined	Not defined	Not defined
	Highlighted	All borders well defined	Defined shape with blurring of borders	Well defined winged shape	Well defined
Extent of landmark on OPG	Normal	Less defined	Not visualized	Not visualized	Not Defined
	Highlighted	Clearly defined	At the lateral aspect of the superior border of orbit	Starting from the intersection of panoramic innominate line and infraorbital rim till superior border of PMF	Semilunar shaped(simulating eye) radio-opacity in the orbital cavity with lateral border at infraorbital rim and medial border projected superiorly and directed laterally to conform to orbital pyramid and projected beyond the lateral orbital rim
Internal structure	Normal	shaped radiolucency with radiopaque	-	-	-
	Highlighted	Tear drop shaped radiopacity	Totally radiopaque	Totally radiopaque	Totally radiopaque
Surrounding structures	Normal	-	-	-	-
	Highlighted	-	-	-	Lateral orbital rim visualized through the lead foil
Presence of ghost shadow	Normal	No	-	-	No
	Highlighted	No	No	Yes projected superiorly in the middle of orbital cavity. Appears as a straight line	Yes of right side located superior to the left OFM.

PRT	MLPP	PSM	MS
In the cranium with medially upward directed slant	Lateral to maxillary tuberosity	Not discernible	Within the maxilla above posterior teeth
In the cranium with medially upward directed slant	Lateral to maxillary tuberosity	Well Defined	Within the maxilla above posterior teeth
Defined	Not well defined and Medial plate not visualized	Not defined	Anterior, floor and posterior borders defined
Well defined	Well defined both the plates	Well defined	Well defined anterior, floor, superior and posterior border
Superior to external auditory meatus till a point perpendicularly above the coronoid process	Not defined	Not defined	Seen from lateral nasal wall to PSM and extension in alveolus to infraorbital rims
Extension seen much lateral to external auditory meatus	Lateral plate- from Maxillary tuberosity extending superolaterally till zygomatic arch Medial plate- extending from zygomatic arch till the border of coronoid notch in the sigmoid notch area radiolucency	From maxillary tuberosity covering the anterior surface and extending till superior surface of PMF	The superior borders are seen extending into the orbital cavity
Radiopaque	Radiopaque lateral plate	Mixed	Radiolucent with radiopaque borders
Clearly radiopaque	Totally radiopaque medial and lateral plate	Totally radiopaque	Totally radiopaque. Anterior portion appearing radiolucent due to underfilling by contrast material
Multiple superimpositions by landmarks but differentiation difficult	Visualized	Other superimposed landmarks visualized	Innominate line and other structures visualizable
Not visualized	Visualized through thin lead foil	Obscured other landmarks	Obscured Innominate line
Yes(seen as parallel radiopaque line superiorly but blurred margins	No	No	No
Yes(1real image and 1 ghost image)	Yes but difficult to interpret arising from which plate	No	No

Figure 1: Demonstration of some midskull landmarks on normal skull OPG. a- Pterygomaxillary Fissure(PMF), b- Maxillary Sinus(MS), c- Panoramic innominate line, d- Lateral Pterygoid plate(LPP), e- Petrous ridge of temporal bone(PRT).

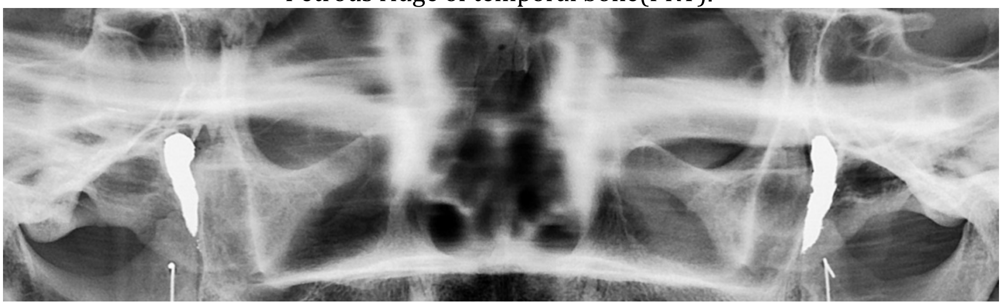

Figure 2: Cropped OPG showing highlighted PMF.

