ORIGINAL ARTICLE

Radiographic localization of unerupted teeth: Further findings about the vertical tube shift method and other localization techniques

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The parallax method (image/tube shift method, Clark's rule, Richards' buccal object rule) is recommended to localize unerupted teeth. Richards' contribution to the development of the parallax method is discussed. The favored method for localization uses a rotational panoramic radiograph in combination with an occlusal radiograph involving a vertical shift of the x-ray tube. The use of this combination when localizing teeth and supernumeraries in the premolar region is illustrated. When taking an occlusal radiograph to localize an unerupted maxillary canine, clinical situations are presented where modification of the vertical angulation of the tube of 70° to 75° or of the horizontal position of the tube is warranted. The limitations of axial (true, cross-sectional, vertex) occlusal radiographs are also explored. (Am J Orthod Dentofacial Orthop 2000;118:439-47)

The 2 accurate means of radiographic localization generally used are the parallax method (image/tube shift method, Clark's rule,[1] buccal object rule) and the right angle technique. The use of a rotational panoramic radiograph (PR) with an occlusal radiograph (OR) has been advocated to localize maxillary and mandibular anterior teeth.[2-5] This combination uses the parallax method for localization, with the x-ray tube being shifted in the vertical plane.

The aims of this article are the following: (1) to discuss the contribution of Richards,[6] the originator of the buccal object rule, to the development of the parallax method, (2) to illustrate how a PR can be used in combination with an OR to localize unerupted maxillary and mandibular teeth and supernumeraries in the premolar region, (3) to explain why difficulties can occur in the interpretation of a vertical tube shift (VTS) using the PR-OR combination and suggest modifications to reduce these difficulties, (4) to illustrate why axial ORs (axial being the preferred descriptor rather than true, cross-sectional, or vertex)[5] are rarely required to localize unerupted teeth, and (5) to warn the clinician to suspect that an unerupted maxillary canine may be palatally positioned if it shows increased magnification on a PR and/or is superimposed on the image of the root of the adjacent incisor.

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Submitted, September 1999; revised and accepted, February 2000.

0889-5406/2000/$12.00 + 0 **8/1/108782**
doi:10.1067/mod.2000.108782

RADIOGRAPHIC LOCALIZATION

Principle of Parallax

In radiologic terms, parallax is the apparent displacement of the image of the object to be localized, relative to the image of a reference object. It is caused by changing the angulation of the x-ray beam, which in turn is caused by a change in the x-ray tube position. Normally, the reference object is the tooth closest to the object to be localized. The image of the object that is farther from the x-ray tube moves in the same direction as the tube, whereas the image of the object closer to the x-ray tube moves in the opposite direction. This technique was introduced into the dental literature by Clark.[1] He used a horizontal shift of the tube; Richards[6] introduced the concept of a vertical shift.

Both Clark[1] and Richards[6] used periapical radiographs (Pa) in their discussion of the parallax method. Keur[2,7] introduced 2 major improvements in the technique: the occlusal radiograph and the combination of panoramic and occlusal radiographs.

Occlusal Radiographs

Keur used ORs rather than Pas for a tube shift because ORs cover a larger area. This has 2 advantages: the tube can be moved much farther between exposures resulting in a greater shift of the image of the impacted tooth relative to its reference tooth, which makes its position easier to determine; and it will show the impacted tooth in its entirety, which is usually not the case with one Pa.

Panoramic and Occlusal Radiograph

Keur introduced the use of a PR-OR combination for a VTS. Keur's discovery that a VTS could be carried out between a PR and an OR resulted from his realization that: (1) a VTS can be carried out between one radiograph taken with the x-ray tube positioned in front of the patient and another with the x-ray tube positioned behind the patient's head; and (2) in a PR, the relationship between the images of the buried and reference objects is unaltered if the x-ray tube is considered to be on the facial side of the arches rather than on the lingual, as is actually the case.

Although a VTS using the PR and OR is usually not as easy to interpret as a horizontal tube shift with 2 ORs, the PR-OR combination is usually preferred. This is because the PR, which contains information about all the teeth in both arches as well as about the jaws and surrounding structures, is often already available; it is usually taken as an initial radiograph so only one additional exposure (the OR) is required.[7,8]

Significance of Distances

The two distances that are important in localization are the distance between the impacted tooth and its reference tooth and the distance over which the x-ray tube is moved.[4]

Buccal Object Rule

Richards[6] coined the term buccal object rule when he introduced the concept of a VTS. He was originally interested in the relationship of the apices of the mandibular third molar to the mandibular canal. He declared that when either the reference structure or the buried object is composed largely of approximately horizontal edges or surfaces, a change in the horizontal angulation of the x-ray beam would produce little or no apparent displacement between the 2 structures. This would erroneously indicate that the 2 structures are in contact. Generally the path of the mandibular canal is more horizontal than vertical in the mandibular third molar region. A change in the vertical angulation so that the beam is directed in a more upward direction will project the image of the buccal object above that of the lingual object. Richards stated that, in general, the roentgenographic image of a buccal object could be shifted in any direction, relative to the image of a lingual object simply by aiming the x-ray beam in the desired direction. He termed this the buccal object rule. Richards was still using the principle of parallax, but previously the shift of the images of the buried and the reference objects relative to each other was determined using the position of the x-ray tube, ie, where the x-ray beam originated, as the starting point for the determination. Instead, Richards used the direction in which the beam pointed, ie, where the beam ended, as his starting point for the determination.

