

The influence of sensor size and orientation on image quality in intra-oral periapical radiography

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The periapical view is one of the standard intra-oral radiographs by which diagnostic information is obtained about the tooth and the periradicular tissues. In a symptom-free patient, treatment outcomes can only be assessed radiographically (Gutmann, Dumsha, Lovdahl, 2006). For dental diagnosis, and particularly in endodontics, it is important to achieve the best quality image possible with minimal exposure to radiation and patient discomfort.

There can be no doubt that in the technological revolution, digital radiography is one of the major leaps forward in recent years. The image size and quality, instant result, reduced radiation, and improved communication have all made digital radiography one of the essential tools of dentistry in the 21st century and nowhere more so than in endodontics.

The major component in direct capture image systems is the sensor itself. Most manufacturers – including Schick, Vatech, Kodak and Digora – make at least two sizes of sensor, which correspond approximately to size one and two films, although the active area is a little smaller. At least one manufacturer (Dexis) offers a single sensor, which is slightly larger than a size one film and, with its beveled corners, the claim is made that it reduces the gag reflex and makes the sensor more comfortable.

With the CCD and CMOS systems, the major expense is

the sensor itself. This can lead to a tendency to use the 'one size fits all' approach even though radiology and radiography texts have always recommended the standard use of two sizes of film for periapical radiography.

The ideal technique to give an undistorted image is the paralleling technique (Figure 1), and the ideal positioning requirements whether using film or digital sensors are (Whaites, 2008):

- The tooth under investigation and the image receptor should be in contact or, if not feasible, as close together as possible
- The tooth and the image receptor should be parallel to one another
- The image receptor should be positioned with its long axis vertically for incisors and canines and horizontally for premolars and molars with sufficient receptor beyond the



Figure 1: Parallel view of upper left maxillary molars.

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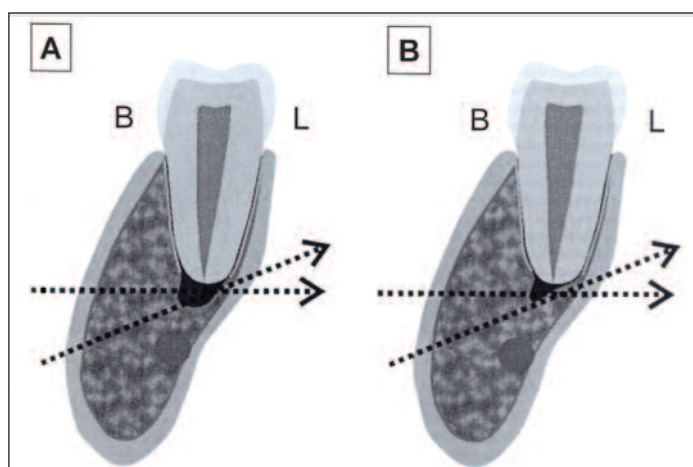
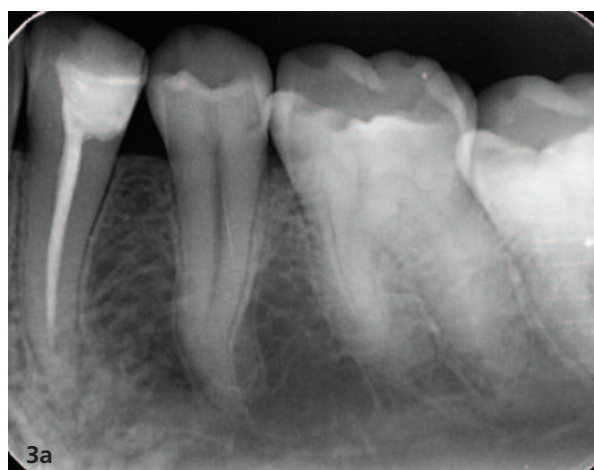


Figure 2: Effects of beam angulation and lesion size on appearance in radiographs. The larger lesion in (A) is visible in different angles, whereas the smaller and more buccally placed oriented lesion in (B) disappears when the beam is from an oblique angle (Huomonen, Orstavik, 2002).