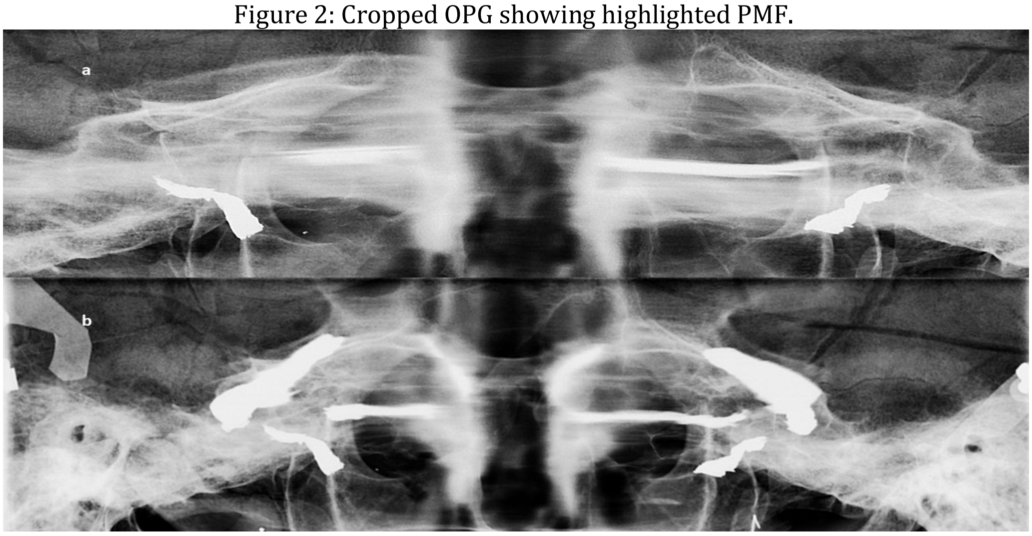

Figure 3: Cropped OPG a) showing highlighted IOF bilaterally and their ghost shadow b) showing highlighted both the SOF and IOF and ghost shadow of IOF.

Figure 4: Cropped OPG showing the OFM and its ghost shadow

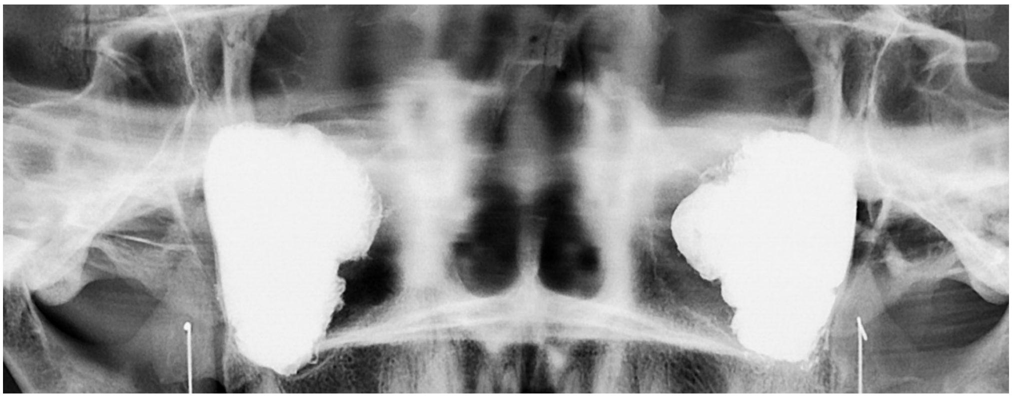
Figure 5: Cropped OPG showing MS bilaterally


Figure 6: Cropped OPG showing PSM bilaterally

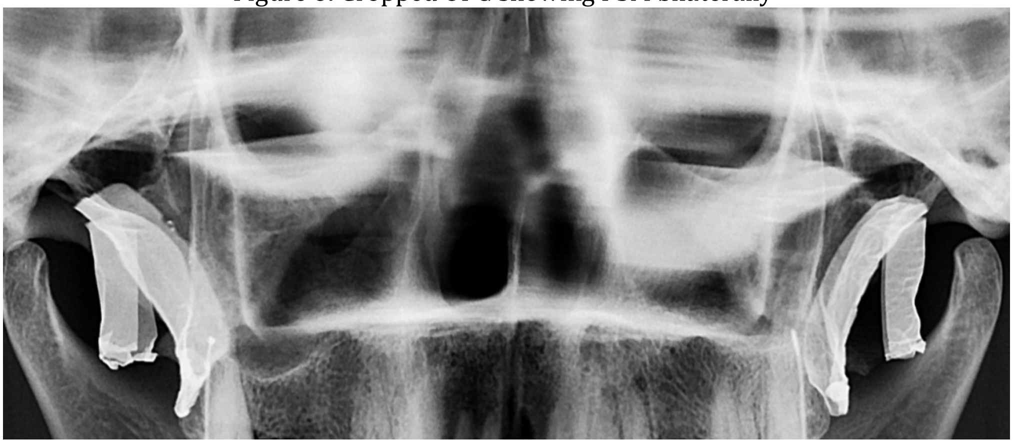
Figure 7: Cropped OPG showing MLPP bilaterally and 1 ghost shadow