In 1953, Richards[9] discussed his buccal object rule in more detail, and in 1980,[10] he wrote an article that provided many clues and exercises about localization using the buccal object rule. Richards claimed that when choosing hidden and known objects to make the buccal object rule determination, it is better to choose points (cusp tips, root apices) or lines (root canals) rather than tooth surfaces. The horizontal angle should be changed when attempting to localize a point relative to a vertical line, such as a root canal. The vertical angle should be changed when attempting to localize a point relative to a horizontal line, such as the mandibular canal, as discussed above.

Localization of Premolars

Case 1. The PR (Fig 1*A*) of an 11-year-old male shows that the maxillary right second premolar is impacted and is possibly lying across the arch. A VTS between the PR and the lateral OR (Fig 1*B*) shows that as the tube moved up from the position for taking the PR (+7°) to the position for taking the OR (+60°), the crown of the second premolar moved in the opposite direction, ie, down toward the crown of the first molar; it is therefore positioned buccally. In contrast, the apex of the premolar has moved in the same direction the tube has shifted. Therefore, the apex is positioned palatally, and indeed the tooth is lying across the arch.

The axial (vertex) OR (Fig 1*C*) confirms the position of the premolar, which is more easily seen on the tracing of the OR (Fig 1*D*). This difficulty in interpreting the axial OR is due to the superimposition of various anatomic structures in the area, one of several disadvantages of this type of radiograph.[4]

Case 2. The patient in case 2 is a 13-year-old male. The PR (Fig 2*A*) shows that (1) the mandibular left deciduous first molar is present, (2) a supernumerary is preventing the eruption of the mandibular left first premolar, (3) the mandibular left second premolar is erupted, and (4) another supernumerary is present at the level of the apical-third of the root of the mandibular left second premolar.

A VTS between the PR (Fig 2*A*) and the Pa (Fig 2*B*) shows that the supernumerary that is occlusal to the first premolar and 2 to 3 mm below the tip of the cusp of the canine in Fig 2*A* has shifted in Fig 2*B* to the same level as the first premolar and onto the root of the canine. The supernumerary associated with the second premolar has also moved; its lowest margin is 1 mm above the apex of the premolar in Fig 2*A* and several millimeters below the premolar in Fig 2*B*. The VTS shows that both super-

