RESEARCH

Ability of two radiographic methods to identify the closeness between the mandibular third molar root and the inferior alveolar canal: a pilot study

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Objectives: The aim was to compare the ability of two radiographic methods: the panoramic radiograph (PR) in combination with a 20-degree negative angle periapical radiograph (-20°Pa) vs two periapical radiographs $\text{Pa} + (-20^\circ\text{Pa})$, in evaluating the closeness of the lower third molar root and the inferior alveolar canal.

Methods: 2 radiographic methods of 32 impacted third molars were used. Two untrained dental students evaluated the closeness of the association between the root tip of the lower third molar and the inferior alveolar canal, both when in contact and separated, using dental cone beam CT as the gold standard. The position of the inferior alveolar canal relative to the third molar root was also recorded. The sensitivities and specificities of these findings were evaluated. Kappa values were used to assess the intra- and interobserver reliability.

Results: Of the 32 teeth, 23 (68.6%) showed contact between the root tip of the third molar and the inferior alveolar canal on dental cone beam CT, and 9 (31.4%) showed separation. The respective mean sensitivities of $\text{PR} + (-20^\circ\text{Pa})$ and $\text{Pa} + (-20^\circ\text{Pa})$ in detecting contact were 97.9% and 84.8% and the respective mean specificities in detecting separation were 16.7% and 44.4%. Intraobserver agreement in both techniques ranged from 0.69 to 0.94. The respective interobserver reliability was 0.88 in $\text{PR} + (-20^\circ\text{Pa})$ and 0.75 in $\text{Pa} + (-20^\circ\text{Pa})$.

Conclusions: Both the $\text{PR} + (-20^\circ\text{Pa})$ and the periapical vertical tube-shift technique $\text{Pa} + (-20^\circ\text{Pa})$ have high potential for detecting the closeness between the third molar root and the inferior alveolar canal.

Dentomaxillofacial Radiology (2010) **39**, 79–84. doi: 10.1259/dmfr/12537634

Keywords: third molar; inferior dental canal; panoramic radiograph; tube-shift method

The extraction of an impacted mandibular third molar can damage the inferior alveolar nerve (IAN) and cause dysaesthesia.^{1,2} Intraoral and panoramic radiographs are the methods of choice for evaluating the lower third molar position and its association with the inferior alveolar canal. Several radiographic markers in panoramic radiographs have been reported for their reliability in predicting the risk of inferior alveolar nerve exposure.³ Some studies used panoramic radiographs as a guideline for deciding whether an axial CT scan was needed, in addition to a preoperative panoramic radiograph, for patients slated to undergo a third molar extraction.⁴ Other studies reported the limited value of

panoramic radiographs for evaluating any physical contact between the mandibular third molar and the inferior alveolar canal.⁵ Experienced oral and maxillofacial surgeons reported that a dependence on a panoramic radiograph alone was unreliable.¹

One of the radiographic interpretation disadvantages of both intraoral and panoramic radiography is that they provide information in only two dimensions. By using the vertical tube shift method, the clinician who uses a panoramic radiograph and a periapical radiograph or two periapical radiographs taken at different vertical angulations may be able to clarify some of the diagnostic uncertainties that the panoramic radiograph or the periapical radiograph alone cannot solve. Dental cone beam CT has been accepted for its high sensitivity and as significantly superior to panoramic radiographs in predicting neurovascular bundle exposure.⁶ It is an excellent method for localizing the canal, and its

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Received 25 November 2008; revised 26 January 2009; accepted 4 February 2009

relationship to the lower third molar roots as reformatted images can be generated through the mandibular body in any plane.⁷ Owing to the cost, limited availability and radiation dose, dental cone beam CT is usually not the radiographic technique of choice for a preoperative radiographic evaluation of lower third molars.

