VALIDITY OF THE PARALLAX METHOD WITH A COMBINATION OF IMAGING RECEPTORS – A REVISIT

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Review Article

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ABSTRACT

To determine the amount of displacement of a structure noticed on an image when the tube of a dental X-ray machine was shifted vertically and horizontally. In addition, various intraoral images were combined with dental panoramic images to determine the location of structures. Our research is based on the parallax technique which requires manipulation of horizontal and vertical angulations of the X-ray tube. A metal object is positioned on the buccal and palatal side of the maxilla on the canine area of a skull. The X-ray tube is shifted incrementally to obtain images on phosphor plates. Subsequently, panaromic and occlusal images were taken to assist in localization of the metal object. To obtain a clear image shift of 2-3mm using the parallax method, there must be an adequate horizontal tube shift of approximately 30-35 degrees. When images were used in combination of dental panoramic images, it was found that the buccally placed structures can be accurately located with the periapical or occlusal images. However, the displacement of images in the palatally placed structures in panoramic imaging is not fully appreciated with the principle of parallax method. Tube movement of 30-35 degrees horizontally is needed for a 2-3 mm image shift. To successfully localize a buccal structure, a combination of either periapical or occlusal images with a dental panoramic imaging can be employed. However, this combination with panoramic imaging is limited when looking at palatally placed structures.

Key words: Dental Radiography; Parallax method; Digital Imaging; Horizontal angulation; Vertical angulation.

INTRODUCTION

Many disorders affecting the crowns of teeth can be assessed by inspection and palpation methods. Radiography or imaging technology aids in visualizing beyond the barrier created by the supporting structures of the dentition. There are innumerable situations where this is critical for diagnosis, treatment planning and provision of appropriate treatment. The most popular radiographic technique today, discovered in the twentieth century, is still the intra-oral radiographs and dental panoramic radiographs. However, studies have shown a significant discrepancy between what was found anatomically and seen radiographically (1). These radiographs provide good structural information with nominal magnification of the images on the mesio-distal plane, but inadequate details on the bucco-lingual plane.

Parallax is an apparent displacement or difference in the apparent position of an object caused by an actual change of position on the point of observation (2). In radiological terms, this is the apparent displacement of the image of an object to be localized relative to the image of a reference point. It results by changing the angulations of the X-ray beam which in turn is caused by change in the X-ray tube position. The method is also therefore sometimes referred to as the image/tube shift method (3). Application of the parallax method is most relevant especially when there is a failure to locate a “structure” as it is hidden by another structure. Conventional radiographs compress a three-dimensional structure into a two-dimensional image, which limits the diagnostic accuracy of the treatment (4-5). When a different vantage point is adopted from where structures do not overlap, their relative position becomes clear even though the actual intrinsic relationship in question has not altered. In this way, apart from visualizing features in the usual mesio-distal dimension, we are also able to appreciate features in a third dimension, the bucco-lingual dimension.

The parallax method was introduced by Clark (1910) as a preferred means of radiographic localization (6). With the help of two periapical radiographs and the horizontal tube shift (HTS), he was able to ascertain the relative position of an unerupted tooth. Due to parallax, the more distant object appears to travel in the same direction as the tube shift and the object closer to the tube appears to move in the opposite direction [the so called *Same Lingual,* *Opposite Buccal (SLOB) rule]*. This study was followed by Richards (1952), when he introduced the vertical tube shift (VTS) to localize the mandibular canal (7). These two studies proved that localization can be achieved on both vertical and horizontal plane. It is also believed the further the tube is moved, the more they will separate (3, 8). However, no mention was made about the required amount of movement of the tube. In 1986, Keur combined a maxillary anterior occlusal to an already available panoramic radiograph (9). This modification allows greater tube movement resulting in greater image shift and structure localization in the oral cavity. In addition, it will show impacted teeth in entirety which is not the case with only a periapical radiograph.

Today, parallax method is extensively used in localization of impacted maxillary and mandibular teeth (9-11), localization of mandibular canals (1, 12), determination of root angulation (13) as well as endodontic therapy (14-15). Intraoral radiographs taken at different angles are also crucial in management of dental trauma (16) such as root fractures, luxation and avulsion as well as for localizing foreign objects embedded in the tooth (17).

