Panoramic ghost images as an aid in the localization of soft tissue calcifications

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Mapping of the ghost envelope for an Orth Oralix panoramic x-ray unit (Philips Medical Systems) was carried out with a lead sphere suspended at various locations around a dry mandible. The ghost envelope is a three-dimensional zone within which an object or anatomic structure must lie to produce a ghost image on panoramic radiographs. If the three-dimensional shape of the ghost envelope for a particular panoramic unit is known, information can be gained about the clinical location of objects appearing on radiographs produced with that machine. Objects outside the envelope will not result in ghost image formation. Objects within the envelope will result in characteristic ghost images depending on their position. This article analyzes ghost image characteristics in relation to object position and discusses the limitations of the method. A series of ready reference diagrams is provided, which may aid in the localization of soft tissue calcifications and foreign objects observed on panoramic radiographs.

A number of soft tissue calcifications occur in the head and neck region, which may be observed close to or superimposed over the mandible on panoramic views. Such conditions may include sialoliths, calcified lymph nodes, tonsilloliths, and calcifications in blood vessels, muscles, and skin. With conventional radiographic techniques, it is difficult to determine the position of the calcifications in relation to the mandible. This is especially true in the angle and ramus region, inasmuch as occlusal films cannot be made.

Rotational panoramic radiography is an imaging technique that produces a flat picture of curved dental arches and surrounding structures. The result is achieved by synchronous rotation of the X-ray source and image receptor around the stationary head of the subject. This rotational system results in the formation of a zone of sharpness within which structures appear in focus and outside of which they are blurred. As the X-ray source rotates around the subject, the center of rotation varies, resulting in the formation of a zone of sharpness that roughly conforms to the shape of the dental arches. One of the features of rotational panoramic radiography is the formation of ghost images (reverse shadow, shadow, secondary image, contralateral image, earring cysts). A ghost image is formed when the object is located between the X-ray source and the center of rotation.

Ghost images have been reported to have the following characteristics: they have the same morphology as their real counterparts; they appear on the opposite side of the radiograph from their real counterparts; they appear higher up on the radiograph than their real counterparts; they appear more blurred than their real counterparts; the vertical component of ghost images is more blurred than the horizontal.
component; the vertical component of ghost images is always larger than their real counterparts whereas the horizontal component of ghost images may or may not be severely magnified.\textsuperscript{12}

It has been reported that a three-dimensional zone (ghost envelope) exists within which an object or structure must lie to produce a ghost image.\textsuperscript{6, 8} Edge and Champion\textsuperscript{b} stated that the zone was limited to the areas of the mandibular molars and ramus, and immediately posterior to the ramus. Kaugars and Collett\textsuperscript{6} found that the ghost envelope was different for three panoramic machines they studied. Generally, objects on the buccal side of the mandible anterior to the ramus, and objects lingual to the mandible and anterior of the third molars, did not result in ghost image formation. The shape of the ghost envelope is dependent on the location of the centers of rotation for the particular machine. Objects that lie within the ghost envelope are located between the X-ray source and the center of rotation during exposures.

Therefore, if the ghost envelope of the particular panoramic unit being used is known, it should be possible to gain some information on the location of an object from the presence or absence of a ghost image. The aim of this project was to map the ghost envelope of an Orth Oralix DC-Ceph panoramic machine and to determine whether the location and appearance of ghost images can be used as a localization method.

**MATERIAL AND METHODS**

With the use of a specially constructed stand, a dry, adult human mandible was positioned in an Orth Oralix DC-Ceph panoramic machine (manufactured under license for Philips in Tanaka, Japan) as it would normally be in a clinical situation. The exposures were carried out with a tube voltage of 62 kVp and additional filtration of 0.5 mm of aluminium to compensate for the lack of soft tissue attenuation. A series of radiographs was made with a lead sphere suspended at various locations around the mandible. At each location, the sphere was first positioned in contact with the mandible and then moved progressively further away in a buccal, lingual, anterior, or posterior direction. The actual position of the sphere on each occasion was recorded on the radiograph to avoid confusion. The location and shape of the resulting ghost image, if present, were recorded. The entire experiment was then repeated with the use of a dried skull of a 7-year-old child.

**RESULTS**

By following a similar method to that used by Kaugars and Collett,\textsuperscript{6} it was possible to map the ghost envelope for the Orth Oralix unit. A diagrammatic representation of the envelope and its relationship to the mandible is shown in Fig. 1. As stated by Kaugars, the envelope is constant in relation to the panoramic unit. The relationship of the envelope to the mandible is dependent on correct patient positioning (Fig. 1). Objects that lie within the three-dimensional zone depicted in Fig. 1, irrespective of the patient's position, will project a ghost image. Objects situated posterior to the V in the middle of the envelope will result in a ghost image but no primary image will be visible on the radiograph.