The aim of the study was to compare the performance of two radiographic methods for determining the closeness of the lower third molar root and the inferior alveolar canal from (1) a rotational panoramic radiograph (PR) in combination with a periapical radiograph (Pa) taken at a vertical angulation of -20° (-20° Pa); and (2) two periapical radiographs taken at 0° and -20° , Pa + (-20° Pa). Cone beam CT was used as the gold standard.

Material and methods

27 dry human mandibles were selected from the Department of Anatomy, Faculty of Medicine, Khon Kaen University, Thailand. Panoramic radiographs of these dry mandibles were taken to evaluate the closeness of third molar impaction and the inferior alveolar canal, using orthopantomograph OP 100 (Trophy®, Rydalmere, Finland) operated at 78 kVp, 16 mA and 17.6 s.

32 impacted third molars were selected for this study. Two intraoral radiographs of each investigated tooth were made using two different projections: (1) the parallel technique and (2) the overaxial, with a vertical angulation of -20° using an intraoral dental machine (Trex, Trophy®, Beaubourg, France) operated at 65 kVp, 8 mA, 0.4 s. The focus–film distance was 35 cm. Panoramic films and intraoral Kodak Ultra speed films (Kodak®, New York, NY) were developed using an automatic processor (Konica SRX-101A, Orlando, FL, and Periomat plus®, Berlin, Germany, respectively) as per the manufacturers' instructions.

Dental cone beam CT examination (iCAT™, Imaging Sciences International, Hatfield, PA) was performed at 120 kVp, 5 mA, 20 s. The dry mandible's occlusal plane was parallel to the scan plane. The mid-sagittal plane was centred in the image field.

The Ethics Committee at Khon Kaen University approved the study as it conformed to the Helsinki Declaration (HE510228).

Radiographic assessment

Two untrained dental students, who knew and understood the buccal object rule, but had not practised tube shift image interpretation before reading the experimental images, evaluated the PR + (-20° Pa) and two intraoral radiographs Pa + (-20° Pa) and classified the physical relationship between the third mandibular molar and the inferior alveolar canal as "in contact" or "separate". "In contact" meant that the inferior alveolar canal remained at the same position vis-à-vis the third molar root even though the tube angulation

changed (Figures 1 and 2). "Separate" meant that the inferior alveolar canal *moved* upwards or downwards away from the original root tip. The position (buccal, lingual or in-line with apex) of the inferior alveolar canal relative to the third molar root was also recorded.

All of the images were viewed blind on at least 2 occasions, with at least a 2 week interval between viewings. The number of correct readings compared with the cone beam CT was recorded. The dental cone beam CT (Figure 3) was three-dimensionally evaluated to determine the association between the inferior alveolar canal and the third molar root by an oral and maxillofacial radiologist using iCAT vision® (version 1.3.0.1, Hatfield, PA).

Statistical analysis

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 14.0 (SPSS, Tokyo, Japan). Sensitivity, specificity, positive predictive value, negative predictive value and accuracy were calculated using cone beam CT as the gold standard. Intra- and interobserver reliabilities were evaluated using kappa values.

Results

The distribution of the impacted teeth included 24 vertical cases, 7 mesioangular and 1 horizontal. The number of findings showing the relationship between the inferior alveolar canal and the mandibular third molar root detected from the dental cone beam CT are

Figure 1 A crop of a panoramic radiograph showing the left mandibular third molar adjacent to the inferior alveolar canal

Figure 2 (a) Periapical radiograph (Pa) at 0° of the same patient as in Figure 1. (b) Periapical radiograph at -20° (-20°Pa) of the same patient as in Figure 1

presented in Table 1, and those detected from the two radiographic methods and two observers are presented in Tables 2–5.

