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Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography

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Abstract. This study investigated the diagnostic accuracy of cone beam computed tomography (CBCT) compared to panoramic radiography in determining the anatomical position of the impacted third molar in relation with the mandibular canal. The study sample comprised 53 third molars from 40 patients with an increased risk of inferior alveolar nerve (IAN) injury. The panoramic and CBCT features (predictive variables) were correlated with IAN exposure and injury (outcome variables). Sensitivity and specificity of modalities in predicting IAN exposure were compared. The IAN was exposed in 23 cases during third molar removal and injury occurred in 5 patients. No significant difference in sensitivity and specificity was found between both modalities in predicting IAN exposure. To date, lingual position of the mandibular canal was significantly associated with IAN injury. CBCT was not more accurate at predicting IAN exposure during third molar removal, however, did elucidate the 3D relationship of the third molar root to the mandibular canal; the coronal sections allowed a bucco-lingual appreciation of the mandibular canal to identify cases in which a lingually placed IAN is at risk during surgery. This observation dictates the surgical approach how to remove the third molar, so the IAN will not be subjected to pressure.

Keywords: diagnostic accuracy; cone beam CT; third molar surgery; panoramic radiography; inferior alveolar nerve injury; third molar position.

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Damage to the inferior alveolar nerve (IAN) is a serious complication following third molar removal. The overall risk of temporary IAN injury associated with third molar removal ranges from 0.4% to 6%[4,26]. The reported rate of permanent IAN injury, in which the sensory impairment lasts longer than 6 months, is less than 1%[4,26]. The overall risk of permanent impairment during third molar removal is low, but a significant number of patients are affected because many third molars are removed.

The most evident risk factor for injury of the IAN is the proximity of the root of the third molar to the mandibular canal[4,25,26]. When a close relationship between the third molar and the mandibular canal is observed radiographically, the risk of temporary IAN injury increases[6,7]. It is important to assess the position, and establish the relationship, of the third molar with the mandibular canal preoperatively to minimize the risk of nerve injury. Panoramic radiography is the standard diagnostic tool for this purpose. Clinicians use various radiographic markers to indicate a close relationship between the third molar and the mandibular canal[7]. If the radiological marker on the panoramic radiograph indicates there is a close relationship between the third molar and the mandibular canal, additional investigation using computed tomography (CT) may be recommended to verify the relationship in a three-dimensional (3D) view[10,14,18]. The drawbacks of CT are the higher radiation dose[22] and increased financial costs compared with panoramic imaging.

Cone beam computed tomography (CBCT) has been introduced to improve conventional CT, because it reduces the radiation dose[9], offers high spatial resolution[1] and decreases costs. CBCT provides better image quality of teeth and their surrounding structures compared with conventional CT[5,8]. CBCT seems to be a more accurate imaging modality for determining the relationship of the third molar to the mandibular canal. To justify the application of CBCT in the preoperative assessment of impacted third molars, it is necessary to assess whether it gives the practitioner a more detailed insight into the anatomical relationship of the third molar and the mandibular canal than conventional imaging techniques. CBCT is a relatively new imaging technique so there is little literature available concerning its diagnostic value. This study aims to investigate the potential benefits of CBCT by comparing the diagnostic accuracy of CBCT and panoramic radiography in predicting IAN exposure and evaluating the reliability of CBCT in determining the bucco-lingual position of the third molar in relation to the mandibular canal.

Table 1. i-CAT™ 3-D imaging system specifications for mandibular scan.

X-ray source	High frequency, constant potential, fixed anode 120 kVp, 3–8 mA (pulse mode)
X-ray beam	Cone-beam
Focal spot	0.5 mm
Field of view	6 cm
Image detector	Amorphous silicon flat panel 20 cm * 25 cm
Voxel size	0.25 mm
Gray scale	14 bit
Scan time	20 s
Radiation dose	32 μSv

Materials and Methods:

Study sample/design

This is a prospective study of consecutive patients who consulted the department of Oral and Maxillofacial Surgery, for mandibular third molar removal between February 2007 and September 2007. A power analysis was performed based on data obtained from the literature[23,24].