Figures 3a and 3b: Pre- and post-operative periapical radiographs with slightly different vertical angulation of the lower left first bicuspid taken on the same day. The endodontic lesion is more apparent in the post-operative than the preoperative.

apices to record the apical tissues

- The X-ray tubehead should be positioned so the beam meets the tooth and the image receptor at right angles in both the vertical and horizontal planes
- The positioning should be reproducible.

The purpose of this paper is to discuss the influence of sensor size and orientation on image quality. With any given X-ray set, the image quality and consequently the information gleaned are dependent on a number of determinants, including:

- Positioning technique
- Exposure
- Size of the sensor.

An optimal image can only be achieved when these factors are considered in combination. Positioning

technique is critical as small changes in the beam angle can make the endodontic lesion increase, decrease or disappear altogether (Figures 2 and 3) (Cohn, 1988).

Textbooks on dental radiology and radiography have universally recommended that for incisors and canines a small film packet (size one) should be used (22mm x 35mm) with its long axis vertical, whereas for premolars and molars a large film packet (size two) should be used (30.5mm x 40.5mm) with its long axis horizontal (Whaites, 2008; Haring, Jansen, 2000; Langland, Langlais, 1997; White, Pharoah, 2004; Miles, van Dis, Razmus, 1992; Johnson, McNally, Essay, 2003). One group of authors has suggested that the full mouth survey can be made with any of the three periapical film sizes or any combination of these films (Johnson, McNally, Essay, 2003). However, no



Figure 4: *Narrow arch and small palatal vault.*



Figure 5a: *Periapical size one.*



Figure 5b: *Periapical size two.*

explanation was given as to how or when to make modifications from the standard recommendations.

While these recommendations are appropriate as a guideline, there are a number of situations where modification may provide improved diagnostic information and increased patient comfort.

Difficulties encountered with positioning of the sensor may be caused by a number of factors, including:

- Shape of the maxillary arch (Figure 4)
- Height and shape of the palatal vault (Figure 4)
- Palatal torus and exostosis
- Shape of the mandible
- Depth of the floor of the mouth
- Mandibular torus
- Gag reflex
- Length of the roots.

To overcome these problems it is not always possible to use the paralleling technique and the bisecting angle technique has been recommended as an alternative. This produces a distorted image, but may be the only way that the apical anatomy can be captured on the image when following the established guidelines. However, a change of sensor size or orientation may enable a paralleling technique to be used in difficult circumstances.

In the adult mouth, it is appropriate to use either the size one or size two sensor. The advantages of the size one sensor are:

- Greater flexibility in positioning
- Better chance of capturing an undistorted image of the tooth

- Greater comfort for the patient
- May overcome gag reflex more easily.

The disadvantages of the size one sensor are:

- It may not be possible to capture the whole tooth on one image
- Multiple teeth cannot be viewed on one image
- It may not be possible to see the full extent of a large periapical lesion
- Positioning of the sensor is critical.

The advantages of the size two sensor are:

- Teeth with long roots can be seen on one image
- Multiple teeth can be seen on one image
- The extent of large periapical lesions can be seen on one image (Figure 5).

The disadvantages of the size two sensor are:

- Reduced positioning flexibility
- May not be possible to use the paralleling technique
- Reduced patient comfort.

Choice of sensor size

The size of sensor chosen for any particular situation will depend on a number of factors that may not always be obvious from a clinical examination. A preliminary radiograph may be required to provide the information from which modifications can then be made to optimize the quality of the result.

The principles of ALARA should be followed as closely as possible and the patient should not be subjected to repeat doses of radiation unless the result fails to give adequate diagnostic information.

