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Research Article

Double and Triple Images in the Panoramic Technique: An Experimental Approach

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Abstract

Objectives: Panoramic radiograph is a simple technique that is generally used in all dental specialties. In addition to the formation of real images, ghost images may also form into the panoramic radiograph, and prevent an appropriate diagnosis.

The objective of this experimental study was to show the patterns leading to the formation of panoramic radiograph ghost images caused by metal objects placed in different regions of the skull model and to present some clinical illustrations showing the formation of multiple images of a single object. These phenomena may lead to difficulties in radiographic interpretation if they are not properly understood.

Methods: This experimental study was conducted using an educational human adult skull model placed in a panoramic device according to standard procedures, presenting the formation, in panoramic radiographs, of ghost and real images caused by metal spheres, attached to different areas of the maxilla.

Results: A ghost image occurred when the metal object was located between the X-ray source and the rotation center, and when it had a density that was sufficient to attenuate the X-ray beams.

This image subsequently presented the same morphology as the object, but with distortion, and appeared on the opposite side and at a higher point than the corresponding real object.

Double images appeared when the object or anatomical structure was located between the X-ray rotation center and the image receptor.

Conclusion: Understanding the principles of the formation of panoramic radiograph ghost images prevents incorrect diagnoses and inappropriate treatment for patients.

Keywords: Panoramic Radiography; Ghost Images; Experiment; X-Ray Diagnosis

Introduction

Radiology has long been used in all dental specialties. Panoramic radiography, also known as orthopantomography (OPT), is among the various radiographic techniques used by dental surgeons) [1]. It is a first-line examination which is often necessary, and it is sometimes sufficient to allow the overall observation of the entire oral sphere [2]. It is an "unscrambling examination", which is still used in all dental specialties [2,3]. It is not a simple projection technique on an X-ray receptor; it is rather a thick section tomography allowing to obtain a clear image of a single section of varying thickness of the examined object. This tomography follows the morphology of maxillary arches and performs a real unfolding, from one temporomandibular joint to another [1]. However, this technique has certain drawbacks, including image overlap of some anatomical structures, geometric distortion, and production of ghost images [4]. Ghost images can hinder accurate diagnoses as they can simulate lesions or can be projected on inappropriate places, thus masking abnormalities or underlying anatomical structures [4,5].

Panoramic radiographs of patients with piercings or other metal objects in their facial zone are the most common example of how

ghost images may be formed, and how these non-anatomic objects can distort the quality of the panoramic radiograph image and its interpretation [4].

The objective of this experimental study was to show the patterns leading to the formation of panoramic radiograph ghost images in panoramic radiographs caused by metal objects placed in different regions of

The skull model and to present some clinical illustrations. Understanding these mechanisms allows to prevent misinterpretations and false diagnoses, thus making it easier to establish a treatment plan in the best possible conditions.

Material and Methods

This study was conducted using Sirona Orthophos XG Plus digital panoramic X-ray machine with the following characteristics:

- Size of the focal point measured in the central beam: 0.5 mm.
- Active sensor area, Pan type: 138 x 6.48 mm.
- Focus/sensor distance: 497 mm.
- Angulation of the x-ray beam: 7 degrees.

An educational human adult skull model was used. A small metal sphere, 2 millimeters in diameter, was used to simulate a foreign body in the maxillo-mandibular structures. When located in the section plane, this metal sphere produced a clearly visible radio-opaque image, called a real image. However, when located outside the section plane, this metal sphere gave ghost images.

To evaluate the formation of real and ghost images, the metal sphere was fixed with a glue stick as follows:

- **Zone 1A:** The retro-incisor region in the focal trough (Figure 1a).
- **Zone 1A:** Midway between the 2nd molar and the middle of the bony palate in the focal trough (Figure 1b).
- **Zone 2:** In the sub-mandibular region and outside the focal trough (Figure 1c).
- **Zone 3:** At the posterior region of the bony palate outside the focal trough (Figure 1d).

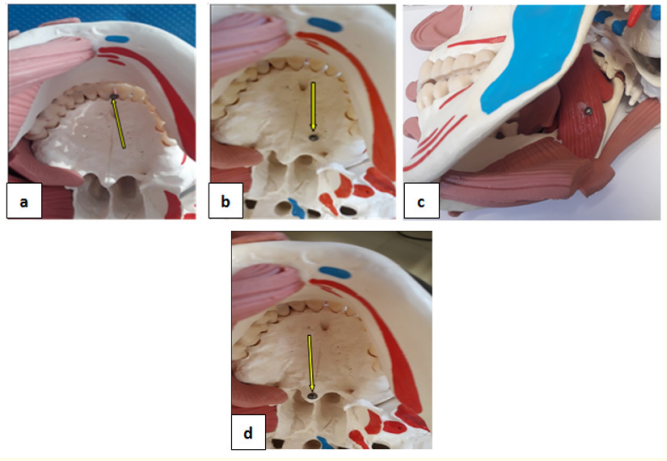

Figure 1: Location of the metal sphere in the educational skull.