Although this principle is commonly applied, the scope of knowledge of this method is still not fully understood. The aim of this research was to determine the optimum prescribed amount of tube shift necessary to shift the intraoral image of a structure for appropriate viewing without compromising the quality of information deciphered. In this study, we present an analytical research to comprehend dimensional changes (magnification or distortion) of objects and their relative movement when incremental movement were applied to the cone beam in performing the parallax method. We also combined both the periapical and occlusal images with dental panoramic images to determine the localization of the particular object. This is necessary because the x-ray source for the intraoral radiographs are in front of the patient whereas in panoramic radiographs the x-ray source is posterior and below to the patient's occiput.

MATERIALS AND METHOD

A human skull provided by the Oral Radiology Division, Faculty of Dentistry at the University of Malaya was employed for image acquiring in this study. This study required movement in horizontal and vertical direction of the X-ray tube. However none of the intraoral dental X-ray machines in the faculty had standard scale markings for horizontal movement, unlike for the vertical angulations. To be able to manipulate the horizontal movements, we had to prepare a horizontal angulations scale. We first measured the perimeter of the controlling arm moving the tube-head (X cm). By dividing X cm with 360º, the distance for 1 degree (Y cm) was then obtained. Then we employed the AutoCAD software to convert the whole perimeter of the vertical controlling arm to a new degree scale (Figure 1).