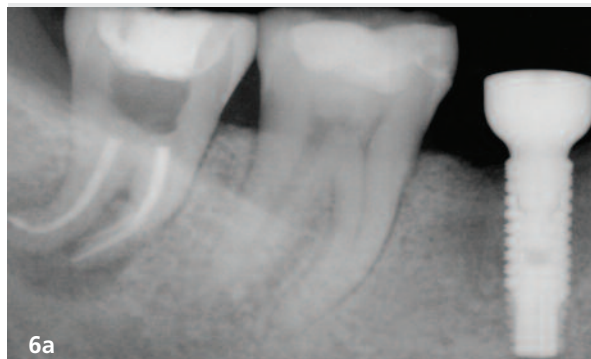


Figure 6a: Post-operative radiograph of root canal treatment of lower third molar. Note that the distal extent of the periradicular lesion has not been captured on the radiograph.

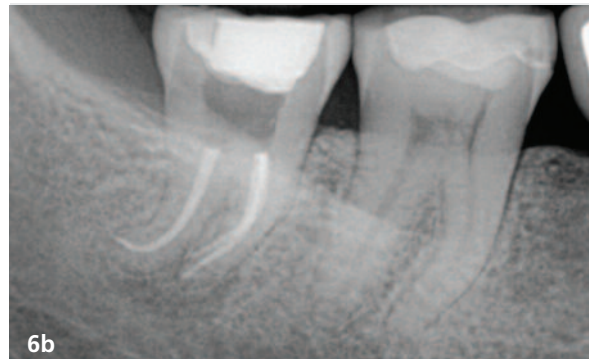


Figure 6b: The review radiograph at six months has been taken to show the tooth more centered so that healing of the periradicular area of the distal root can be confirmed.

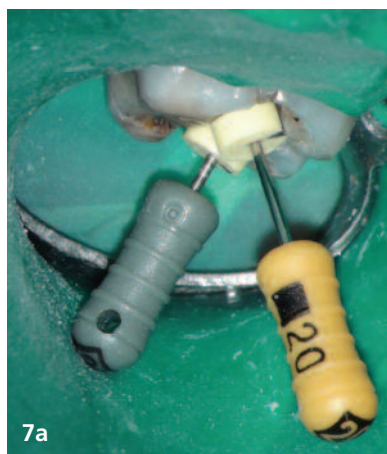
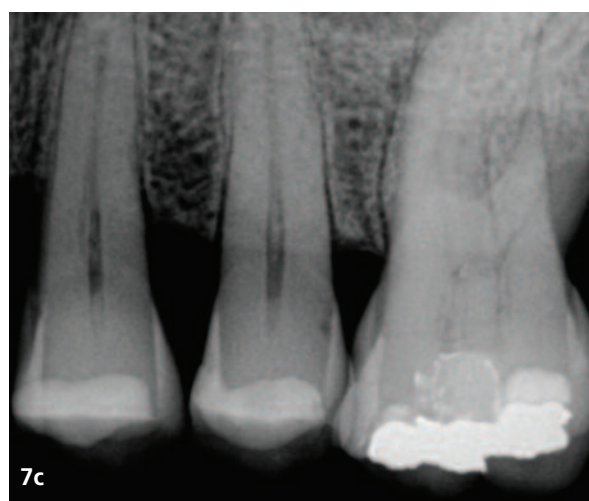
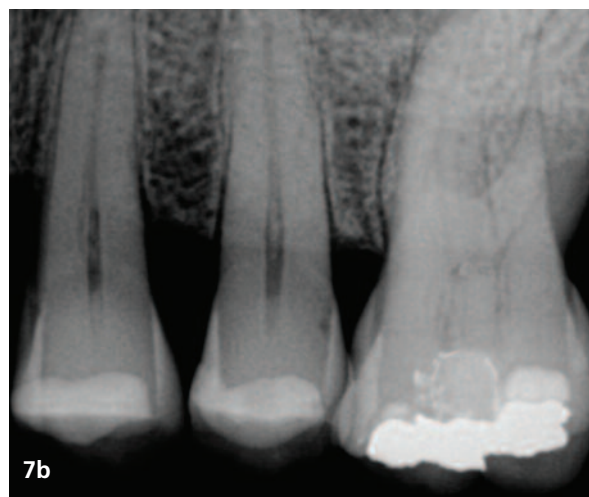


Figure 7a: Diagnostic files in the palatal and distobuccal canals showing root divergence in the case shown in Figures 7b and 7c.



