

An atypical case involving real, ghost, and pseudo-ghost images on a panoramic radiograph

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ABSTRACT

Purpose: This report presents a unique case featuring real, ghost, and pseudo-ghost images on the panoramic radiograph of a patient wearing earrings. It also explains the formation of these images in an easy-to-understand manner.

Materials and Methods: One real image and two ghost images appeared on each side of a panoramic radiograph of a patient wearing earrings on both sides. Of the two ghost images on each side, one was considered a typical ghost image and the other was considered a ghost-like real image (pseudo-ghost image). The formation zones of the real, double, and ghost images were examined based on the path and angles of the X-ray beam from the Planmeca ProMax. To simulate the pseudo-ghost and typical ghost images on panoramic radiography, a radiopaque marker was affixed to the right mandibular condyle of a dry mandible, and the position of the mandible was adjusted accordingly.

Results: The center of rotation of the Planmeca ProMax extended beyond the jaw area, and the area of double image formation also reached beyond the jaw. The radiopaque-marked mandibular condyle, situated in the outwardly extending area of double image formation, exhibited triple images consisting of real, double (pseudo-ghost), and ghost images. These findings helped to explain the image formation associated with the patient's earrings observed in the panoramic radiograph.

Conclusion: Dentists must understand the characteristics and principles of the panoramic equipment they use and apply this understanding to taking and interpreting panoramic radiographs. (*Imaging Sci Dent* 2024; 54: 57-62)

KEY WORDS: Patient Positioning; Radiography, Panoramic; Foreign bodies

Introduction

Panoramic radiography is a tomographic technique in which the tube and image receptor rotate around the patient to form a focal trough that matches the shape of the dental arch while scanning. The focal trough is also called the image layer, and the imaged patient's teeth appear spread out as if they are neatly arranged in a full-mouth intraoral radiographic image. The anatomical structure located in the focal trough is imaged with the dentition, so that the upper and lower jaws can be examined together with the dentition.¹

Panoramic radiography has the advantage of conveniently obtaining diagnostic information about the jaw and dentition in a short time with minimal discomfort to the patient. Moreover, the diagnostic ability of panoramic radiography has improved due to continuous developments and advances, and it has become a primary diagnostic tool in dentistry.^{2,3}

Currently, panoramic radiography is used to diagnose oral diseases and conditions in nearly all patients. However, although panoramic radiography has been widely emphasized in textbooks and is very familiar to dentists, the geometric method of imaging is rather complicated, and structures other than those in the focal trough are often visible on the image, making diagnosis challenging and confusing for dentists.^{1,2,4}

The interpretation of diagnostic images involves the process of identifying normal anatomical structures and inferring normal and abnormal findings. When interpreting pan-

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oramic radiographs, dentists must distinguish among real, double, and ghost images. To achieve this, dentists should be aware of the principles of panoramic imaging and the characteristics of the imaging equipment they use.⁴

It is common knowledge that one real image and one ghost image may appear due to one earring in a panoramic radiograph of a patient taken while wearing an earring.^{1,2,5} However, the authors experienced a case in which one real image and two ghost images appeared on each side of the panoramic radiograph of a patient wearing earrings on both sides. Of the two ghost images, one was a typical ghost image and the other was a ghost-like real image (pseudo-ghost image).

There have been several reports about atypical ghost images appearing in panoramic radiographs, but they were difficult to understand and there were some errors in distinguishing between real and ghost images or explaining the principles of image formation.^{4,6,7}

Therefore, this report presents a unique case in which real, ghost, and pseudo-ghost images appeared in the panoramic radiograph of a patient wearing earrings, describes the reproduction of these images them using a dry mandible, and provides an easy-to-understand explanation of how these images were formed. This report will improve dentists' understanding of panoramic radiography.

Materials and Methods

This study was approved by the Institutional Review Committee of Chosun University Dental Hospital (IRB no. CUDHIRB 1903 002).

Panoramic radiograph with atypical ghost images

A pediatric patient underwent panoramic radiography while wearing earrings. Panoramic radiography was performed using ProMax (Planmeca, Helsinki, Finland) and was taken in standard mode under a field of view and exposure conditions for pediatric imaging.

On the panoramic radiograph, the occlusal plane depicted a gentle smile line, the anatomical structures were relatively symmetrical, the anterior portion of the maxilla and mandible corresponded to that of the focal trough, and the alveolar bone and successive teeth were clearly observed, thereby demonstrating a well-taken image.