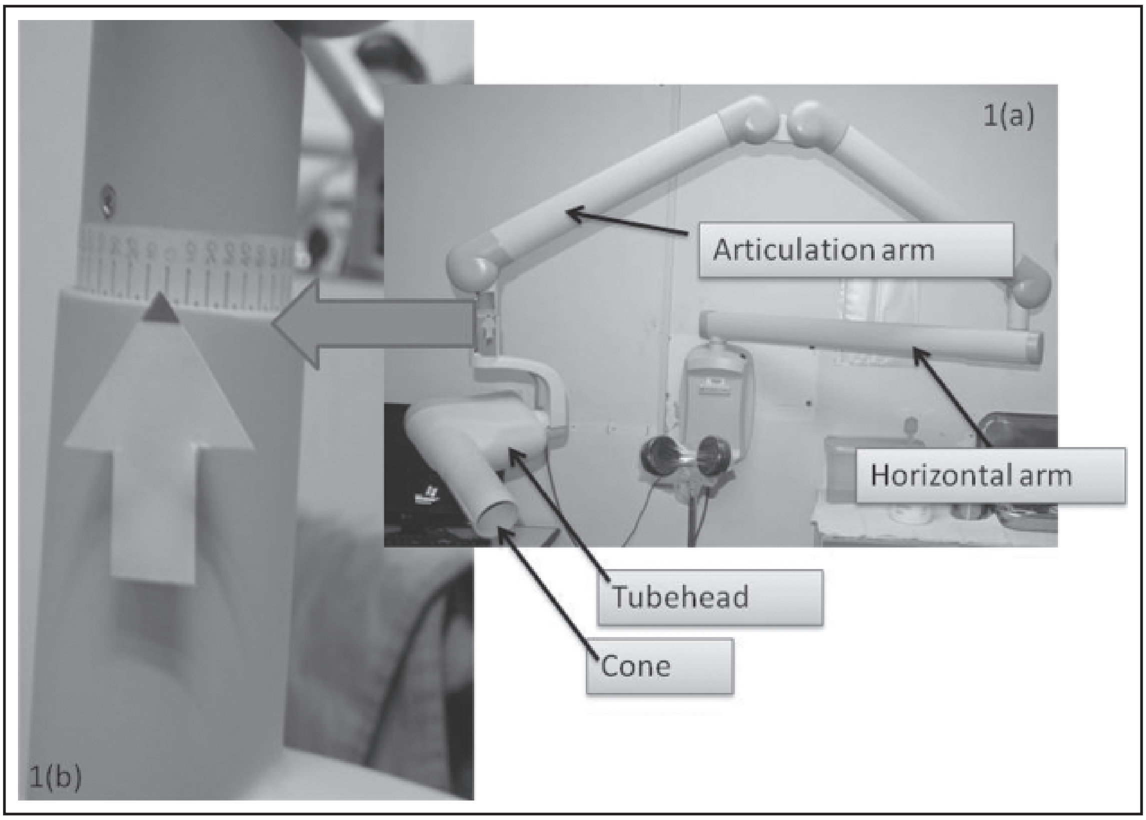


Figure 1 (a). Preva dental X-ray System (Progeny Dental, Illinois, USA) (b) Vertical arm of the X-ray machine with constructed scale markings to ascertain HTS angulations

All periapical and occlusal images were taken with the Preva dental X-ray System (Progeny Dental, Illinois, USA). Panoramic imaging was obtained employing the Orthopantomograph OP100D (Instrumentariuam Dental, Kehl, Germany) and Orthophos XG5 (Sirona Dental system, Bensheim, Germany) machines. The skull was secured on a tripod and its legs were spread-out to ensure stability. The position of the tripod legs were marked on the floor for reproducibility. The occlusal plane of the skull was adjusted and fixed parallel to the floor. This standard position of skull was employed for both the vertical and horizontal parallax method. For acquiring panoramic images, the standard procedure for human maxillofacial imaging was employed. A square stainless-steel metal object with a rounded hollow in the middle was used in this study. The object was placed on the palatal and buccal surfaces of the alveolar bone of the maxilla respectively; apical to the canine-premolar area (Figure 2) as this is the commonest area for the occurrence of impacted maxillary canines.

Two final year dental students (NS, NRAT) and an oral and maxillofacial radiologist (PN) evaluated and assessed the measurements on the periapical, occlusal and panoramic images. Digital imaging plates using photostimulable phosphor (PSP) were employed for capturing, processing, measuring and subsequent storage of images. The panoramic imaging was perfomed with Fuji imaging plates and cassette (Fuji Photo Film, Malaysia) while Vistascan and Dürr DBSWIN image processing software (Dürr Dental GmbH & Co. KG, Bietigheim-Bissingen, Germany) were employed for intraoral imaging.

The images were selected according to the following inclusion criteria:

- Images must contain all the chosen reference points and the metal object.
- A good quality image with appropriate contrast and brightness.
- Elongations and magnifications that is negligible.
- Images showing no cone-cut interference of the chosen reference points.
- Images that are devoid of scratch marks and exposure/processing artefacts.

To ensure the reproducibility of the position of the imaging plate, a receptor holder was used with its position secured using silicone material (Figure 2).

Figure 3 shows the reference lines used for measurement in this study. All periapical images were taken with paralleling technique to ensure negligible enlargement. AT-MD was used for the horizontal parallax method to measure the amount of image shift of the object in the horizontal plane. Point AT represents the alveolar crest, mesial to the associated canine while MD is the uppermost distal point of the image of the object. As horizontal angulation is increased, the tube moves in the mesial direction resulting in the shifting of the images in a horizontal plane. RT-MS was used for the vertical parallax analysis to measure how much the image of the object shifted in the vertical plane. RT represents the root tip of the related canine while MS is the most superior mesial edge of the image. As the vertical angulation increased, the tube moved upwards resulting in the

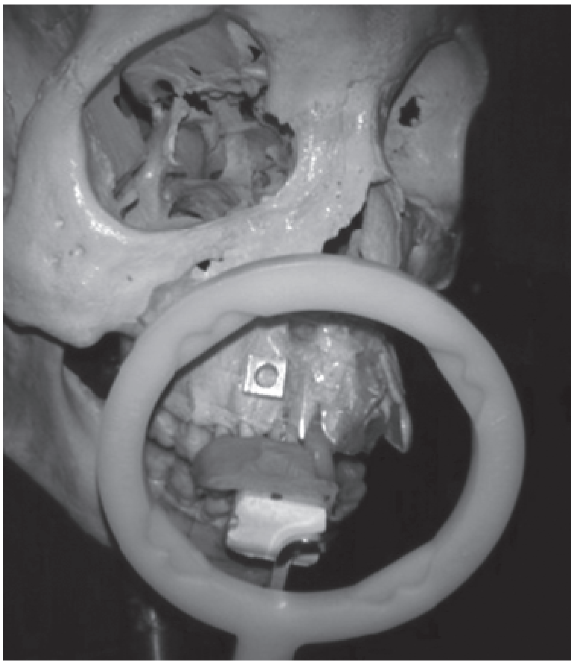


Figure 2. Buccally placed metal object prepared for imaging.