**Ghost image characteristics**

When the object was located on the labial side of the mandibular incisors in the midline, no ghost image was visible on the radiograph (Fig. 2). On the lingual side of the incisors, again in the midline, no ghost image was visible. However, as the object moved posteriorly along the midline, the primary image of the object became elongated in a horizontal direction (Fig. 3). Moving the object further posteriorly in the midline resulted in the appearance of three images (two primary and one ghost) with the ghost image in the center (Fig. 4). As the object was moved further posteriorly in the midline, the double primary images

**Fig. 1.** The ghost envelope for the Orth Oralix DC-Ceph (Philips). Objects or anatomic structures must be within this zone to cause ghost image formation. Fine shadowing over the rami indicates the regions within the envelope. Objects posterior to the large V in the middle of the envelope do not project primary images onto the film.
moved further laterally on the radiograph. When the object was a short distance posterior to the condyles, the double images did not appear on the film but the ghost image remained in the center of the film.

Objects on the buccal side of the body of the mandible did not result in a ghost image on the film. Objects on the lingual side in contact with or very close to the body did not result in ghost image formation. However, as the lingual object moved toward the midline, the image became progressively more elongated as in Fig. 3.

Objects inferior to the angle of the mandible or
Fig. 5. Panoramic view of mandible with lead sphere lying below inferior border of mandible in right third molar region. Note that no ghost image has been produced.

Fig. 6. Panoramic view of mandible with lead sphere in similar position to that in Fig. 5, except more toward the lingual. A ghost image (g) results on the left side, which is slightly higher and more elongated than the primary image.

Fig. 7. Panoramic view of mandible with lead sphere contacting lateral surface of right ramus. The resulting ghost image (g) can be seen on the left side with a tail pointing toward the midline (arrow).

buccal to this position did not result in ghost image formation (Fig. 5). As the object moved in a lingual direction from the aforementioned position, a ghost image started to appear (Fig. 6).

If the object was positioned lateral to the ramus, a ghost image was observed lateral to the opposite ramus on the radiograph (Fig. 7). If the ghost image is considered as having a body and a tail, the tail of the
Fig. 8. Panoramic view of mandible with lead sphere contacting medial surface of right ramus. The resulting ghost image (g) can be seen on the left side with a tail pointing away from the midline (arrow).

Fig. 9. Panoramic view of mandible with lead sphere positioned 10 mm from right ramus on medial side. The resulting ghost image (g) on the left side can be seen as well as double primary images (*).

Fig. 10. Panoramic view of mandible with lead sphere touching posterior aspect of right condyle. The resulting ghost image (g) can be seen on the left side at the top of the radiograph.

ghost image is medial to the body on the radiograph (Fig. 7). When the object was on the medial side of the ramus, the radiographic appearance of the object (primary image) was almost identical to a laterally positioned object (Fig. 8). In this position, ghost images were always observed but were longer horizontally, and positioned more toward the midline (Fig. 8) than those for more lateral objects (Fig. 7). Furthermore, the relationship of the tail to the body of the ghost image was reversed, with the tail being lateral to the body on the radiograph (Fig. 8). As the object was moved further toward the midline, the ghost im-
Fig. 11. Panoramic view of mandible with lead sphere positioned 10 mm posterior to right condyle. The resulting ghost image (g) is narrower in the vertical dimension and closer to the midline than the ghost image in Fig. 10.

When the object was positioned posterior to the condylar head, ghost images were observed but were not elongated horizontally (Fig. 10). As the object was moved further posteriorly (closer to the X-ray source), the ghost image moved toward the midline and became narrower in the horizontal plane (Fig. 11).

The characteristics and behavior of the ghost images were the same for both skulls studied. Bearing in mind that the mandible of a 7-year-old child would be smaller than an adult mandible, the object, although having the same relationship to the anatomic landmarks, would be closer to the midline. Therefore, the changes observed in the ghost image as the object was moved toward the midline developed a little earlier.

The height of the ghost image on the film in relation to the primary image was dependent on the location of the object in the vertical plane. For objects below or at the level of the body of the mandible, the ghost image was at a slightly higher level than the primary image (Fig. 6). As the object moved superiorly, the resultant ghost image became more superior to the primary image (Fig. 7).

DISCUSSION

The ghost envelope mapped for the Orth Oralix unit in this study was similar to that found by Kaugars and Collett for the Panelipse unit. However, no posterior boundary was found in this study, which is consistent with other reports.

The results indicate that a good understanding of the principles of ghost image formation and the boundaries of the ghost envelope can be helpful as a localization technique. For an object to form a ghost image, the beam must be attenuated by the object twice on its way to the film. On one occasion, the object is close to the film, resulting in the primary image being formed. On the other occasion, the object is between the source of the beam and the center of rotation, resulting in the ghost image being formed. The usual result is that the ghost image is more distorted and higher on the film than the primary image. As noted in this study and by others, as the object moves lower in the ghost envelope, the difference in
height between the ghost image and the primary image becomes less.