Patients thought to have a close relationship between the mandibular canal and one or both mandibular third molars, diagnosed from digital panoramic radiographs, underwent additional CBCT imaging. 42 patients, with 56 impacted mandibular third molars (22 women and 20 men) were enrolled in this study. Patients with radiological evidence of a cyst and those for whom the time interval between imaging and third molar removal exceeded 6 months, were excluded from the study. All were informed of possible complications following removal of the third molar and written informed consent was obtained from all patients.

System specifications

Digital panoramic radiographs were taken with a Soredex Cranex Tome device (Soredex, Helsinki, Finland), operated at 81 kV and 10 mA using a photostimulable phosphor plate. The CBCT mandibular scan was acquired using i-CAT™ 3-D Imaging System (Imaging Sciences International Inc, Hatfield, PA, USA). The scanner specifications are listed in Table 1.

Clinical evaluation

All third molars were removed under local anaesthesia by 2 senior oral and maxillofacial surgeons who had at least 15 years' experience of the procedure. After raising the mucoperiosteal flap, with a burr buccally and distally, bone was removed. If necessary, the tooth was sectioned one or more times. Postoperatively, after rinsing and irrigating, the extraction sites were examined to monitor if the IAN was visible.

Postoperative surveillance

The patients had a postoperative review appointment 2 weeks after surgery. Neurosensory disturbances of the lip and chin were assessed by measuring the function of the IAN with light touch sensation (large nerve fibres), using Semmes Weinstein (SW) monofilaments nr. 1.65, 2.83 and 3.22, and thermal discrimination (small nerve fibres), by applying an aluminum rod (cold) and a Perspex rod (diameter 4 mm).

A test procedure using two alternative choices was used, as described by van der Glas *et al*.[3] The contralateral halves of the lip and chin were taken as control site. The area with impaired sensation was drawn on the skin and recorded photographically. Patients with altered sensation returned 3 and 6 months postoperatively and their recovery pattern was noted. Patients who recovered fully within 6 months were defined as suffering from temporary IAN injury. Altered sensations lasting longer than 6 months were scored as permanent IAN injury. The neurosensory testing of all patients was carried out by one investigator.

Evaluation of images

In a darkened room, the CBCT and panoramic images were shown in a random order on a 17 inch PC monitor. Evaluation was carried out by two trained oral and maxillofacial surgeons, but not those who had surgically removed the wisdom teeth. Both were experienced in diagnosing maxillofacial structures and familiar with both imaging modalities. They were blinded for the clinical outcome.

Panoramic radiographs were scored for the presence or absence of the following radiographic signs, all of which had been reported to be suggestive of a close relationship between the mandibular canal and the third molar:[21,23] interruption of the