However, two ghost images were observed from the right and left earrings. The real images of the earrings (R0 and L0 in Fig. 1) were ring-shaped and had a thick anterior-inferior part, whereas the ghost images formed by the earrings expanded horizontally and vertically and appeared blurred and higher than their original positions.

The ghost images (R2 and L2 in Fig. 1) extending from the mandibular coronoid process to the maxillary posterior teeth were consistent with the shape and position of a typical ghost image - namely, enlarged without inversion of the left and right sides of the earring.

However, the ghost images (R1 and L1 in Fig. 1) located in the ear area appeared in a place different from that where ghost images typically appear; and the left and right sides were contralateral to the real image (R0 and L0 in Fig. 1); the shape was symmetrical compared to a typical ghost image (R2 and L2 in Fig. 1). Considering the principles of panoramic radiography, these atypical ghost images could be interpreted as ghost-like real images (pseudo-ghost images).

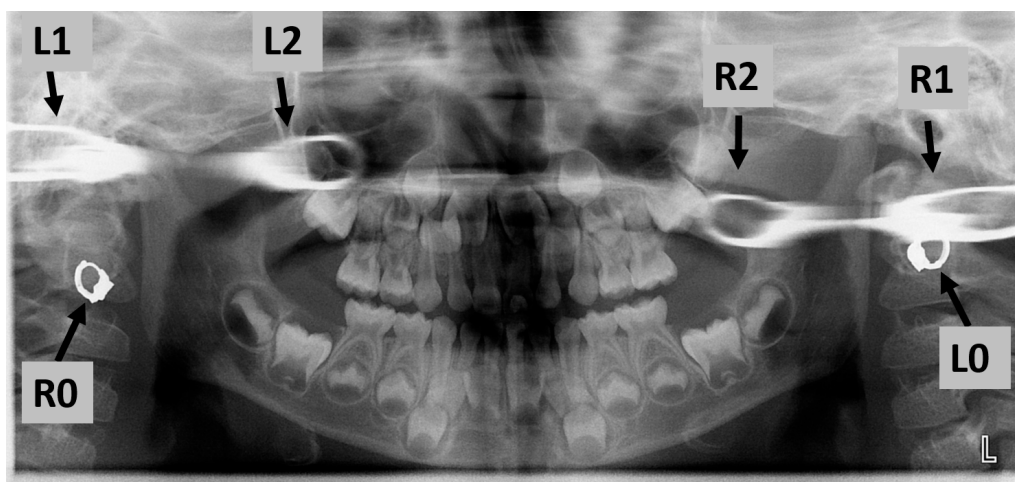


Fig. 1. Triple images formed by right and left earrings on a panoramic radiograph. Note that each earring (R0 and L0) makes two ghost-like images: an atypical ghost-like real (pseudo-ghost) image (R1 and L1) and a typical ghost image (R2 and L2).

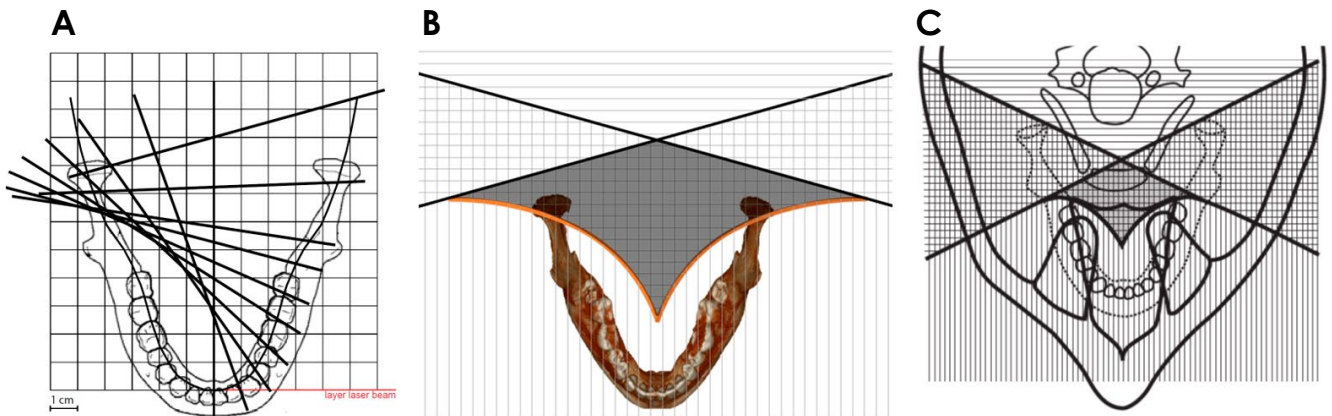


Fig. 2. The path of the center of rotation and areas of real, double, and ghost image formation. A. The path and angles of the beam of Planmeca ProMax's standard panoramic program, taken from the user manual, shows that the path of the center of rotation extends outside the mandible. B. Based on Figure 2A, the areas of real, double, and ghost image formation are marked together with the mandible by referring to Figure 2C. C. Areas of real (vertical line), double (diamond-shaped shaded area in the middle), and ghost (horizontal line) image formation are shown.¹ Note that the real image and ghost image are divided based on the center of rotation, and a double image can be formed up to the area where the rotation center extends outward.