In endodontic treatment, multiple radiographs are often taken throughout the procedure and this means that the opportunity exists to improve image quality in subsequent exposures by adjusting exposure time, positioning, sensor size and orientation (Figures 6a and 6b).

As the direct capture sensors are thicker than either film or phosphor plate sensors, it may be difficult for some patients to tolerate the bulk of a size two sensor. The required diagnostic information for endodontic treatment usually requires an image of only one tooth and can often be obtained from a size one sensor, particularly at the back of the mouth, although positioning is more difficult than when using a size two sensor.

Upper molars

Radiography of upper molars can often present a major challenge. The apices can easily be obscured by adjacent structures such as the zygomatic arch, particularly when a bisecting angle technique is used (Tamse, Kaffe, Fishel,

1980). A parallel view can only be obtained if the vault of the palate is sufficiently high in relation to the length of the roots. Where the palatal root is at a very divergent angle to the buccal roots (Figure 7a), a modified paralleling technique can be used, which entails taking a second radiograph at an increased vertical angulation of 10 to 20

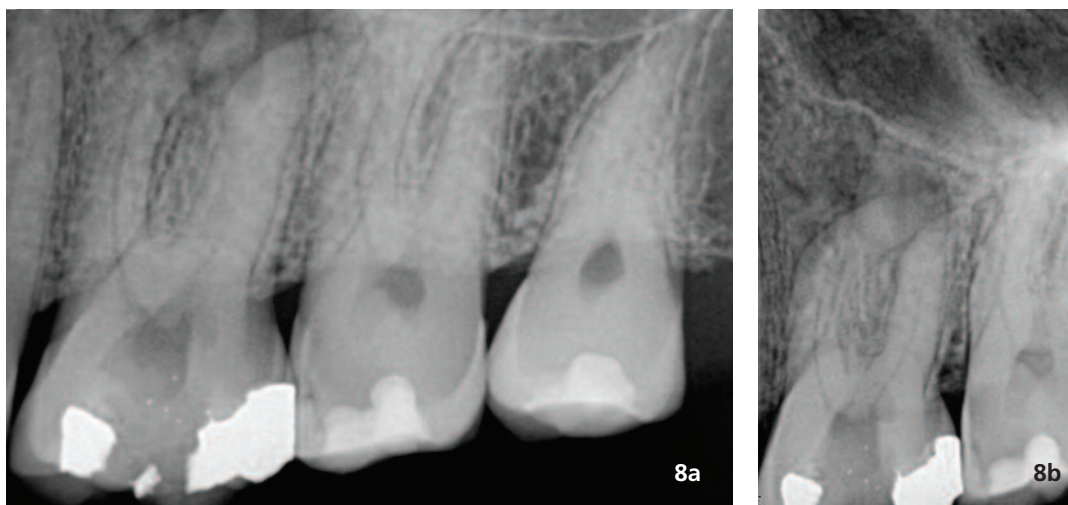


Figure 8a: Parallel view of upper first molar buccal roots clearly showing endodontic lesion. **Figure 8b:** Modified parallel view showing all roots, but the endodontic lesion is not as clear as in Figure 8a.