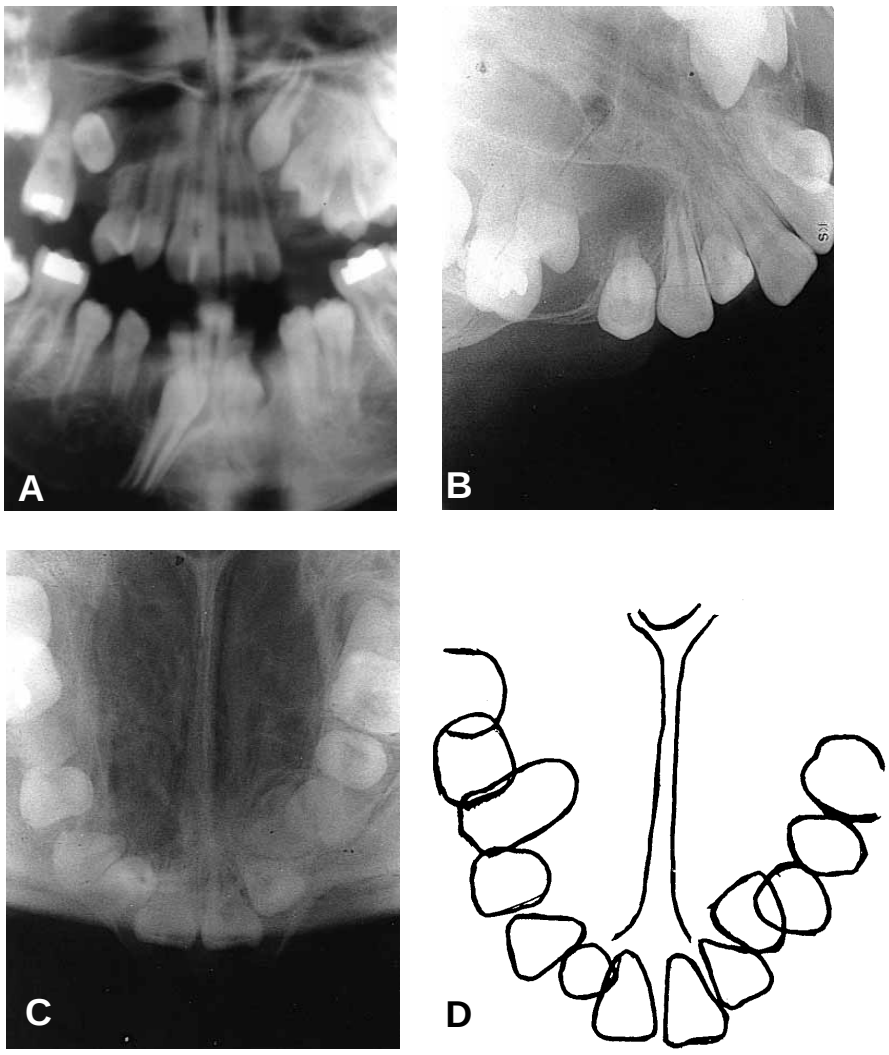

Fig 1. A, Cropped PR shows impacted maxillary right second premolar, possibly lying across arch; **B**, lateral OR; **C**, axial (vertex) OR shows right second premolar lying across arch with crown buccal and apex palatal; **D**, tracing of axial (vertex) OR in Fig 1*C*.

numeraries are lingual because they have moved in the same direction as the shift of the tube.

A VTS between the PR (Fig 2*A*) and lateral OR (Fig 2*C*) shows a greater shift of the images of the supernumeraries in relation to their reference teeth than in the VTS between the PR (Fig 2*A*) and the Pa (Fig 2*B*). This is because there is a greater angular shift between the latter combination (PR at effective +7° to the occlusal plane, OR –35° to –45° to the occlusal plane, a difference of 42° to 52°), compared with the former combination (PR +7°, Pa –10° to –15°, a difference of 17° to 22°).[11] The supernumeraries are difficult to see in Fig 2*D*, an OR axial to the mandibular left second premolar.

ANGULATION CHANGES FOR ORs

Vertical Angulation Changes for ORs

Increasing the usual vertical angulation of the OR from 60°-65° to 70°-75° has been recommended[3] because, with a given distance between the impacted tooth and its reference tooth, increasing the movement of the tube will result in a larger shift between the images.

In addition, increasing the vertical angulation of the tube will foreshorten the reference tooth, which aids the interpretation of a VTS when using a vertical structure, such as the long axis of a tooth, as a reference object.

However, although this increase in angulation is usually helpful, it is not always advisable, as cases 3 and 4 illustrate.