The choice of the different positions where to place the metallic sphere was guided by Reuter diagram (Figure 2) [6]. This study was conducted by placing the anatomical skull model in Sirona Orthophos XG digital panoramic x- ray machine while respecting the correct orientation of the image layer, the Frankfurt plane and the midsagittal plane. The incisors were placed in the patented bite block (Figure 3). A wooden rod was used as a support for the fixation of the anatomical skull within the machine. The following exposure parameters were used: a voltage of 62 kV, an intensity of 8 mA, and an exposure time of 14.1s. The image layer comes in different shapes U, V and elliptical. The most commonly used image layer is the elliptical shape with a thickness of approximately 5 mm and 15 mm in the anterior and posterior areas, respectively (Figure 4).

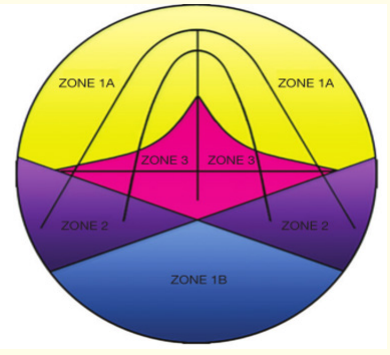

Figure 2: Diagram showing zones 1A and 1B (forming one image), zone 2 (forming double images) and zone 3 (forming triple images) [6].

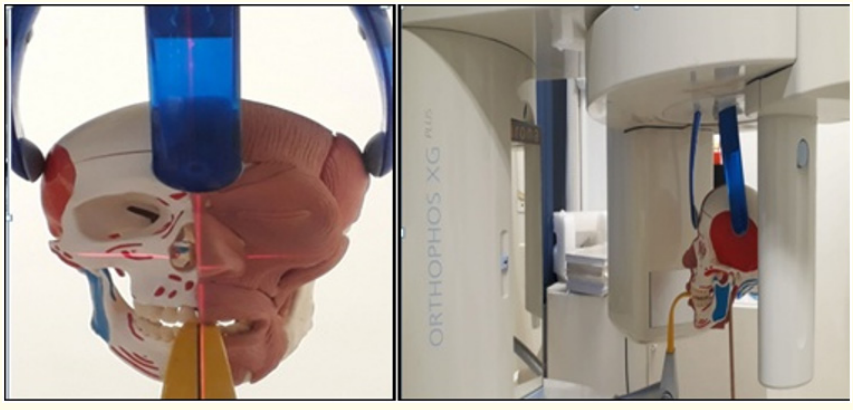

Figure 3: Anatomical skull placed in a panoramic x-ray machine according to standard procedures.

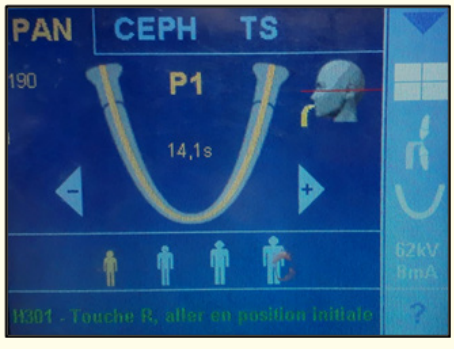

Figure 4: Exposure parameters.

Results

In the first case, a panoramic radiograph was taken with a metal sphere attached in the retro incisor region (zone 1) (Figure 1a). This experience led to the formation of a single real image of the metal object in area 1A of Reuter diagram (Figure 5).

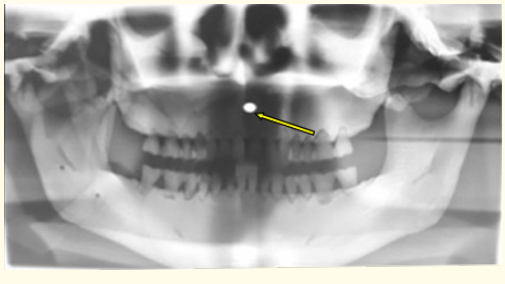

Figure 5: Panoramic radiograph with a metal sphere attached in the retro incisor region showing a single real image of the metal sphere.