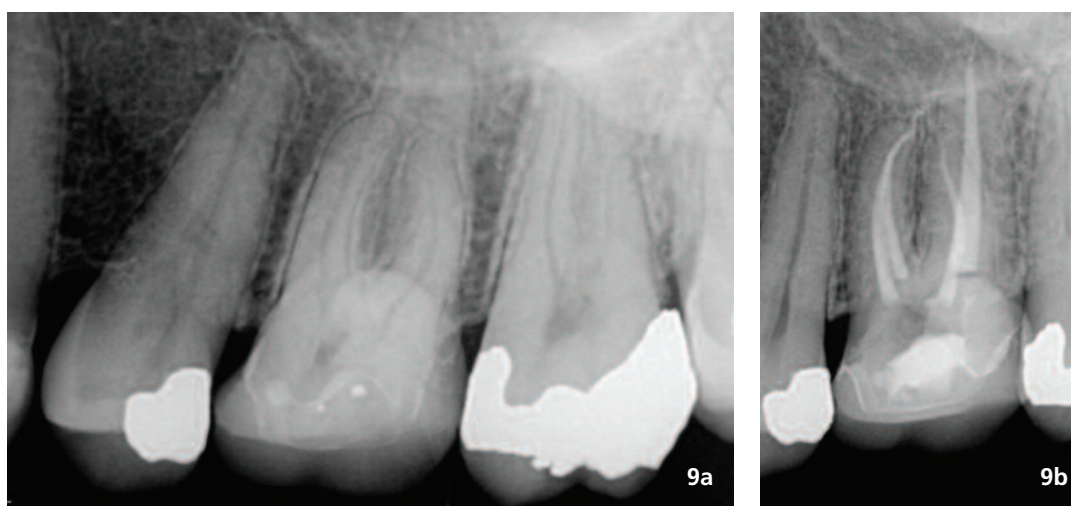


Figure 9a: Preoperative radiograph taken with a size two sensor in the horizontal orientation. **Figure 9b:** Post-operative radiograph taken with a size one sensor in the vertical orientation overcoming the patient's gag reflex.

degrees to show the apex of the palatal root clearly (Tamse, Kaffe, Fishel, 1980) (Figures 7b and 7c). This view may, however, obscure important information on the buccal roots, so it may be beneficial to take a parallel view first and, if necessary, take the modified view subsequently, rather than depend on just the one modified technique to obtain diagnostic information about all the roots (Figures 8a and 8b). When the palatal vault is short in a mesio-distal direction, the use of a size two sensor in horizontal orientation may also either be precluded or cause discomfort to the soft palate.

The use of a size one sensor in either the vertical or horizontal orientation will often overcome a gag reflex triggered by the use of the larger sensor (Figures 9a and 9b).

With small upper second molars, a size one sensor used in horizontal orientation will often give a better result than a size two sensor as the apices will not be obscured by other anatomical structures (Figures 10a and 10b).

Upper bicuspid

The standard recommendation for X-raying bicuspid is to use a size two sensor in horizontal orientation. A parallel view can only be achieved if the size and curvature of the palate and angulation of the teeth permit. The first bicuspid in particular are often positioned on the curve of the arch and only a bisecting angle view can be achieved with a size two sensor. Because the resulting image is distorted, preoperative estimation of root length can be very inaccurate. A size one sensor is used in vertical

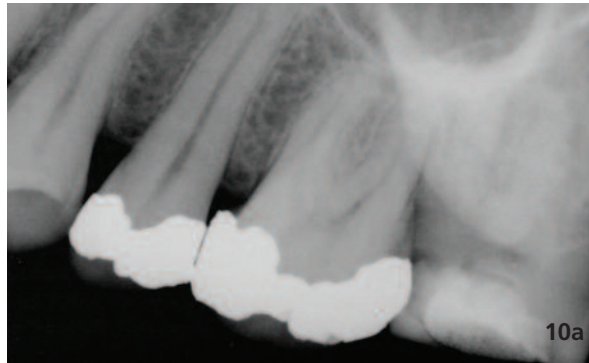


Figure 10a: Upper second molar preoperative using a size two sensor. **Figure 10b:** Upper second molar post-operative radiograph using a size one sensor.