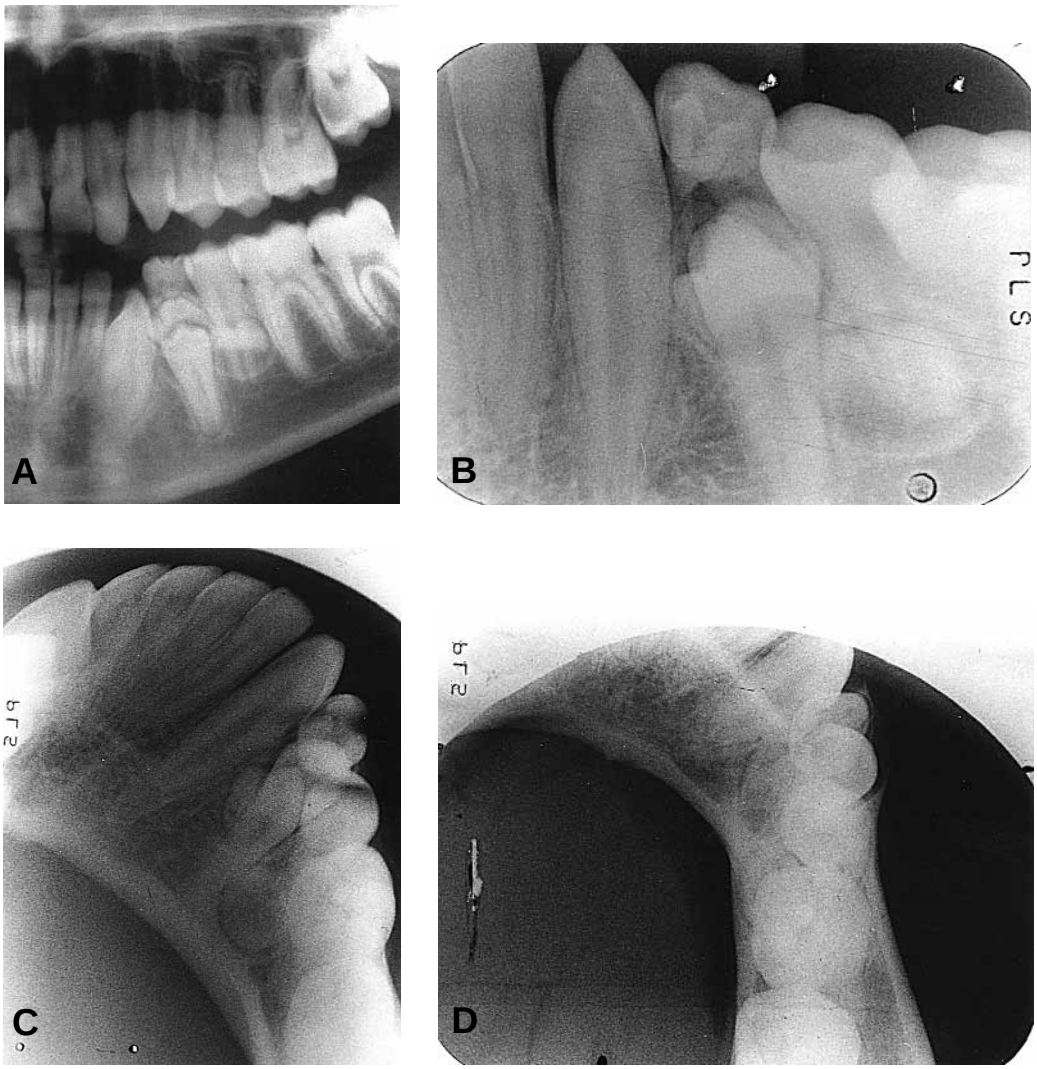

Fig 2. A, Cropped PR shows mandibular left deciduous first molar present, supernumerary above unerupted mandibular left first premolar, second supernumerary over apical-third of mandibular left second premolar; **B**, Pa of mandibular left canine/premolar region; **C**, left lateral OR; **D**, OR axial to mandibular left second premolar. Supernumeraries are difficult to see.

Case 3. Case 3 is a 17-year-old female with a Class II Division 2 malocclusion. The PR (Fig 3*A*) shows that both maxillary canines are unerupted. An OR (Fig 3*B*) taken at 70° to 75° produced such foreshortening of the central incisors that they appear as cross-sections and the view resembles an axial (vertex) OR. This occurred because the maxillary central incisors are extremely retroclined, as can be seen in the cephalometric radiograph (Fig 3*C*). The inclination of the maxillary central incisors to the maxillary plane (ANS-PNS) is 85° (norm 109°) and to the NA line -10° (norm +22°).

For most projections, recommended angles of the x-ray tube to the film are based on averages and must be modified according to the clinical situation, ie, when the alignment of the tooth/teeth used for reference deviates markedly from the norm. Although some foreshortening of the reference tooth aids the interpretation of the shift, excessive foreshortening should be avoided. This is because the OR should also supply fine detail about the condition of the crown and the root of the unerupted tooth, the roots of the reference teeth, and the alveolar bone. This information is not available from PRs or axial ORs.

Case 4. Case 4 is a 16-year-old male. The PR (Fig 4*A*) shows that the maxillary right canine is unerupted. The cephalometric radiograph (Fig 4*B*) shows that the maxillary incisors are retroclined, as the patient has a