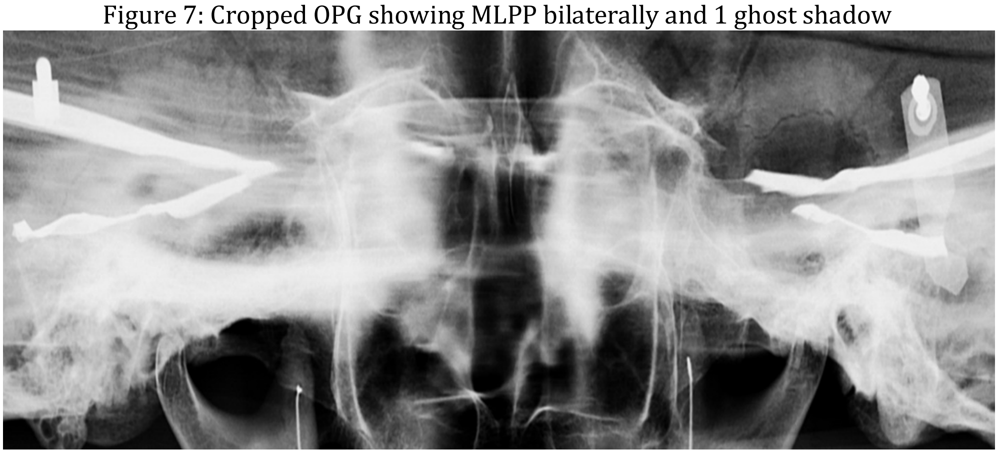
Figure 8: Cropped OPG showing PRT bilaterally and their ghost shadow

The PSM is generally confused with posterior border of maxillary sinus on an OPG. The PSM is continuous with the maxillary tuberosity inferiorly and extends superiorly to form the anterior concave surface of the PMF. The superior border of PMF signifies the superior extent of the PSM. On an highlighted OPG, the exact extent of PSM was appreciated. The highlighted radiopacity was noted extending lateral to the lateral orbital rims but actually it extended posterior to the orbits and zygoma and is seen flattened due to its capture during the lateral projection. No ghost images are seen.(Figure 6)

On an OPG, the lateral pterygoid plates (LPP) are visible lateral and superior to the maxillary tuberosity. The anterior border of the pterygoid plate is appreciated as the posterior border of the PMF. The pterygoid hamulus is also sometimes appreciated as small radiopaque hook like projection from LPP. On the highlighted image, the LPP was noted extending superolaterally and posteriorly from the maxillary tuberosity till the inferior border of zygomatic arch. The medial pterygoid plate is projected as a perpendicular plate in the sigmoid notch area (Figure 7). The ghost shadows are also noted projected superiorly at the infraorbital rims but difficult to interpret the causative plate.

The PRT appeared as downward and laterally slanting radiopaque lines in the region above the TMJ and mastoid air cells. Each PRT showed 1 real image and a magnified ghost shadow projected superiorly and on the contralateral side suggesting the location of PRT in the zone 2 of the image layer as mapped by Reuters *et al* [8]. The structures located in zone 2 are portrayed on the radiograph twice.(Figure 8)

Thus, the midskull landmarks that were not easily delineated on OPG have been shown to have clear position, extent and borders. The projection of these complex landmarks on 2D OPG has not been extensively described in the radiology literature. Thus, even though the landmarks may have been captured but their projection, radiologic anatomy has not been adequately described and thus the usefulness of OPG for diagnosing the disorders affecting these landmarks has not explored. This paper can thus act as a visual guide for the students, oral radiologists to understand the anatomy of these complex midskull structures on OPG.

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