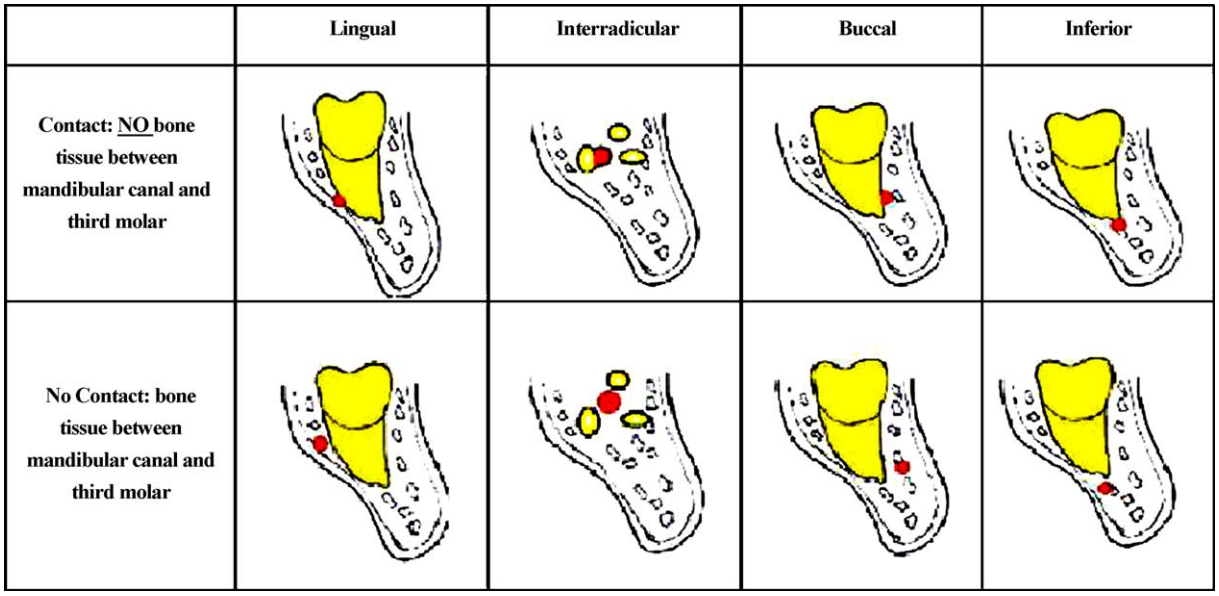

Fig. 1. Classification of the position and relationship of the third molar root to the mandibular canal, as seen on CBCT images.

white line of the mandibular canal wall; darkening of the root; diversion of the mandibular canal; narrowing of the mandibular canal; narrowing of the roots; and deflection of the roots. Using these marks, the investigators aimed to find the optimal diagnostic criteria for predicting IAN exposure from panoramic radiographs.

The CBCT images were assessed through the i-CAT Vision® software program. The implant planning screen and the multiplanar reconstruction (MPR) screen were used to scroll through the axial, sagittal and coronal planes. The slice thickness was 1 mm. The images were evaluated in all three dimensions to establish if the cortical layer of the mandibular canal between the third molar and IAN was still intact. The position of the mandibular canal with respect to the third molar was classified as lingual, buccal, interradicular or inferior (Fig. 1).

Statistical analysis

The panoramic and CBCT features (predictive variables) were correlated with the intra-operative finding of IAN exposure and the postoperative occurrence of IAN injury (outcome variables). The X^2 and Fisher's exact test were used to assess the association between the predictor and outcome variables. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of each imaging modality in predicting IAN exposure were calculated. The difference between the sensitivity and specificity of panoramic radiography and CBCT were tested with a X^2 test. Probability values less than 0.05 were considered statistically significant.

Possible predictors of radiographic signs for IAN exposure were tested with X^2. After selection of significant predictors a stepwise logistic regression was carried out to obtain the effect after correction for the other predictors.

To judge the inter-observer agreement Kappa (κ) values were calculated. A κ value <0.40 was considered poor agreement, 0.40–0.59 was fair agreement, 0.60–0.74 was good agreement and 0.75–1.00 was excellent agreement.

All statistical analyses were performed using the SAS program (SAS Institute Inc., Cary, NC, USA), version 9.1.

Results

3 of the 56 impacted third molars were excluded because digital panoramic radiographs were not available. The study sample consisted of 53 impacted third molars from 40 patients (20 women and 20 men) with an average age of 27.6 years (ranging from 20 to 62 years).

Following removal of the 53 mandibular third molars, the IAN was exposed in 23 cases (43%). Based on neurosensory testing, temporary IAN injury occurred in 5 patients (9%). In 4 of these 5 patients the inferior alveolar nerve was noted as exposed following the extraction. The frequency of temporary IAN injury after visualization of the IAN was 17%. After 6 months, 3 patients (6%) continued to have some sensory impairment, although in one patient this could not be verified using light touch sensation and thermal discrimination.

No significant correlation was observed between IAN exposure and postoperative sensory impairment compared with gender, site of extraction or angulation of the third molar.

The inter-observer agreement for CBCT, represented as the κ-value in the assessment of the bucco-lingual position of the mandibular canal, was 0.80. The κ-value in the assessment of contact between the third molar root and the mandibular canal on CBCT images was 0.78. Owing to these excellent inter-observer agreements, the results achieved from one observer were used for further analysis.