Another panoramic X-ray radiograph was taken with a metal sphere placed laterally in zone 1A, half way between the 2nd molar and the middle of the palate (Figure 1b), and it produced a single real image (Figure 6).

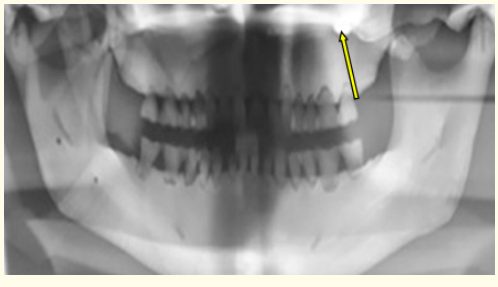

Figure 6: Panoramic radiograph with a metal sphere attached between the 2nd molar and the middle of the bony palate showing a single real image.

In the second experiment, the metal sphere was placed in the sub-mandibular region (zone 2) (Figure 1c). In this case, 2 images were obtained: one real image on the same side as the metallic sphere and another distorted ghost image located in the contralateral side, in a higher position than the first image (Figure 7).

In the third experiment, a panoramic radiograph was taken with the metal sphere attached in the central and posterior region of the bony palate (Zone 3) (Figure 1d). Three images were formed: two symmetrical images projected onto the right and left side of the bony palate and one image located in the center of the film (Figure 8).

Figure 7: Panoramic radiograph with a metal sphere attached in the sub-mandibular space (zone 2) showing two images: a real homolateral image and a distorted contralateral phantom image (enlarged in the vertical and horizontal planes).

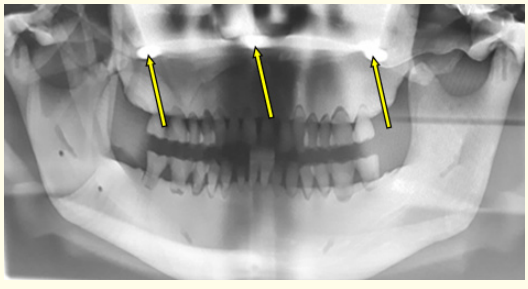

Figure 8: Panoramic radiograph with a metal sphere attached in the most posterior region of the bony palate (zone 3) showing two bilateral images and one image in the center.

Discussion

This experimental study showed the formation of real and ghost images in digital panoramic radiographies through the positioning of a metal sphere in different maxillo-mandibular regions of a human skull model.

A real image is formed when the object is located between the rotation center of the x-ray beam and the x-ray receptor. High definition and sharpness are exhibited when the object is in a focal trough that is similar in shape to the dental arch [7,8]. The x-ray beam should be perpendicular to both the object and the detector [9]. In this case, a perfect image without any distortion is obtained.

Double images (one real image and one ghost image) are seen when a unique and a lateral object or anatomical structure exist outside the focal trough. It occurs when the object or anatomical structure is located between the source and the center of rotation, and when it is thick enough to attenuate X-rays.

The ghost image has the following characteristics: it keeps a shape broadly similar to the real image, but it is larger, blurry and located on the opposite side of the object. It also appears at a higher position than the real image due to the upward angulation of the x-ray beam, which is estimated at 7 degrees [10,11].

Two symmetrical bilateral images and a central one are observed when the involved median structure is located outside of the apparatus image layer [12]. Both symmetrical images are seen when the object/anatomical structure is located between the rotation center source and the x-ray receptor, thus being intercepted twice during the exposure. The distance separating the object and the x- ray receptor is fixed throughout the exposure time, which explains the similarity of the two X-ray images in terms of shape that will nearly be the same [11]. These double lateral images are well-defined although they do not reflect the real position of the object, which is a median one.

With regard to the central image, it always appears blurry and horizontally distorted. In our experiment, the metallic sphere was placed outside the focal trough and therefore its projection produced a median enlarged image, reflecting the real position of the object [11].

Reuter et al. established a diagram of the maxillo-mandibular zones showing the number of images formed according to the position of the object [13] (Figure 2).

In the zone corresponding to area 1A (anterior regions of the mandible and the maxilla), a single real image is formed. In zone 1B (occipital bone and the foramen magnum, etc.), only one single ghost image is observed. As for the structures located in zone 2, two images are seen (a real image and a ghost image). For the anatomical structures belonging to the diamond shaped zone 3 (i.e. spine and hyoid bone), a triple image is seen.