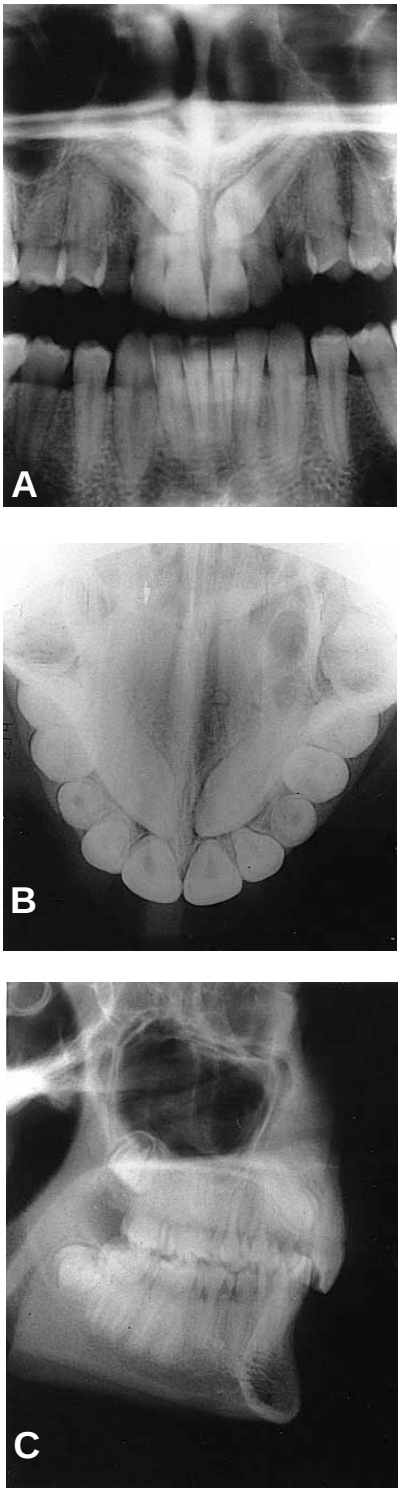

Fig 3. A, Cropped PR shows permanent maxillary canines unerupted; **B**, 70° to 75° OR. Central incisors appear in cross-section, radiographic appearance resembles axial (vertex) OR; **C**, cropped cephalometric radiograph shows markedly retroclined Class II Division 2 central incisors.

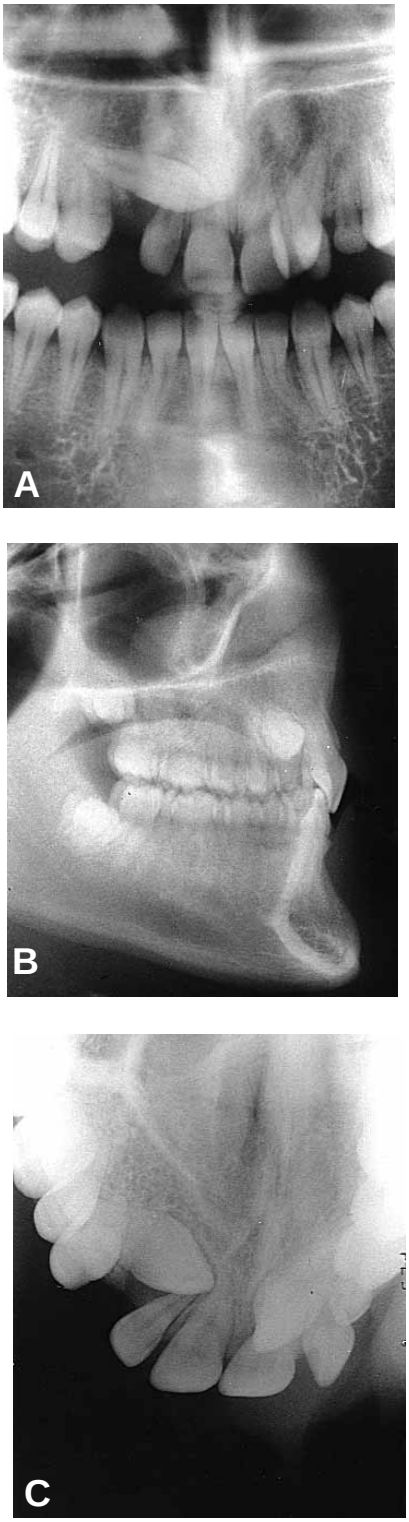

Fig 4. A, Cropped PR shows impacted maxillary right canine; **B**, cropped cephalometric radiograph shows markedly retroclined Class II Division 2 central incisors; **C**, 60° to 65° OR shows right central incisor is not excessively foreshortened.