In the assessment of panoramic radiographs the agreement was poor: κ-value ranged from 0.35 (darkening of the root) to 0.52 (interruption of the white line). Owing to this poor agreement the panoramic images were assessed again by both observers and consensus was reached by discussion. The results obtained from the consensus were used for further analyses.

Three of the panoramic radiographic signs were statistically associated with IAN exposure: interruption of the white line, darkening of the root, and diversion of the mandibular canal (Table 2). Stepwise logistic regression analysis of these predictor variables was performed and only one radiographic sign, darkening of the tooth root, was taken into the model and showed a significant association with IAN exposure (P=0.007) with an odds-ratio of 0.204 (95% CI 0.062–0.672).

As determined on CBCT images, the mandibular canal was positioned lingual

Table 2. Sensitivity, specificity and predictive values of the radiographic signs on panoramic radiographs.

Panoramic radiographic signs	Sensitivity	Specificity	PPV	NPV	P value
Interruption of the white line	1.0	0.17	0.48	1.0	0.040
Darkening of the roots	0.74	0.63	0.61	0.76	0.007
Diversion of the canal	0.22	0.97	0.83	0.62	0.036
Narrowing of the canal	0.13	0.87	0.43	0.57	0.975
Narrowing of the roots	–				
Deflection of the roots	0	0.93	0	0.95	0.207

PPV, positive predictive value; NPV, negative predictive value.

Table 3. Relationship between the buccolingual position of the mandibular canal with IAN exposure during third molar removal and postoperative sensory disturbances.

Position CBCT		Contact CBCT	IAN visible	IAN not visible	Postoperative sensory impairment
Lingual *	26	26	15	11	5*
Interradicular	8	8	5	3	0
Buccal	9	7	1	8	0
Inferior	10	4	2	8	0
Total	53	45	23	30	5

* $p < 0.05$.

to the third molar in 49% of cases, 17% were buccal, 19% inferior and 15% interradicular. The rates of IAN exposure and IAN injury following third molar removal were significantly correlated with the position of the mandibular canal as seen on CBCT images (Table 3). The IAN was more frequently exposed following third molar extraction when the mandibular canal was situated lingually than in a buccal position ($P < 0.02$). In all patients with postoperative sensory impairments the mandibular canal was positioned lingual to the third molar roots as seen on CBCT images ($P < 0.02$).

In 48 cases in which one or both white lines of the mandibular canal were interrupted, as scored on panoramic radiographs, 42 (88%)showed contact between the third molar roots and the mandibular canal on CBCT.

The diagnostic accuracy of panoramic radiography and CBCT in predicting IAN exposure is given in Table 4. No significant differences in sensitivity and specificity between the cone beam CT and panoramic radiography in predicting inferior alveolar nerve exposure were seen. As example, two cases are shown in Figs. 2 and 3.

Discussion

A well-described risk factor that is significantly correlated with IAN injury following third molar removal is exposure of the neurovascular bundle during extraction[6,7,24,25]. In this study postoperative sensory disturbances occurred in 17% of cases of IAN exposure during removal, which is in agreement with other studies[4,23,24,25]. An accurate preoperative prediction of IAN exposure is important to determine the risk of IAN injury. This information can be helpful in deciding whether to remove a symptomless third molar and can be used to obtain correct informed consent.

The panoramic radiograph is the standard diagnostic tool in the preoperative assessment of mandibular third molars and their relationship with the mandibular canal. Clinical studies have identified radiographic signs on panoramic radiographs that indicate a high risk of IAN exposure or IAN injury following third molar removal. In this study, the panoramic signs, interruption of the white line, darkening of the root and deviation of the mandibular canal were significantly associated with IAN exposure. This results are in agreement with a study by Rood and Shehab[21], who analysed the association of panoramic signs of 1560 third molars and IAN injury. In most cases a combination of these signs is present on the panoramic radiograph, so the authors performed a logistic regression analysis to obtain the optimal independent radiographic sign that could predict IAN exposure. Only one radiographic sign, darkening of the root, was significantly associated with IAN exposure. This result corroborates other reports, that darkening of the root is one of the most significant radiographic signs in predicting IAN exposure[23], and IAN injury[6,21].