To summarize, it is worth noting that objects located in the focal trough exposure result in real and well-discerned images, while objects located outside the image layer tend to be blurred in panoramic radiography [6]. The image layer is virtual and it is predetermined by the manufacturer. It measures approximately 15mm posteriorly and 5mm anteriorly, which is adequate to fit the shape of the dental arches. Projections of the structures posterior to the

focal trough are blurred and magnified while those corresponding to the structures anterior to this layer are blurred and shrunk. Hence, a correct patient positioning within the panoramic x –ray machine is paramount in order bring the dental arches into the focal trough [1]. One should keep in mind that ghost images can occur even when the patient´s dental arches are properly positioned in the image layer. This is due to the examined structure being outside the focal trough. Therefore, panoramic radiography may contain real or ghost images depending on the relative position of the object and the image layer, as defined in the Reuter diagram.

To illustrate the importance of anatomical and technical knowledge of the principle of the formation of images in panoramic radiograph, we report two clinical cases showing the presence of ghost images leading to confusion when interpreting the panoramic radiograph.

In the first case, the object (endodontic sealer) was anatomically located outside the focal trough although the patient was correctly positioned.

The panoramic radiograph (Figure 9) showed two radio-opaque images, superimposed on the right and left maxillary sinuses. The image located in the right maxillary sinus had well-defined borders. It was the real image corresponding to the overflow of the endodontic sealer actually pushed back inside the right maxillary sinus. The other image, radio-opaque contralateral image (ghost image), was seen at a higher level, with blurred borders. It was also slightly enlarged compared to the first one. On the diagram established by Reuter et al., extruded sealer occurs in zone 2, leading to the formation of two images: a real image and a ghost one. Being unaware of this issue, the latter image can mislead the practitioner when interpreting the radiograph, thus resulting in poor patient care.

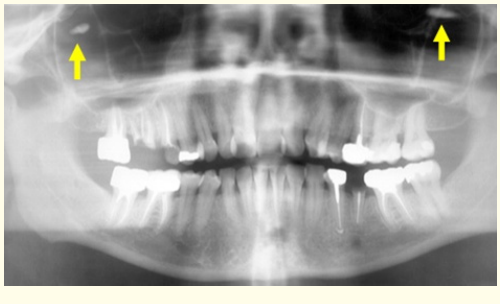

Figure 9: False double image of the endodontic sealer pushed back into the right maxillary sinus. The image on the right side has well-defined limits. The radio-opaque image on the left side (ghost image) appears higher, enlarged and blurry.

In the second case, the object was outside the focal trough due to an incorrect patient position in the x-ray device.

The patient was referred with an orthopantomograh for dentascanner exploration of impacted maxillary and mandibular supernumerary molars on the left side. Non respect of the patient's correct position within the panoramic x- ray machine with regard to both the focal trough (posterior translation)and the mid-sagittal line (head rotation to the right) was observed as the right side was clearly larger than the left one in the radiograph in addition to the anterior teeth which were blurred and enlarged (Figure 10).

Figure 10: Presence of two supernumerary maxillary and mandibular molars located just behind the wisdom teeth on the left side.

As part of a pre-surgical radiological assessment aimed at the extraction of supernumerary molars a CT scan was performed and it paradoxically showed the absence of any supernumerary tooth (Figure 11).

Figure 11: Multiplanar Reconstruction of the left-side of mandibular horizontal branch showing absence of supernumerary teeth.

A second panoramic radiograph was performed with a correct positioning of the patient (Figure 12). Panoramic reading confirmed the CT scan findings. It led to the conclusion that the supernumerary teeth observed on the first panoramic radiograph on the left side were only ghost images of the 18 and 48 that were outside the focal trough due to the patient's wrong positioning.

Figure 12: Panoramic radiograph after correction of the patient´s position showing the absence of supernumerary teeth.

In fact, the combination of both, important posterior translation and rotation of the patient's dental arches towards the right side caused the molars to pass from zone 1 to zone 2 of Reuter diagram.

The previously reported clinical cases showed that failure to comply with the standard rules for patients' positioning automatically had repercussions on the image quality. The dental practitioner must be conscious of the patients' positioning guidelines as well as the physical principles of the formation of double and triple images that may be observed even in cases of a well-positioned patient. Misinterpreting images can lead to repeated panoramic examinations or to unnecessary explorations, and consequently to an increase in patients' exposure to ionizing radiation [13-15].

Conclusion

Understanding the principles of the formation of panoramic radiograph ghost images prevents incorrect diagnoses and inappropriate treatment for patients.

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