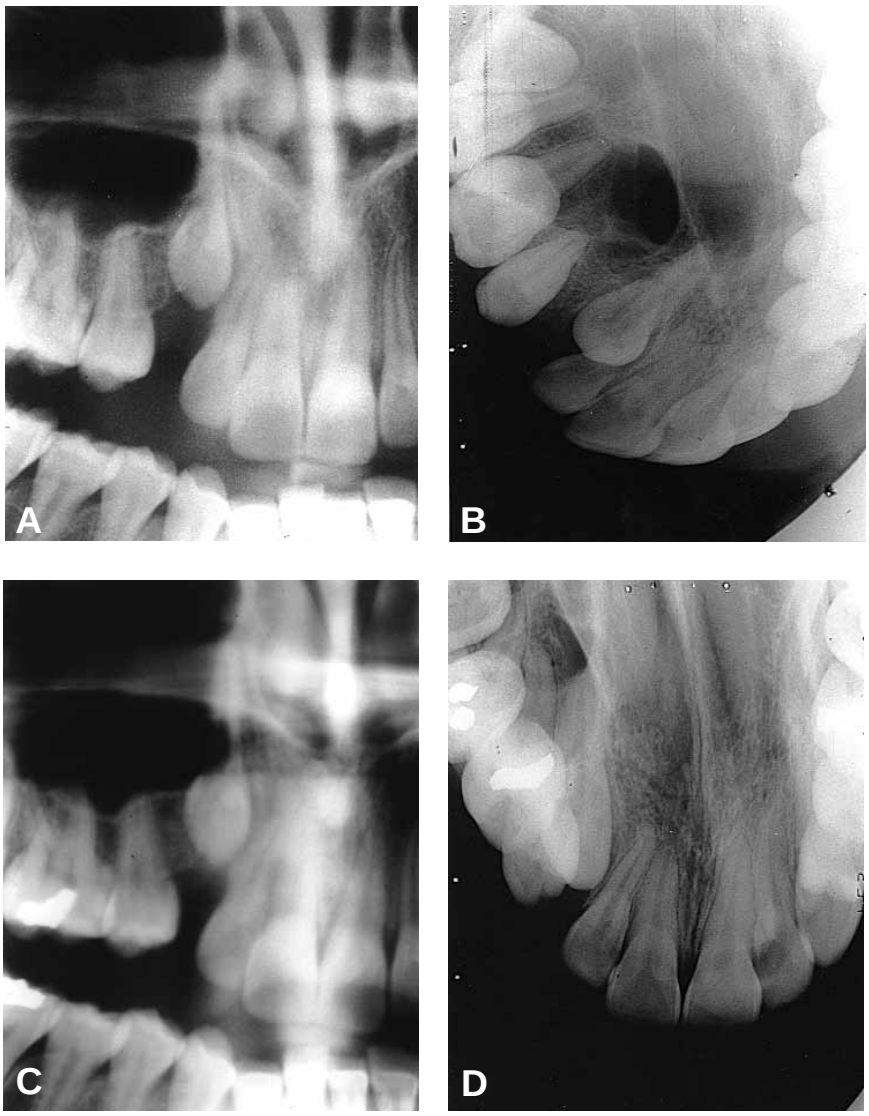

Fig 5. A, Cropped PR shows impacted maxillary right canine–9/19/96; **B**, lateral OR–9/19/96; **C**, cropped PR shows canine not moved–8/25/98; **D**, anterior OR–8/25/98.

Class II Division 2 malocclusion. The maxillary central incisors are 90° to the maxillary plane and +8° to NA.

The clinician requested that the OR (Fig 4*C*) be taken at 60° to 65° to prevent excessive foreshortening of the incisors, as seen in the previous case. The maxillary right central incisor is 26 mm long in the PR and 18 mm in the OR. Because the image of the crown of the maxillary right canine shifts between the PR (Fig 4*A*) and OR (Fig 4*C*) in the same direction as the shift of the tube, the crown is palatal. However, the shift of the image of the apical-third of the root of the canine down onto the crown of the first premolar in the OR is in the opposite direction to the shift of the tube. Therefore, the apical-third of the root is labial, ie, the tooth is lying across the arch.

Horizontal Angulation Changes for ORs

The horizontal angulation of the tube for the OR should usually be perpendicular to the dental arch (orthoradial). However, the mesiodistal position of the tube should be modified according to the clinical circumstances, as cases 5 and 6 illustrate.

Case 5. Case 5 is a female patient, born Feb 16, 1983. The PR (Fig 5*A*) shows that the maxillary right canine is unerupted. A VTS between the PR and the OR (Fig 5*B*) shows that the image of the canine moves in