Panoramic geometry

The X-ray beam geometry of Planmeca ProMax's standard panoramic program, taken from the user manual (publication number 10007367), is shown in Figure 2A, and the path of the center of rotation extended to the area outside the mandible. Based on the path of the center of rotation and beam geometry in Figure 2A, the areas of the real (vertical line), double (diamond-shaped shaded area in the middle), and ghost (horizontal line) image formation were marked together with the mandible (Fig. 2B) by referring to the illustration included in a textbook (Fig. 2C).¹

In panoramic radiography, the real and ghost images are divided based on the rotation center, and a double image can be formed up to the area where the rotation center extends outward. As shown in Figure 2B, when the center of rotation extends to the area outside the jaw, the jaw and the structure outside it may also appear in double images. However, as shown in Figure 2C, if the center of rotation is limited within the jaw, double images are only formed in structures located inside the jaw.

Reproduction of ghost images

Using a dry mandible, we attempted to reproduce the pseudo-ghost and typical ghost images of the right mandibular condyle. A radiopaque marker was placed on the outside of the right mandibular condyle (Fig. 3A), and the mandible was rotated to the right so that the midline deviated to the right, and the right mandibular condyle was located posterior to the left (Fig. 3B). The right mandibular condyle was intended to be located behind the path of the center of

rotation, and the left mandibular condyle was intended to be located in front of the center of rotation (Fig. 3C).

Results

On the panoramic radiograph of the dry mandible, ghost images were generated only by the right mandibular condyle and the mandibular angle, but not by the structures on the left. The radiopaque marker of the right mandibular condyle was clearly observed in the real image and was enlarged and faintly observed in the ghost images on the contralateral side. The pseudo-ghost and typical ghost images were symmetrically located, merged with each other at the mandibular angle, and overlapped with the left mandibular ramus. Based on the location and direction of the radiopaque marker, it was confirmed that the pseudo-ghost image and typical ghost image were formed by the right mandibular condyle, and that the pseudo-ghost image was a double image of the right mandibular condyle (Fig. 3D).

The center of rotation of the Planmeca ProMax extended to the area outside the jaw, and the double image formation area likewise reached outside the jaw. The radiopaque-marked mandibular condyle located in the outwardly extending double image formation area showed triple images of real, double (pseudo-ghost), and ghost images.

Referring to the above results, the images formed by the earring in Figure 1 were analyzed (Fig. 4). The center of rotation of the panoramic radiography moved during imaging, but for explanatory purposes, the center of rotation was shown as if it were stationary. Three images were