The usefulness of CBCT has been described in endodontology[19], implantology[15], periodontology[13] and oral surgery[17], but few systematic validation studies are available. One study has reported the diagnostic accuracy of CBCT in predicting IAN exposure following third molar removal[24].

Tantanapornkul *et al*.[24] concluded that the 3DX CBCT (Morita Corp.) was significantly more accurate compared with panoramic radiography in predicting IAN exposure during third molar removal with a sensitivity of 93% and a specificity of 77%. In the present study, a comparable high sensitivity (96%), but a lower specificity (23%) for the i-CAT CBCT was scored. Owing to the low specificity, no significant difference in the diagnostic accuracy between the i-CAT CBCT and panoramic radiography in the prediction of IAN exposure was measured. The authors found the same positive predictive value (0.49) for the i-CAT CBCT as Tantanapornkul *et al.* for the 3DX CBCT. This means that in the absence of cortical bone between the mandibular canal and the third molar root as seen on CBCT images, the IAN was visible during extraction in almost half of the cases. The negative predictive value for CBCT found in this study (0.88) was also comparable with that found in the study of Tantanapornkul *et al.* (0.90). The only factor that could explain the lower specificity is the relatively high prevalence of positive test results and the low prevalence of negative test results in this study, due to the more strict selection criteria. In the present study sample, 98% of cases had one or more radiographic signs on the panoramic radiograph that suggested a close relationship between the third molar root and the mandibular canal and 85% of the cases showed contact on the CBCT. In the study of Tantanapornkul *et al.* these values were 44% and 36%, respectively. In cases in which one or more signs of an intimate relationship between the mandibular canal and the third molar roots is present on

Table 4. Diagnostic accuracy of CBCT images and panoramic radiographs in predicting IAN exposure during third molar removal.

	TP	TN	FN	FP	Sensitivity	Specificity	PPV	NPV	Accuracy
Panoramic radiography	23	1	0	29	1,0	0,03	0,44	1,0	0,45
CBCT	22	7	1	23	0,96	0,23	0,49	0,88	0,55

TP, true positive; TN, true negative; FN, false negative; FP, false positive; PPV, positive predictive value; NPV, negative predictive value.