The mean sensitivity of PR + (-20°Pa) and Pa + (-20°Pa) in detecting the contact of the third molar root and the inferior alveolar canal was 97.9% and 84.8%, respectively. The mean specificity of PR + (-20°Pa) and Pa + (-20°Pa) in detecting the separation of the third molar root and the inferior alveolar canal was 16.7% and 44.4%, respectively. The average accuracy of PR + (-20°Pa) and Pa + (-20°Pa) was 75.0% and 73.5%, respectively (Table 6). The sensitivities and specificities of two radiographic methods in identifying the position (buccal, lingual and in-line with apex) of the inferior alveolar canal related to the mandibular third molar root are presented in Table 7.

The first observer had good intraobserver agreement in PR + (-20°Pa) (0.75 (95% CI 0.74–0.76)) and very good intraobserver agreement in Pa + (-20°Pa) (0.81 (95% CI 0.81–0.82)), respectively. Similarly, the intraobserver agreement by the second observer ranged from 0.688 (95% CI 0.68–0.70) in PR + (-20°Pa) to 0.938 (95% CI 0.94–0.94) in Pa + (-20°Pa). Interobserver reliability was 0.88 (95% CI 0.87–0.88) in PR + (-20°Pa) and 0.75 (95% CI 0.74–0.76) in Pa + (-20°Pa), respectively.

Discussion

It is important for the oral surgeon to know whether the inferior alveolar canal is in contact with, or

Figure 3 Dental cone beam CT of the same patient as in Figure 1, showing contact between the left mandibular third molar root and the inferior alveolar canal

Table 1 The number of findings showing the relationship between the inferior alveolar canal and the mandibular third molar root detected from dental cone beam CT ($n = 32$)

<i>In contact</i>	<i>Separate</i>	<i>Buccal</i>	<i>Lingual</i>	<i>In-line with apex</i>	<i>Total</i>
23 (68.6%)	9 (31.4%)	14 (43.7%)	2 (6.3%)	16 (50%)	32 (100%)

separated from, the third molar roots for the purpose of predicting any possible complications or providing information to patients before surgery. Prevention of inferior alveolar nerve exposure should be based on a thorough understanding of the anatomy in addition to radiographic interpretation. In oral and maxillofacial surgery practice, the panoramic radiograph is the most widely used technique for evaluating the lower third molar position and the relationship with the inferior alveolar canal.⁸ A panoramic radiograph alone, however, is not sufficient for determining the relationship between the inferior alveolar canal and the lower third molar roots.^{1,5,8} By use of the vertical tube shift method, the buccolingual position of the roots is revealed. In addition, the dilacerated root or multiple curved roots can be better observed because of the improved capacity for interpretation.⁹

This study showed that a pre-operative radiographic examination using two different projections gave adequate insight to the association of the lower third molar and the inferior alveolar canal. PR + (-20° Pa) provided higher sensitivity (97.9%) than Pa + (-20° Pa) (84.8%). Other studies⁶ have reported the sensitivity of the panoramic radiograph alone, compared with the dental cone beam CT for evaluating the association of the lower third molar, and the inferior alveolar canal, was 70%. Unfortunately, no studies reported the performance of the shift tube method compared with a single panoramic radiograph in identifying this relationship. Many studies reported the sensitivity of the single panoramic radiograph ranged between 0.42 and 0.75, depending on the radiographic criteria.^{3,10}

There are two main factors¹¹, which influence the appearance of the shift tube image. First, the distance between the third molar root and the inferior alveolar canal (both in the mesiodistal and buccolingual direction): the larger the distance the greater will be the shift of the image. If the image of the inferior alveolar canal does not move along with the tube shift, it is supposed to be in contact between these two structures. Second, tube movement: the larger the movement of the tube, the larger the shift of the image. Tube movement between

Table 2 2×2 table showing the number “in contact” and “separate” as detected by observers 1 and 2 using two radiographic methods, PR + (-20° Pa) and Pa + (-20° Pa) (in parentheses)