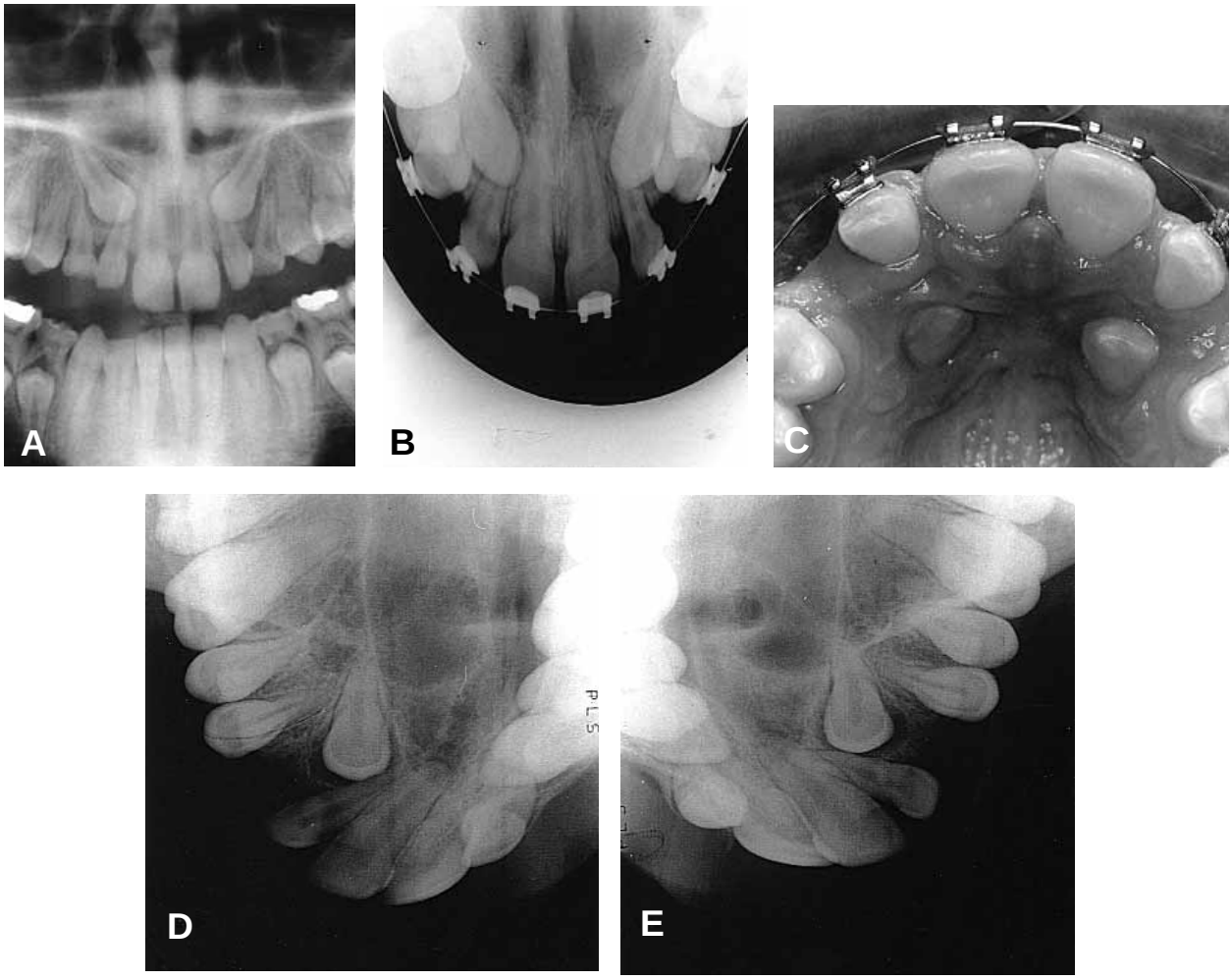

Fig 6. A, Cropped PR shows both maxillary canines are unerupted–5/8/97; **B**, anterior OR–6/9/98; **C**, intraoral photograph–8/1/98; **D,** right lateral OR–10/23/97; **E**, left lateral OR–10/23/97.

the opposite direction to the shift of the tube, demonstrating that the canine is labial. The PR taken 23 months later (Fig 5*C*) shows that the canine has not moved. A VTS between that PR and an OR taken at the same visit (Fig 5*D*) again confirms that the canine is labial. The tube shift is easier to discern between Fig 5*A* and 5*B* than between Fig 5*C* and 5*D*; in Fig 5*B* the unerupted canine is superimposed on the reference tooth, whereas in Fig 5*D*, it is projected clear of the reference tooth. This difference in ease of localization occurred because the unerupted canine is labial and, in relation to the reference tooth, its image moved away from the direction of the shift of the tube.

In Fig 5*B* the tube was directed through the right canine/first premolar space, projecting the image of the unerupted canine mesially to the image of the right lateral incisor. In Fig 5*D* the tube was directed through the right lateral/central incisor region and the image of the canine was projected distally to the canine/premolar space.

The clinician is able to determine in which direction the tube moved between the ORs in Fig 5*B* and 5*D* by 2 means:

1. If the erupted teeth are aligned normally in the mouth, as in this case, then the absence of overlapping contact points in the OR means that the central beam has been directed orthoradially to the dental arch at the level of these teeth. In the OR of Fig 5*D*, there is no overlap of the contact between the central incisors, whereas the right second premolar and first molar overlap. In the OR of Fig 5*B*, there is an open contact between the second premolar and the first molar, whereas the central

Fig 7. A, Cropped PR shows, among other findings, mandibular left lateral incisor and canine unerupted with odontome (*arrow*) superimposed on tip canine cusp; **B**, Pa shows unerupted lateral incisor, canine, and odontome; **C**, OR axial to left central incisor. Odontome not visible.

incisors overlap. Therefore, it can be determined that Fig 5*D* is an anterior OR and Fig 5*B* is a lateral OR.