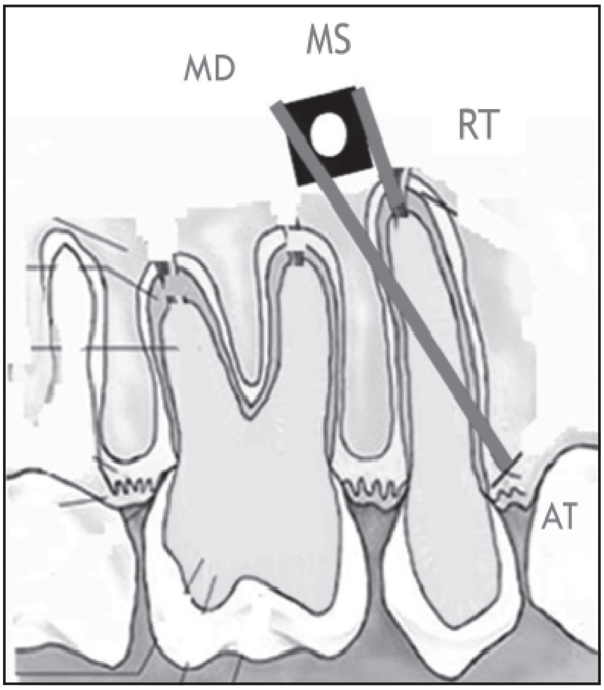


Figure 3. Measurement of distance of object from reference point on radiograph (for HTS: distance between AT-MD; for VTS, distance between RT-MS)

shifting of the image in the vertical plane. All measurements were then recorded in a table for ease of evaluation and analysis. It was calculated that there was a 20% increase in the length of the image in both the dental panoramic machines. Therefore, a 20% reduction was done for all measurements of the panoramic images when comparing with periapical and occlusal images.