	<i>Dental cone beam CT</i>		
	<i>In contact</i>	<i>Separate</i>	<i>Total</i>
In contact	23, 22 (18, 21)	7, 8 (5, 5)	30, 30 (23, 26)
Separate	0, 1 (5, 2)	2, 1 (4, 4)	2, 2 (9, 6)
Total	23, 23 (23, 23)	9, 9 (9, 9)	32, 32 (32, 32)

Table 3 2×2 table showing the number of “buccal” and “not buccal” positions as detected by observers 1 and 2 using two radiographic methods, PR + (-20° Pa) and Pa + (-20° Pa) (in parentheses)

	<i>Dental cone beam CT</i>		
	<i>Buccal</i>	<i>Not buccal</i>	<i>Total</i>
Buccal	10, 10 (12, 12)	11, 13 (11, 10)	21, 23 (23, 22)
Not buccal	4, 4 (2, 2)	7, 5 (7, 8)	11, 9 (9, 10)
Total	14, 14 (14, 14)	18, 18 (18, 18)	32, 32 (32, 32)

the panoramic radiograph and the -20° periapical radiograph differed from that of the two different angled periapical radiographs Pa + (-20° Pa).

Miloro and DaBell¹² reported that the mean distance from erupted mandibular third molars to the superior border of the inferior alveolar canal was 0.88 mm. They also found a significant difference in this distance from unerupted teeth. All impacted teeth had a negative mean value, indicating that root apices were inferior to the inferior alveolar canal: -0.97 mm for mesioangular, -0.61 mm for vertical, -0.31 mm for distoangular and -0.24 mm for horizontal impactions. The superimposition of the third molar root and the inferior alveolar canal reveals the close relationship of the third molar root and the inferior alveolar nerve in many studies.^{5,13,14} Levine *et al*¹⁵ reported the distance between the buccal aspect of the inferior alveolar canal and the buccal cortical margin of the mandible was 4.9 mm; this distance is found to be statistically less in older and Caucasian patients. These findings suggest that the tube-shift image should be interpreted carefully, especially when the relationship of two structures is close.

Since the anatomy and inclination of teeth are not a straight line, the movement of the tooth root and the inferior alveolar canal in an image may not be straightforward. Careful observation is needed before drawing a correct conclusion. This technique is not 100% precise. The present study showed the sensitivities were high, but the specificities were low for both techniques, meaning that the performance of two radiographic methods is high for identification of the closeness of the lower third molar and the inferior alveolar canal. Meanwhile, there is also a high potential for mistakenly reading “in contact” when it should be “separated”. The low specificities might be the result of inexperienced observers reading the shift tube image and/or the low sample size.

The sensitivities and specificities of two radiographic methods in localizing the position of the inferior alveolar canal related to the third molar root have the same direction in both observers. The sensitivity in identifying the buccal position of the inferior alveolar

Table 4 2×2 table showing the number of “lingual” and “not lingual” positions as detected by observers 1 and 2 using two radiographic methods, PR + (-20° Pa) and Pa + (-20° Pa) (in parentheses)

	<i>Dental cone beam CT</i>		
	<i>Lingual</i>	<i>Not lingual</i>	<i>Total</i>
Lingual	1, 0 (1, 0)	1, 1 (0, 0)	2, 1 (1, 0)
Not lingual	1, 2 (1, 2)	29, 29 (30, 30)	30, 31 (31, 32)
Total	2, 2 (2, 2)	30, 30 (30, 30)	32, 32 (32, 32)

Table 5 2 × 2 table showing the number of “in-line with apex” and “not in-line with apex” as detected by observers 1 and 2 using two radiographic methods, PR + (−20°Pa) and Pa + (−20°Pa) (in parentheses)

	<i>Dental cone beam CT</i>		
	<i>In-line with apex</i>	<i>Not in-line with apex</i>	<i>Total</i>
In-line with apex	6, 4 (5, 6)	4, 4 (3, 3)	10, 8 (8, 9)
Not in-line with apex	10, 12 (11, 10)	12, 12 (13, 13)	22, 24 (24, 23)
Total	16, 16 (16, 16)	16, 16 (16, 16)	32, 32 (32, 32)