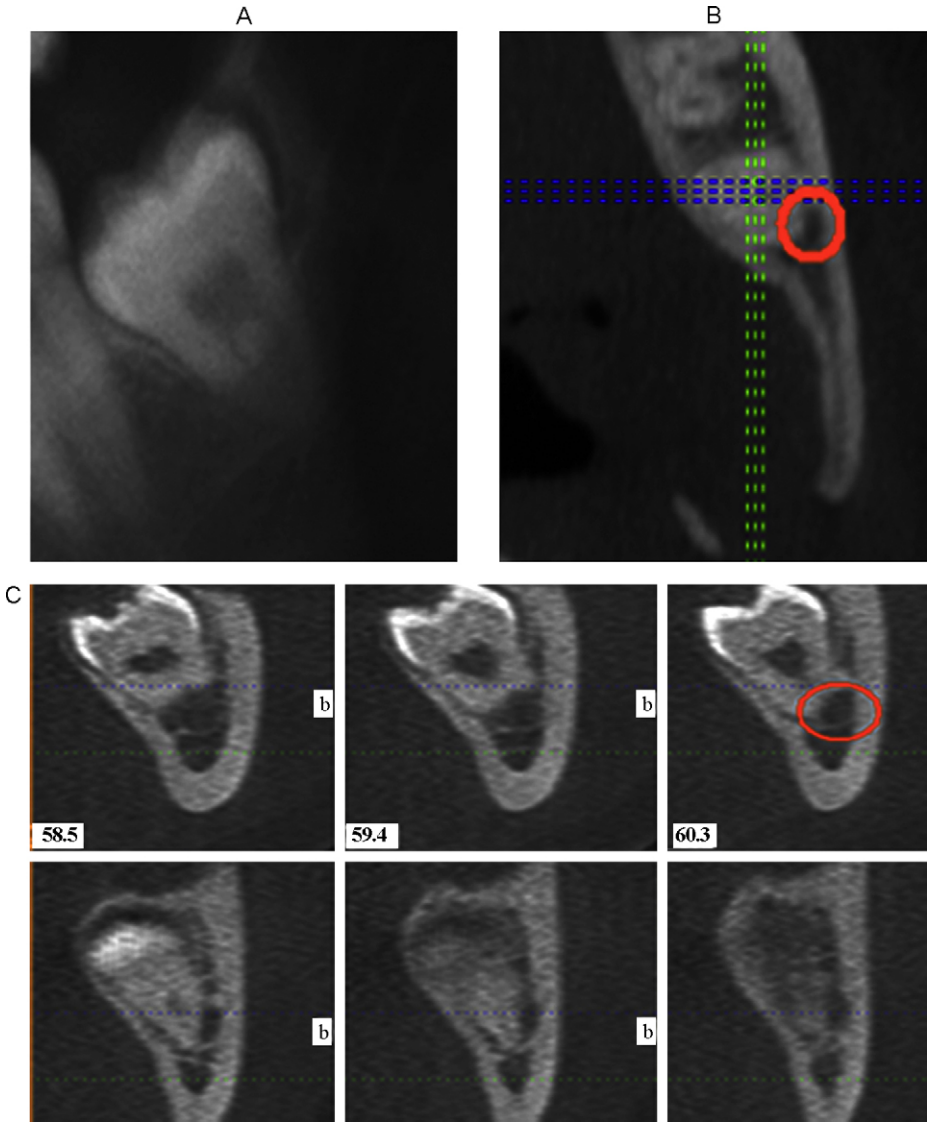

Fig. 2. Panoramic radiograph showing darkening of the roots and interruption of the white lines of the mandibular canal (A). Transverse (B) and coronal (C) CBCT images show a flattened mandibular canal between the root and buccal cortex with disappearance of the cortical layer of the mandibular canal. The IAN was exposed during removal as anticipated from the CBCT images.

panoramic radiographs, the CBCT is not significantly more accurate in predicting IAN exposure compared with panoramic radiographs. This is mainly because if these signs are present on the panoramic radiographs, the third molar root is in contact with the mandibular canal on the CBCT images as well. The association of one of these radiographic signs, interruption of the white line, with CBCT images is confirmed in a study by Nakagawa *et al.*[16] They concluded that in 86% of cases in which the superior white line of the mandibular canal was interrupted on panoramic radiographs, the CBCT images (PSR 9000, Asahi Roentgen) also showed contact between the third molar root and the mandibular canal. In the present study, the authors found a comparable high rate of 88%.

CBCT has a relative low accuracy in predicting IAN exposure in those highly selected cases where there is a close relationship between the mandibular canal and the third molar, however it is highly reliable in determining the bucco-lingual position of the mandibular canal with respect to the third molar. Tantanapornkul *et al.* also found a high inter-observer agreement in the assessment of the bucco-lingual position of the mandibular canal using the 3DX Accuitomo CBCT.

The mandibular canal was more often positioned lingually to the third molar root than buccally. This is in accordance with some studies using volumetric imaging[12,18,24], while others found more mandibular canals positioned buccally to the third molar root (Table 5)[10,11,14].

The position of the third molar in relation to the mandibular canal was a significant risk factor in the occurrence of IAN exposure. The IAN was more frequently exposed during third molar removal when the mandibular canal was positioned at the lingual side or interradicular to the third molar root rather than buccally. This result was in agreement with other studies[10].