RESULTS

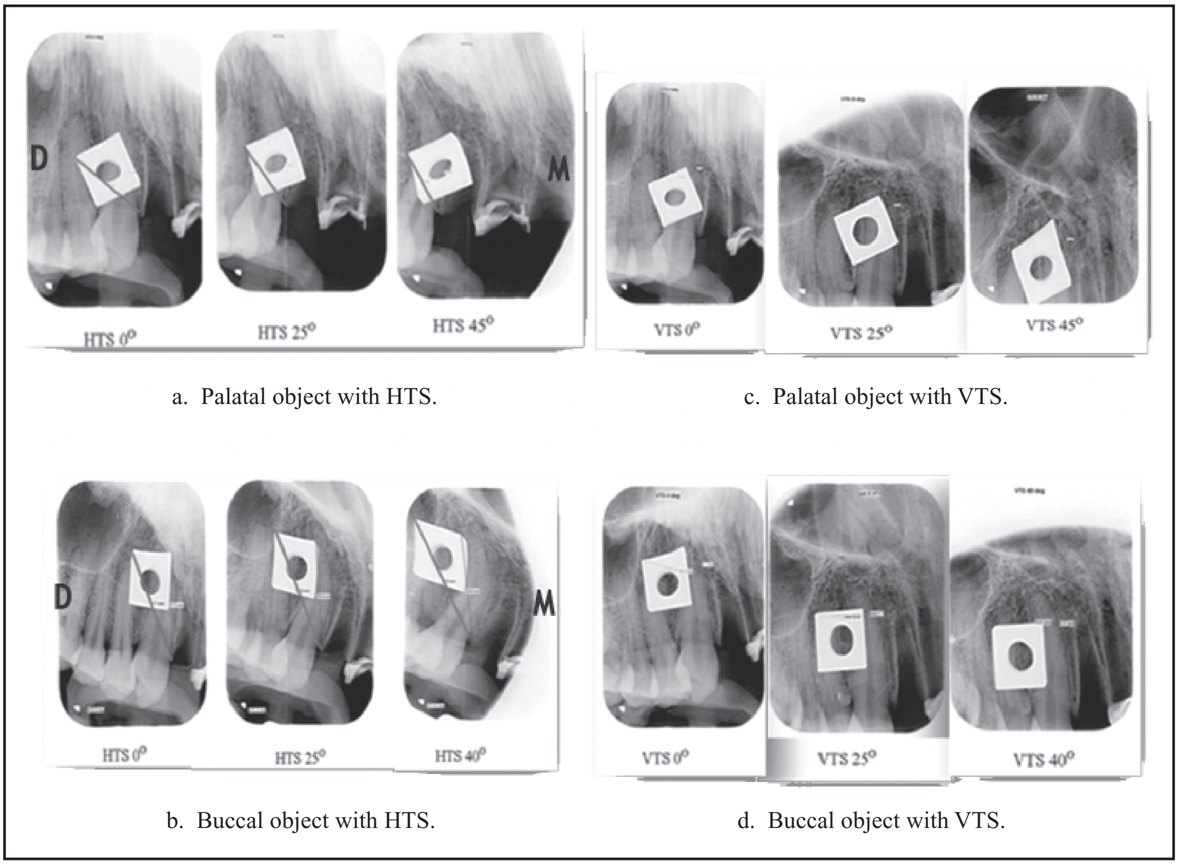
The measurement data (Table 1) was categorized broadly into buccally placed and palatally placed object respectively. Each of the group was then further divided into Horizontal Tube Shift (HTS) and Vertical Tube Shift (VTS). Figure 4 (a-d) shows the position of the object when placed bucally and palatally, in relation to the reference point at different tube angulations for both the horizontal and vertical tube shift. The difference in distance of the reference points at the various tube angulations is shown in Figure 5a–d.

For the HTS of the palatally placed object, the AT-MD length decreased as the angulations increase (Table 1 and Figure 5a). The length difference of each manipulated horizontal angulation when compared with the initial image at 0 degree, showed a gradual increase of about 0.5mm with every 5º increment which continued until it reaches 35º where the measurement shows no increment of length and it remains the same until 45º. Subsequently at the horizontal angulation of 50º the distance increased by 0.5 mm but reduced again at 55º (Figure 5a). In addition, by increasing tube angulations we noticed that the hollow circle in the metal object becoming more oval and then elliptical (Figure 4a). For the HTS of the buccally placed object, the AT-MD length increase was not constant (Table 1 and Figure 5b). From 5 to 10º the length difference reduced by 1.2 mm but beyond 10º the increment was

Table 1. Variation in length of object at different shift of cone angulation when object is placed buccal and palatal of the reference points

Angulation (/°)	Palatally placed HTS* AT-MD (mm)	Palatally placed VTS# RT-MS (mm)	Buccally placed HTS* AT-MD (mm)	Buccally placed VTS# RT-MS (mm)
0	14.3	5.2	19.7	9.7
5	13.8	5.4	21.3	9.3
10	13.5	5.5	20.1	8.2
15	13.3	6.2	21.0	7.2
20	12.7	6.5	21.6	6.5
25	12.1	6.8	22.6	7.1
30	11.6	7.2	23.1	6.3
35	11.0	7.9	24.1	6.9
40	11.0	8.8	25.6	6.5
45	10.9	10.3	–	5.9
50	10.4	9.7	–	6.2
55	10.8	11.0	–	–