Table 6 Diagnostic accuracy of two radiographic methods in identifying the closeness between the inferior alveolar canal and the mandibular third molar root by observers 1 and 2

<i>Technique</i>	<i>Sensitivity (%)</i>	<i>Specificity (%)</i>	<i>PPV (%)</i>	<i>NPV (%)</i>	<i>Accuracy (%)</i>
PR + (−20°Pa)	100.0, 95.7	22.2, 11.1	76.7, 73.3	100.0, 50.0	78.1, 71.9
Pa + (−20°Pa)	78.3, 91.3	44.4, 44.4	78.3, 80.8	44.4, 66.7	68.8, 78.1

PPV, positive predictive value; NPV, negative predictive value

Table 7 Sensitivities and specificities (in parenthesis) in identifying the position of the inferior alveolar canal and the mandibular third molar root by observers 1 and 2.

<i>Technique</i>	<i>Buccal (%)</i>	<i>Lingual (%)</i>	<i>In-line with apex (%)</i>
PR + (−20°Pa)	71.0 (38.9), 71.4 (27.7)	50.0 (96.7), 0.0 (96.7)	37.5 (75.0), 25.0 (75.0)
Pa + (−20°Pa)	85.7 (38.9), 85.7 (27.8)	50.0 (100.0), 50.0 (100.0)	31.3 (81.3), 12.5 (75.0)

canal was high. The specificity in indicating the lingual position and in-line with root apex was high. Owing to the limited sample size, there were only two cases in which the lingual position was detected from the dental cone beam CT; consequently, these sensitivities and specificities might not be representative nor have significance for clinical practice, in which the “in contact” or “separate” relationship is more meaningful concerning the trauma to the nerve.

If the panoramic films have poor patient positioning, the structures that lie outside the focal trough decrease the definition. The vertical head rotation in panoramic radiography changes the relationship between the inferior alveolar canal and the third molar root in the image because of the change of the path of the X-rays through the object. An observer may interpret these films correctly if they understand the direction of the beam and the subsequent image formation. Stramotas *et al*¹⁶ reported that tilting the head vertically <10° does not affect the linear and angular measurement. This fact, however, emphasizes the importance of having an adequate understanding of the principles of image formation and sufficient training/practice in using the panoramic radiograph and doing shifted tube image interpretation.

In terms of diagnostic performance, three-dimensional CT currently provides the best accuracy and is recommended when the panoramic radiograph presents one or more predictive radiographic markers.^{4,10,17} A panoramic radiograph and a periapical radiograph for a vertical

tube shift were selected in this study because a panoramic radiograph is often taken as an initial radiograph. Only one additional exposure is required. Owing to the limited availability and its high cost, dental cone beam CT is not the first choice tool for identifying the closeness of the third molar root and the inferior alveolar canal. Dental cone beam CT should be used when a single radiograph and the shift tube image do not provide sufficient clarity for interpretation and when the intraoral radiograph is impossible to perform because of trismus or vomit reflex.

In conclusion, a panoramic radiograph with vertical periapical tube shift and two different vertical angulation periapical radiographs provided high potential for detecting the closeness of the relationship of the third molar root and the inferior alveolar canal. Further study should be done by trained dental practitioners with a large number of subjects, and the optimum negative angle should be evaluated.

Acknowledgments

This study was supported by the Faculty of Dentistry, Khon Kaen University, Thailand. Special thanks to Dr Kowit Chaisiwamongkol from the Department of Anatomy, Faculty of Medicine, Khon Kaen University, for the dry human mandibles; Dr Wichit Tharanon from the Advanced Dental Technology Center for the Dental Cone Beam CT Facility; and Mr Bryan Roderick Hamman for assistance with the English-language presentation of the manuscript.

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