Image formation becomes more complicated when the object is situated in the midline or close to it. As the object moves posteriorly along the median plane, its image becomes elongated horizontally (Fig. 3). This is due to the object being closer to the rotational center of the unit. This results in the object being in the path of the X-ray beam for a longer period of time and so its image is blurred horizontally.\(^1\) In the case of the Oralix, further posterior movement of the object along the midline eventually results in the horizontally elongated image separating into double primary images and a central ghost image (Fig. 4). In this situation, the beam passes through the object three times on its way to the film. On two occasions during the exposure, the object is located between the rotation center of the beam and the film, resulting in the formation of two primary images. On one occasion, the object lies between the X-ray source and the center of rotation, resulting in the formation of a ghost image.\(^1\) When the object is located in the midline, the double primary images are of equal dimensions and laterally placed on the radiograph (Fig. 4). Double primary image formation can occur with objects approaching the midline (Fig. 9). However, in this situation, the primary images are not of equal dimensions and the ghost image is not in the midline (Fig. 9). The primary image closest to the ghost image is more magnified horizontally because the object is close to the center of rotation during its projection onto the film. The central ghost image occurs when the X-ray beam is behind the subject's head.\(^6\)

Objects inferior to the angle of the mandible or buccal to this position do not result in ghost image formation because they do not lie between the center of rotation and the source (Fig. 5). However, as the object position becomes more lingual (toward the midline), a ghost image eventually results as the object enters the ghost envelope (Figs. 1 and 6).

As mentioned previously, the vertical dimension of the ghost image will always appear larger than the primary image.\(^1\) The horizontal dimension of the ghost image is affected by both magnification and blurring effects. However, the closer the object is to the center of rotation, the greater the horizontal elongation of the ghost image.\(^1\) The closer the object is...
Use of ghost images for localization

Fig. 15. Diagrammatic representation of characteristics of ghost image when object is lateral or medial of ramus. The location of the object is illustrated in two planes with an occlusal and a lateral view of the mandible. The radiographic appearance is illustrated on the right.

...to the X-ray source, the less the horizontal elongation of the ghost image. This can also be stated another way: the further the object is from the center of rotation, the less the horizontal elongation.

Localization technique

Only soft tissue calcifications or objects inside the ghost envelope of the unit will result in a ghost image. If the calcification is outside the envelope of the unit, no ghost image will be formed. For example, calcifications in lymph nodes just below the inferior border of the mandible will not result in a ghost image. The technique may have most application when soft tissue calcifications are superimposed on the ramus of the mandible. Inasmuch as objects on the medial side of the rami are close to the centers of rotation, their ghost images will be horizontally elongated (Fig. 8). Objects on the lateral side of the rami are further from the centers of rotation, and as a result, their ghost images will be shorter horizontally (Fig. 7). The ghost images for medially positioned objects will be closer to the midline of the jaws on the radiograph than those for laterally positioned objects (Figs. 7 and 8). As objects move closer to the midline of the ghost envelope, the ghost image moves closer to the midline from the opposite side and double primary images develop (Fig. 9).

It is important to remember that the object under investigation must be of sufficient density to attenuate X-rays, or no ghost image will be observed even if the structure is within the ghost envelope. However, ghost images of radiopaque material may still be difficult to see, inasmuch as they are often superimposed on other radiopaque structures such as the mandible.

Figs. 12 to 15 are set out as ready references to aid in the localization of structures with the use of ghost image formation. Each of these figures illustrates the location of the object in relation to the mandible and the resulting picture with or without ghost image formation. These figures can also be used to help with the interpretation of Figs. 2 to 11 in the results. Fig. 12 illustrates diagrammatically the information in Figs. 2, 3, and 4; similarly, Fig. 14 illustrates Figs. 5, 6, 10, and 11; and Fig. 15 illustrates Figs. 7, 8, and 9.

CONCLUSIONS

The formation or lack of formation of ghost images resulting from soft tissue calcifications observed on panoramic radiographs can be used as an aid in their localization. The effectiveness of the technique is dependent on several factors:

1. A thorough understanding of the principles behind ghost image formation.
2. Knowledge of the three-dimensional shape of the ghost envelope for the particular panoramic unit with which the radiograph was made.
3. Production of a visible ghost image, which is dependent on (a) the density of the object, (b) the object being within the ghost envelope, and (c) the ghost image not being obscured by other structures.
4. An understanding of how changes in position of the object within the ghost envelope will affect the shape and position of the resulting ghost image.
5. Correct positioning of the patient within the ghost envelope for the panoramic exposure.

REFERENCES


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