** Horizontal Tube Shift; # Vertical Tube Shift*



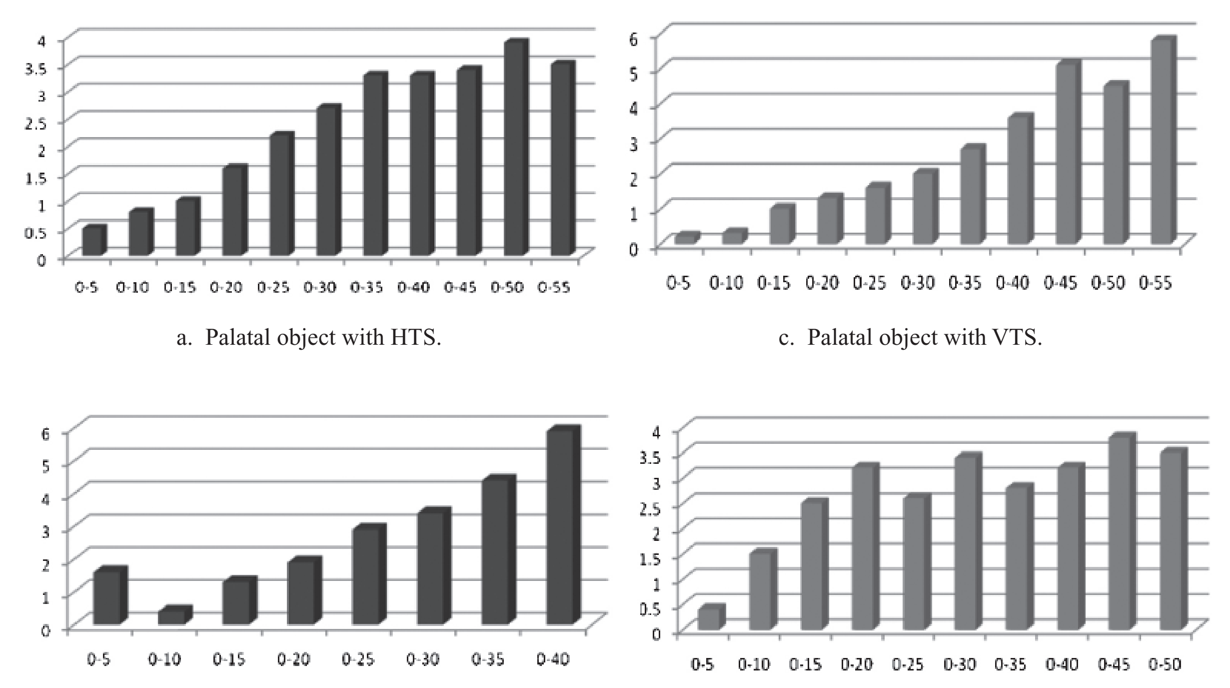
a. Palatal object with HTS.

c. Palatal object with VTS.

b. Buccal object with HTS.

d. Buccal object with VTS.

Figure 4. Periapical image showing position of the object related to the reference point at different tube angulations.



a. Palatal object with HTS.

c. Palatal object with VTS.

b. Buccal object with HTS.

d. Buccal object with VTS.

Figure 5. Difference in distance of reference points at different tube angulations (distance at new angulation minus the distance at 0 degrees).

almost 1 mm for subsequent comparisons up to 40º. The image was greatly distorted as the horizontal angulations increased to 40º. Images produced are seen "bent" severely towards the opposite direction from the tube shift (Figure 4b).

The VTS of palatally placed object had a steady increase in RT-MS length with each increment of the vertical angulation (Table 1 and Figure 5c). The net increase was less than 0.5 mm for every 5 degree increase in angulation. A slight reduction in length was noted at 50º but it increases again at 55º (Figure 5c). It was also noted that there was an obvious increase in the vertical height of the object but not in the mesio-distal width which remains constant in this VTS (Figure 4c). It was noted that beginning from 40º up to 55º, there was an increased distortion of the object. Although this will not give accurate measurement of the object, this enlargement may be useful for identifying small structures embedded in the maxillary arch. The data could only be obtained up to 55º because beyond this angulation the cone-cut produced interferes with the measurements.

The buccally placed object showed characteristics that were opposite to that placed palatally in the VTS procedure. There was a decrease in length from 9.7 mm to 5.9 mm when the angulation of the x-ray cone was increased (Table 1). Figure 5d shows a steady increase in the measurement until 20º but subsequent readings were inconsistent. At 20º cone shift, a 3 mm image shift was appreciated. The images showed that the buccally placed object moved away rapidly from the tube head as we increased the vertical angulation (Figure 4d).