2. By applying Richards' observation concerning the shift of the images of the apices of erupted teeth on radiographs taken with the bisecting technique, it can be determined that the tube has moved distally.[10] Richards explained that when an x-ray beam is directed perpendicular (anteroposteriorly) to the central incisor (which is upright mesiodistally), the image of the apex will appear directly above the crown of the tooth. Because the incisal edges of the teeth are in contact with the film and the apices are not, when the tube is moved mesially or distally the incisal edges remain stationary while the apices move in the direction the x-ray beam is pointed and in a direction opposite to the shift of the tube. In order to apply Richards' observation, both ORs must be viewed with the incisal edges of the teeth parallel. In the OR of Fig 5*D*, the roots of the central incisors are upright over their crowns, ie, the tube is centered over these teeth. In Fig 5*B*, the roots of the incisors are inclined mesially in relation to their crowns. Therefore, it can be deduced that the x-ray tube has moved distally (or as Richards would state, the x-ray beam is directed mesially). This again confirms that Fig 5*D* is the anterior OR and Fig 5*B* the lateral OR. Although a lateral OR is preferable to an anterior OR for this case, a contrasting situation occurs in case 6.

Case 6. Case 6 is a female patient, born Jan 20, 1982. The PR (Fig 6*A*) shows that both maxillary canines are unerupted. From the VTS between the PR and the anterior OR (Fig 6*B*), it can be determined that the right canine is palatal. The position of the left canine is not easy to determine. The intraoral photograph (Fig 6*C*) taken after surgical exposure of the canines shows that both canines are palatal. However, a VTS between the PR (Fig 6*A*) and either of the lateral ORs in Fig 6*D* and 6*E* is more difficult to determine. This is because the canines are palatal and have moved with the tube, away from the reference teeth. As a result, the canines have been projected distal to the lateral incisors, and there are no clear orientation points/structures, such as the root-apex or the cementoenamel junction of the lateral incisor, for comparison.

From the cases in Figs 5 and 6, it can be concluded that if the clinician suspects that an unerupted canine is palatally placed, as approximately 75% of unerupted canines are, and because most palatally displaced canines move mesially with time,[12] the tube for the OR should usually be directed between the central and lateral incisors on the side of impaction. If both canines

are impacted, the tube should be directed between the central incisors. If the clinician has reason to suspect the unerupted canine is labial, then the tube should be positioned more distally.

Axial Occlusal Radiographs

Case 7. Case 7 is a 10-year-old female patient. The PR (Fig 7*A*) shows that the mandibular permanent left lateral incisor is unerupted and is positioned more apically than the unerupted permanent left canine, an odontome is present at the level of the incisal edge of the permanent left canine, and the permanent canine is coronal to the apex of the deciduous left canine. In the Pa (Fig 7*B*), the levels of the incisal edges of the unerupted incisor and canine are equal, the odontome is above the incisal edge of the left permanent canine, and the incisal edge of the permanent canine is below the apex of the deciduous canine.

From the VTS between Fig 7*A* and 7*B*, it can be determined that the left lateral incisor is labial to the permanent canine, the lateral incisor crown is labial to the left central incisor root, the odontome is labial to the permanent canine, and the left permanent canine is lingual to the deciduous canine.

The OR axial to the left central incisor (Fig 7*C*) confirms that the left lateral incisor is labial to the canine. The odontome is not sufficiently radiopaque to be seen in this radiograph. The reference tooth (the left central incisor) is not projected as a perfect cross-section as it can be difficult to position the x-ray tube precisely for axial ORs.

Limitations of Axial ORs

The cases in Figs 1, 2, and 7 show that a VTS using a PR with an OR or even a Pa provides much more information than a PR with an axial OR.

The mandibular axial OR may not show structures that are markedly less radiopaque than the reference teeth, may present difficulties in positioning the x-ray tube precisely, and does not show the fine detail of the unerupted object or of the roots of surrounding teeth and the alveolar bone. Therefore a third radiograph, an anterior OR or a Pa, is necessary, resulting in increased radiation exposure and expense for the patient.

In the maxilla, axial (vertex) ORs are not recommended.[2,4,13] Because an axial OR is one of the radiographs frequently used in the right angle technique of localization, these limitations of axial ORs confirm that the parallax method is the method of choice to localize unerupted teeth.[14]

CONCLUSION

The parallax method is the technique of choice to localize unerupted teeth anterior to the molars in both jaws. A vertical tube shift using a panoramic radiograph and an occlusal radiograph taken at 70° to 75° is the favored combination of radiographs. However, the vertical angulation of the x-ray tube for the occlusal radiograph should not be increased above the standard 60° to 65° when the incisors to be used as reference teeth are markedly retroclined.

The horizontal position of the tube should be such that the image of an unerupted canine is projected onto a reference tooth rather than next to it. This is more likely to be achieved if the tube is positioned mesially, if the canine is palatally positioned (as the great majority are), or distally, if the canine is labially positioned. The limitations of axial (true, cross-sectional, vertex) occlusal radiographs to localize unerupted teeth are such that there are few, if any, indications for their use.

I want to thank Dr J. J. Keur. I have given him every manuscript I have written, including this localization series, for comment. Each time he has been most generous with both his radiologic and grammatical expertise.

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