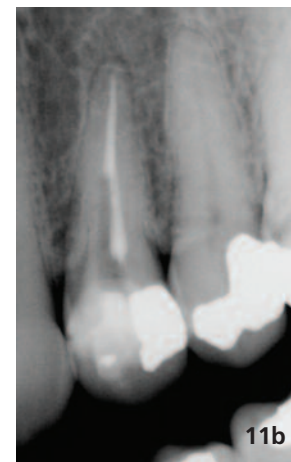
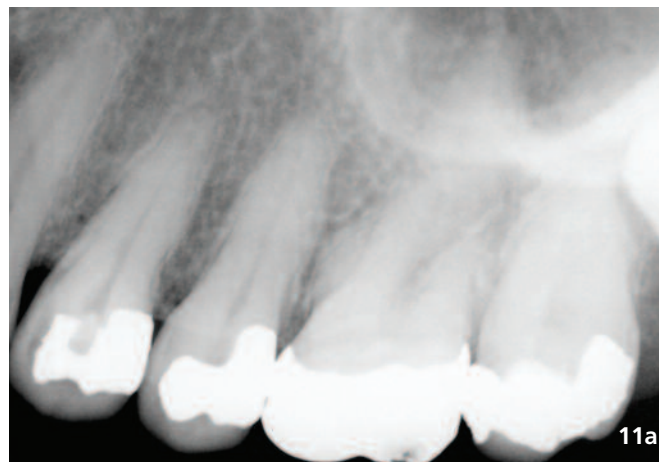


Figure 11a: Digital length estimation of 17mm of the first bicuspid using a size two sensor. **Figure 11b:** Actual length of 21mm of the same tooth using a size one sensor (coinciding with the digital length estimation).

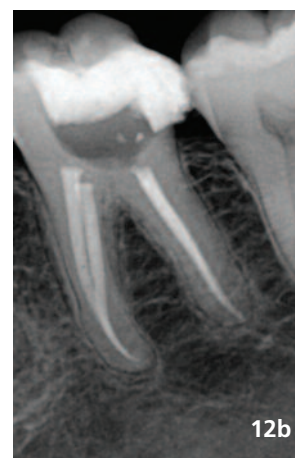


Figure 12a: Preoperative radiograph of the lower first molar. The patient was unable to tolerate a size two sensor due a V-shaped mandible. **Figure 12b:** Post-operative radiograph of the same tooth taken with a size one sensor in vertical orientation.

orientation will often give a better quality and more accurate image (Figures 11a and 11b).

Lower molars

Lower molars usually present less of a problem than upper molars although the bulk of a size two sensor can

sometimes initiate a gag reflex or cause discomfort in the floor of the mouth particularly with radiography of second molars. This can be caused either by the length or the depth of the sensor. A size one sensor may be tolerated more easily when used in either vertical or horizontal orientation depending on the root length (Figures 12a and

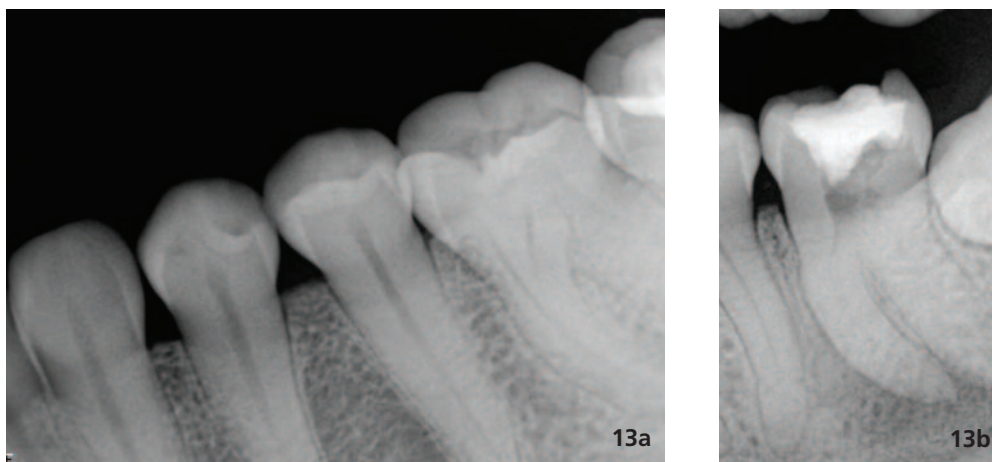


Figure 13a: Periapical radiograph attempting to X-ray lower second molar using a size two sensor in horizontal orientation. **Figure 13b:** Periapical radiograph of the same tooth using a size one sensor in vertical orientation.