A comparison of the 3 different dental radiographic views – periapical, occlusal and panoramic, were done to assist in the actual location of anatomical structures using the VTS method as shown in Table 2. With regards to bucally placed object the RT-MS distance on the occlusal image decreased more than the periapical and dental panoramic images as the vertical angle of the X-ray tube was the largest at 60º. Therefore, the object came closer to the root tip. Paradoxically, the shift of images in the palatally placed object was noticed to be very minimal. The differences in RT-MS distance between occlusal and periapical images was only 1.2 mm while for the panoramic images, the difference was 1.6 mm and 2.2 mm respectively. The RT-MS distance difference between periapical and panoramic image was only in the range of 0.4 to 1 mm.

DISCUSSION

During HTS, to make a palatally placed structure obvious on the periapical radiograph, the tube needs to be shifted 30º to 35º to obtain an image shift of approximately 2-3 mm. The lack of increases at higher angulations is probably due to the position of the object, which is placed at the canine-premolar region of the maxilla. This area is the curved area of the maxilla and therefore this could have affected the length of measurements. Except for the initial increase in angulation (from 5º to 10º), all buccally placed object showed an increase in the range of 1 mm for the HTS procedure. The reduction noted during the 5º to 10º could have been a possible error during acquiring the image as all images were analyzed together only after completion of the study. For both palatally and buccally placed objects there is much distortion when the tube angulation is increased beyond a limit. This is geometric distortion which is compounded by the curved maxillofacial skeleton (14).

From the VTS of palatally placed objects, it is clear that the object is moving upward following the cone position from 0º to 55º, conforming to the parallax principle. The shifting of images and changes in shape of the object are due to positional changes of the tube when the angulation increases from being perpendicular to the object to being relatively parallel. The increase in the vertical height of the object with increase in angulation may not give accurate measurement of the object, but this enlargement can be useful to identify small structures embedded in the maxillary arch. Keur (1986) suggested replacing the periapical radiographs with the occlusal to allow larger area coverage (18). This method also allows the option of increasing the cone shift angle for increased coverage. There was a constant increase in image shift of a buccally placed structure during VTS but to observe at least a 3 mm image shift in the image position, the cone needs to be shifted as much as 20º. As the object moves away from the tube head with increase in vertical angulation, we conclude that buccal object rule of the parallex method is followed.

The acronym SLOB is useful in interpreting radiographs and this principle can be applied for both horizontal and vertical tube shift (2). From the data collected, the buccally and palatally placed object using horizontal and vertical tube shift follows this rule. This study shows that when an image shift using parallax method is required, we need to have at least 30º to 35º shift from the conventional periapical imaging to produce a resultant shift of 2-3 mm of the structures. The problem when using the periapical radiographs was the large cone-cuts, as observed beyond 50º or 55º tube shift. As indicated earlier, the occlusal radiograph is more favorable because they cover a much larger area. However the structures become dimensionally distorted when vertical angulations are increased drastically.

Armstrong *et al.* (2003) reported that 68% of diagnoses using vertical parallax technique are correct (11). Their results are similar to an earlier investigation by Mason *et al.* (2001), who stated that 76% of vertical parallax diagnoses were successful, especially palatally impacted canines (8). Despite achieving good diagnosis rate using VTS technique, Armstrong *et al.* (2003) found that the diagnostic accuracy was much higher when using the HTS technique (11). They reported that 4 out of 6 examiners achieved better kappa scores for HTS method compared to the vertical parallax, indicating substantial or good agreement with the true canine position. However, overall reproducibility was in the substantial to good range for both horizontal and vertical parallax. Furthermore, there has been no evidence of any difference in reproducibility. Jacobs (2000) on the other hand argued that vertical parallax is the technique of choice for localizing on the basis that a dental panoramic is often taken initially by orthodontists and the use of only one additional radiograph with vertical parallax, would minimizes the overall radiation dose (3).