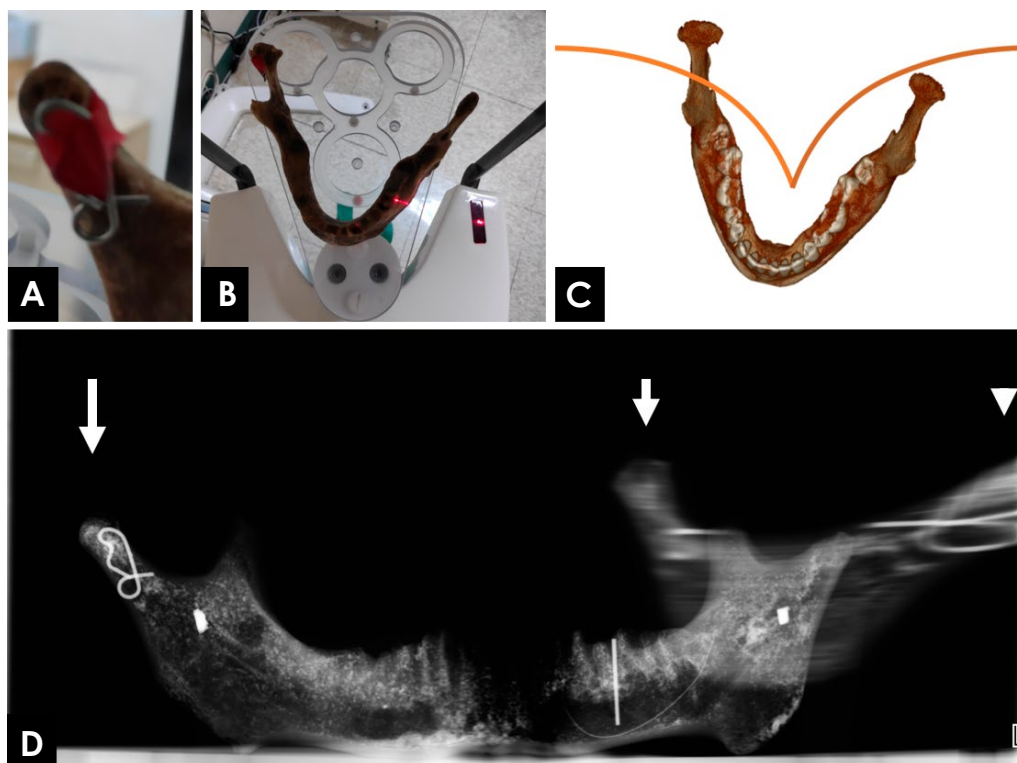


Fig. 3. The creation of pseudo-ghost and typical ghost images of the right mandibular condyle on panoramic radiography. A. Dry mandible with a radiopaque marker on right mandibular condyle. B. Position of the mandible during panoramic radiography. The mandible was rotated to the right, so the midline deviated to the right, and the right condylar head was located behind the left. C. Diagram of the position of the mandible relative to the center of rotation. The right mandibular condyle was intended to be located behind the path of the center of rotation, and the left mandibular condyle was intended to be located in front of the center of rotation D. Panoramic radiograph with unilateral ghost images. Ghost images were generated only by the right mandibular condyle and mandibular angle, but not by the structures on the left. The radiopaque marker of the right mandibular condyle is clearly observed in the real image (long arrow) and is enlarged and faintly observed in the ghost images. The pseudo-ghost image (arrowhead) and typical ghost image (short arrow) are symmetrically located, merged with each other at the mandibular angle, and overlap with the left mandibular ramus. The radiopaque marker proves that the pseudo-ghost image and typical ghost image are images of the right mandibular condyle, and that the pseudo-ghost image is a double image of the right mandibular condyle.

formed by the right and left earrings, respectively. Panoramic projection began from the patient’s left side, and the atypical ghost-like image (R1) was formed by the right earring above the left earring (L0) near the focal trough of panoramic radiography. At this time, the center of rotation was outside the right earring, and the right earring was located between the center of rotation and the image receptor, so this image (R1) was a real image (ghost-like real image, pseudo-ghost image), and looked like a ghost image because it was located on the opposite side of the focal trough (Fig. 4A). Next, when the left mandibular coronoid process and maxillary posterior teeth were radiographed, the right earring was radiographed again, and at this time, the right earring appeared as a typical ghost image located between the center of rotation and the X-ray tube (Fig. 4B). Lastly, the right earring was radiographed located near the focal

trough of panoramic radiography, and at this time, the right earring was a real image located between the center of rotation and the image receptor (Fig. 4C).

Discussion

The advantage of the path of the center of rotation in panoramic radiography extending to the area outside the jaw is not clear. Venkatraman et al.⁴ stated that the goal was to reduce the possibility of ghost images of the mandible, which was thought to be related to the posterior extension and angle of the beam, rather than the outward extension of the center of rotation, as shown in Figures 3C and D.

Additionally, although the extension of the center of rotation to the area outside the jaw may affect the thickness of the focal trough, the focal trough is also influenced by other