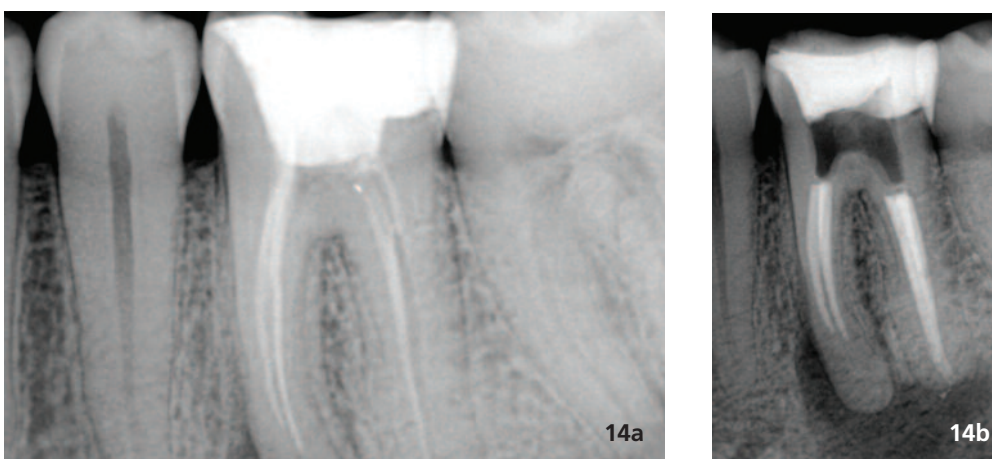


Figure 14a: Long rooted lower first molar taken with a size two sensor in horizontal orientation. **Figure 14b:** A size two sensor in vertical orientation showing the full extent of the periapical lesion.

12b; Figures 13a and 13b). Using a size one sensor in vertical orientation will accommodate an extra 4mm of root length, although the positioning becomes more critical (Figures 12a and 12b).

With long rooted teeth the apices may be cut off when a size two sensor is used in horizontal orientation. Using a size two sensor in the vertical orientation will allow an extra 10mm and may incorporate a large periapical lesion (Figures 14a and 14b).

The presence of a lingual torus (Figure 15) can impair the comfortable positioning of a size two sensor in the floor of the mouth. Placing the sensor further lingually increases the discomfort by encroaching on the tongue space and may trigger a gag reflex. It would also not be possible to keep the sensor parallel to the tooth. The problem can be overcome by placing a size one sensor in the vertical orientation (Figures 16a and 16b).

Lower bicusps

As with upper bicusps, the curvature of the mandible and the angulation of the teeth will determine the result that can be achieved with a size two sensor in horizontal



Figure 15: Lingual torus impedes the positioning of the sensor for a periapical view of the lower right first molar shown in Figures 16a and 16b