Researchers (19, 20) have reported that it is possible to use only panoramic radiograph for determining position of any unerupted tooth. However, the authors feel this is difficult to be pursued as this is based on the dimension of the displaced tooth with either adjacent homolateral tooth or a similar contralateral tooth. According to Jacobs (2000) and Mason *et al.* (2001) although the tube for the panoramic radiograph is positioned behind the subject's head at a vertical angle of -7º, in order to explain the parallax method, it may be considered to be in front of the head at an angle of +7º (Figure 6) (8, 21). Jacobs (2000) further explained that since the maxillary occlusal radiograph is taken at a vertical angle in the range of 60-65º, there is an effective difference ranging from 53-58º between the panoramic and occlusal radiograph (21).

During the VTS procedure, the periapical and occlusal images follow the parallax rule of localization adequately. In addition, when these images were combined with dental panoramic images, we also found that principles of the parallax method being fulfilled. The buccally placed object in the panoramic radiograph was accurately located when comparing with the periapical and occlusal images. However, the shift of images in the palatally placed object was minimal on the panoramic images and did not show a remarkable change in position as expected in the parallax method. Therefore it must be emphasized that although there was a displacement, it was minimal to show a significant change in position. Therefore caution must be expressed when we combine panoramic and periapical images for palatal placed objects. Furthermore, Jacobs (2000) stressed that HTS cannot be attempted with panoramic and occlusal images as the panoramic X-ray machine moves in a standard arc around the patient's head resulting in a projection that is not orthoradial (3). Finally, we must accept that there is a distinct disadvantage of this parallax method as it does not provide accurate information of the bucco-lingual distance of structures. If structures are located further away, then there will be large difference of distance between structures at different angulations than when they are closer (18).

In conclusion, intraoral dental radiographic machines need to have the standard scale markings for horizontal movement of the tube head to facilitate parallax method of localization of structures. Tube movement of 30º to 35º degrees horizontally is needed for a 2-3 mm image shift of structure in the canine-

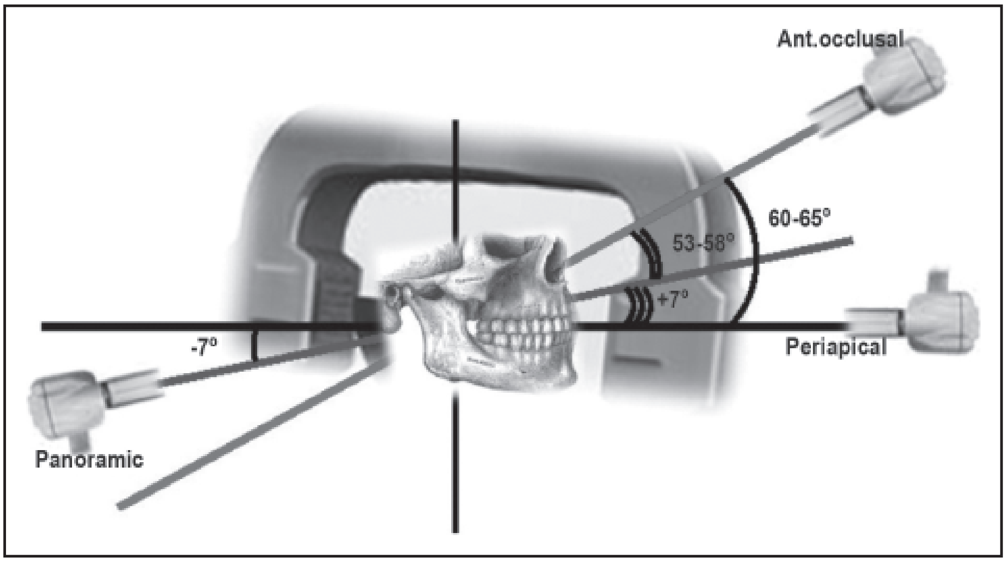


Figure 6. Vertical angulation between panoramic, maxillary anterior occlusal and periapical images (Diagram adapted and modified from: Mason et al 2001).

premolar region of the maxillary arch. To successfully localize a buccal structure, a combination of either periapical or occlusal images with a dental panoramic imaging can be employed. However, this combination with panoramic imaging must be cautiously interpreted when looking at palatally placed structures.

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