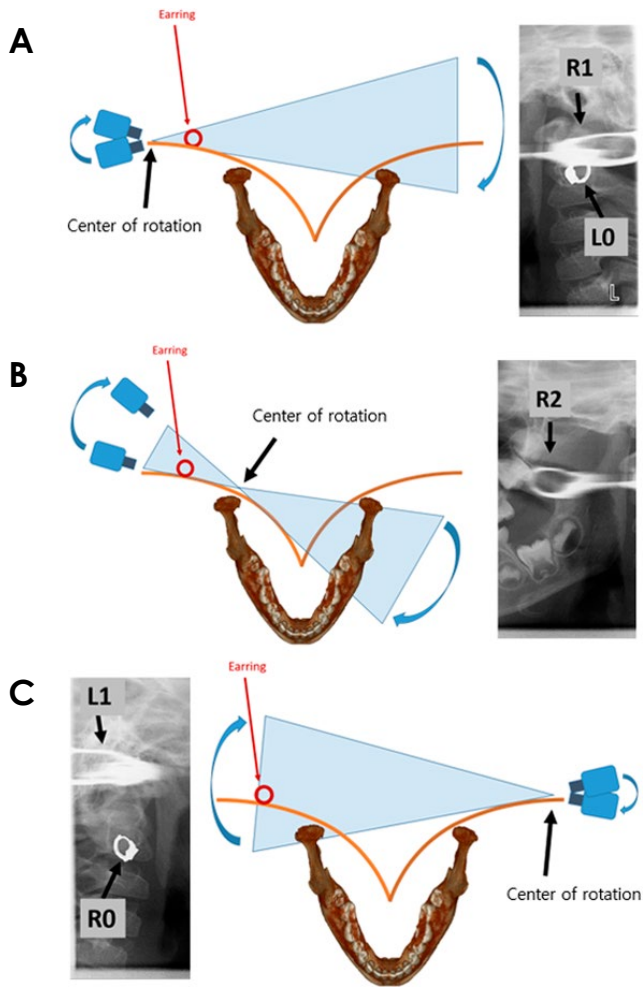


Fig. 4. An explanatory diagram shows the process of triple image formation by right earring. The center of rotation of the panoramic radiography moves during imaging, but for explanation purposes, the center of rotation is shown as if it were stationary. A. R1 (ghost-like real image, pseudo-ghost image): the right earring is located between the center of rotation and the image receptor. However, the image of the ear ring is located on the opposite side of the focal trough on the left side; hence, the real image appears as a ghost-like image. B. R2 (typical ghost image): The right earring is located between the tube and the center of rotation. C. R0 (Real image): The right earring is located near the focal trough on the right side.

factors, such as the movement of the image receptor. In order to understand the principles of panoramic radiography and analyze its advantages and disadvantages, information on the focal trough is needed, and research using a phantom, as in the study by Yeom et al.,⁸ is necessary.

However, the disadvantage of the path of the center of rotation extending to the area outside the jaw is that the area where the triple image is formed increases, so that a pseudo-ghost image can be formed not only by the cervical spine, but also by structures such as the mandible, styloid

process, and earrings. Additionally, because the area where a triple image can be formed is large, the area that is irradiated three times becomes wider, which can increase the patient's absorbed dose and effective dose. In a study by Seo and Yu,⁹ the absorbed dose during panoramic radiography with Planmeca ProMax was found to be higher in the parotid area than other areas at the same phantom level, which could be explained by panoramic geometry.

Venkatraman et al.⁴ reported a case similar to ours; however, the merger of the pseudo-ghost image and ghost image was described as a ghost image only. Although it is often very difficult and sometimes impossible to distinguish between pseudo-ghost and ghost images, it is necessary to try to do so.

Harvey et al.⁶ presented an unusual ghost image that appeared when using non-standard panoramic programs, such as an improved orthogonality program and bitewing program, and explained panoramic geometry as being like a lateral projection. However, panoramic radiography and lateral projections have completely different image formation principles that should be distinguished from each other. Unusual ghost images appearing on panoramic radiography must be explained based on the principles of panoramic radiography.

Regarding pseudo-ghost images, Venkatraman et al.⁴ emphasized that since a pseudo-ghost image is theoretically a real image, it should not be called a ghost image, but rather a second or double primary image. However, according to the principle of image formation, even if it is a real image, the object in the area opposite the focal trough appears as a ghost-like image; thus, it would be better to include the word "ghost" in the name. We suggest the name "pseudo-ghost image" or "ghost-like real image."

Recently, artificial intelligence (AI) has been in the spotlight, and many studies have been conducted on the use of AI to interpret panoramic radiographs.¹⁰⁻¹² However, even if an AI system interprets panoramic radiographs, the dentist must finally confirm and diagnose them. To this end, it is essential for dentists to understand the path of the center of rotation and the principles of image formation in panoramic radiography.

By understanding the principles of panoramic radiography, it is possible to determine the approximate location of abnormalities such as soft tissue calcification that appear on panoramic radiographs.⁷ If necessary, the patient's position can be adjusted to obtain a clear image without a ghost image of the contralateral mandible. Moreover, this results in greater sensitivity to patient positioning, more careful attention to radiography, better-quality images, improved

panoramic radiographic analysis, and improved interpretation ability, thereby improving dentists' diagnostic ability. Therefore, dentists must understand the characteristics and principles of the panoramic equipment used and apply them to panoramic radiography and interpretation.

Conflicts of Interest: None

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