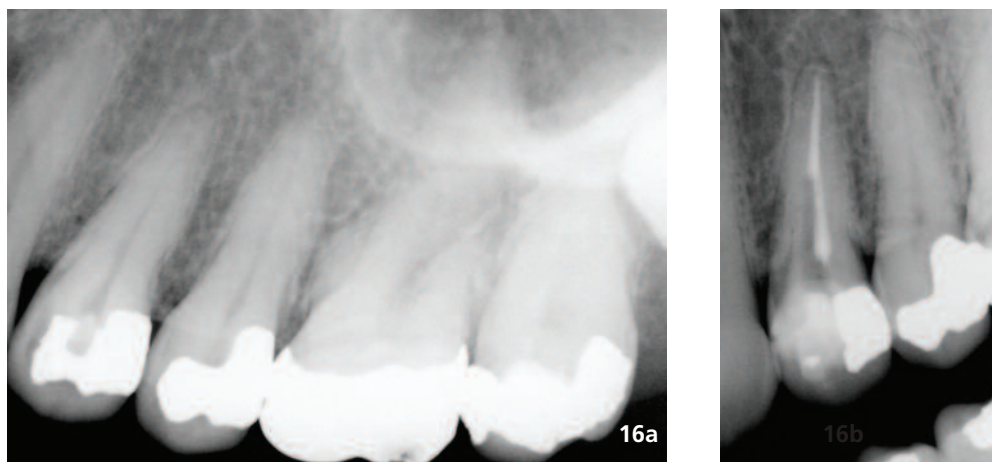


Figure 16a: Preoperative radiograph of lower first molar using a size two sensor in the presence of a lingual torus in the bicuspid region. Figure 16b: Post-operative radiograph of the same tooth using a size one sensor in the presence of a lingual torus in the bicuspid region.

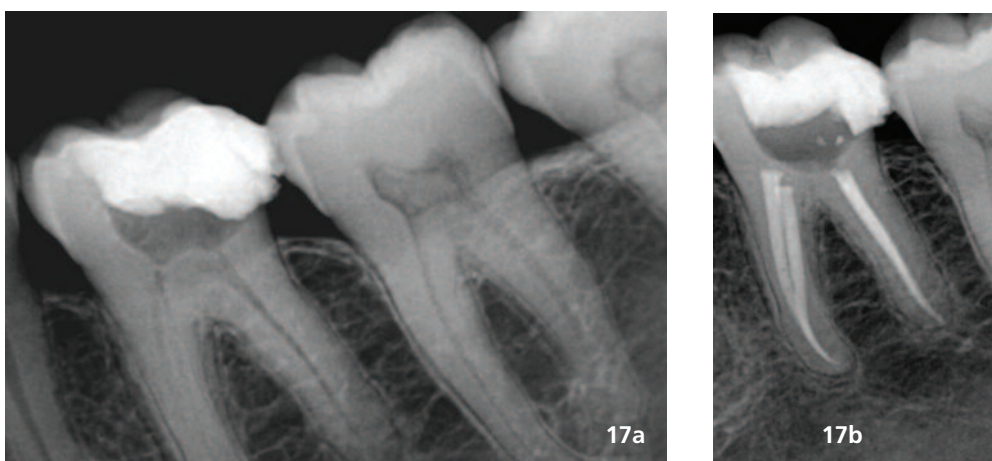


Figure 17a: Preoperative radiograph of lower first bicuspid taken with a size two sensor. Figure 17b: Post-operative radiograph of the same tooth taken with a size one sensor showing greater separation of the roots and more comfortable for the patient.

orientation. If the teeth are on the curve of the mandible, the sensor would have to be positioned diagonally across the arch. This pushes the tongue back and may cause the patient discomfort as well as producing some overlap of the teeth. The presence of a lingual torus may also impair the use of this sensor. A better quality result may be achieved using a size one sensor in the vertical orientation as the width is considerably reduced (Figures 17a and 17b).

Upper and lower anteriors

The narrowest width of sensor will always give the best quality image of anterior teeth as the sensor can be positioned higher in the vault of the palate and more comfortably against the floor of the mouth and, therefore, give a more parallel image than a size two sensor. This is at the expense of the number of teeth that can be seen on the image.

A long cone parallel image, which can be achieved more easily with the smaller sensor, will give accurate information about root length and fit of restorations such as crowns. With long rooted upper canines it may be necessary to angle the sensor so that the long axis of the tooth is on the diagonal of the sensor.

Conclusion

The choice of sensor size and orientation should be assessed individually and made on the basis of clinical circumstances to give the best image quality possible rather than by blanket recommendation. The preoperative radiograph will often allow an accurate assessment to be made and subsequent radiographs can be modified accordingly. This leads to more accurate radiographic information, improved interpretation and increased patient comfort.

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