To the authors' knowledge, this is the only study in which a significant association has been found between the position of the mandibular canal in relation to the third molar and the occurrence of IAN injury. Patients are at higher risk of IAN injury in cases where the mandibular canal is positioned lingually to the third molar root. This could be because the surgeon

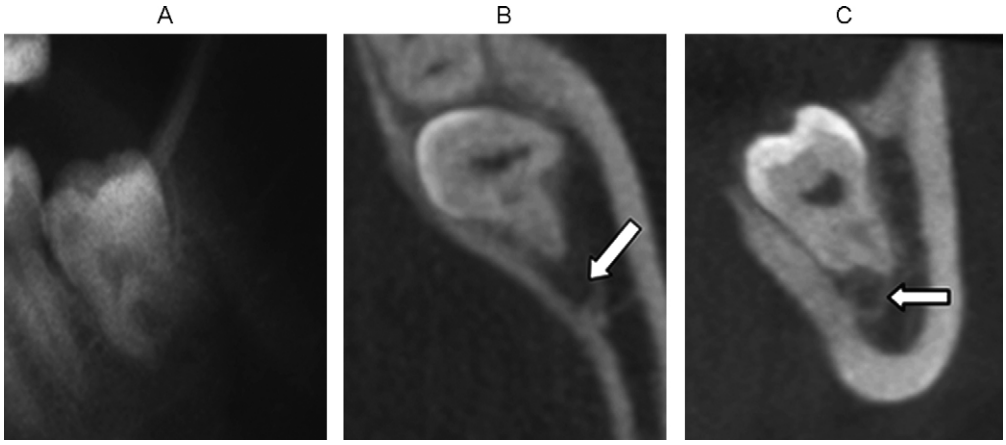

Fig. 3. Panoramic radiograph showing darkening of the distal root and interruption of the superior white line of the mandibular canal (A). Transverse (B) and coronal (C) CBCT images show the presence of bone tissue between the mandibular canal and third molar root (arrows). The neurovascular bundle was not exposed during removal as was expected from the CBCT images.

always starts his surgical approach, even in case of a lingually positioned IAN, at the buccal side of the wisdom tooth, generating unfavourable lingually directed forces.

Maegawa *et al*.[10] reported the same finding using medical CT, although their results were not significant. Howe and Poyton[6] reported that grooving of the tooth root mainly occurs at the lingual site, indicating a high risk of IAN injury. Ohman *et al*.[18] also found that in most teeth that showed grooving of the root on medical CT images, the mandibular canal was positioned lingually to the third molar root. In the present study, 4 patients had sensory impairment after exposure of the neurovascular bundle during third molar removal. In one case, the neurovascular bundle was damaged directly by the burr, due to a sudden movement by the patient. After reviewing the CBCT images of the other 3 patients, the authors found grooving of the tooth root at the lingual side in all cases (Fig. 4). These cases also showed the radiographic sign, darkening of the tooth root, on the panoramic radiographs. Other studies have corroborated the association between darkening of the third molar root on panoramic radiographs with grooving of the root[6,18] and IAN injury[6,7,21].

CBCT scanners produce a lower radiation dose than medical CT scanners. According to the European Guidelines on radiation protection in dental radiology[2], an effective dose in the range of 364–1200 μSv is provided by a medical CT scan of the mandible. The radiation dose of CBCT scanners depends on the apparatus used. According to Ludlow *et al*.,[9] the i-CAT produces an effective dose of approximately 135 μSv for a full field of view scan, which is in accordance with the data provided by the manufacturer. The same data give an effective dose of 32 μSv for a mandible i-CAT scan. With an approximate dose of 32 μSv for a mandible scan, the effective dose would be reduced by a factor 11–37 compared with a medical CT scan. The CBCT scan gives a higher radiation dose than conventional panoramic radiographs, which are in the range 4–30 μSv. A sectional panoramic view, capable of imaging the mandible alone, would reduce the dose even further. It is important to weigh up the potential benefits of using CBCT images against the risk of extra exposure to ionizing radiation.

The results of this study show that CBCT is not better than panoramic radiography in predicting IAN exposure in patients who are at high risk of IAN injury. CBCT images provide a reliable insight in the bucco-lingual relationship between the third molar root and the mandibular canal, which cannot be achieved with panoramic radiography. This information is important when planning and carrying out the surgical removal, to avoid subjecting the mandibular canal to pressure from movements of the roots or the careless use of burrs and elevators. Knowing the bucco-lingual position of the mandibular canal in relation to the third molar root is valuable because it identifies cases that are at higher risk of IAN injury: patients with a lingually positioned mandibular canal and grooving of the third molar root. In these cases the information could help to decide whether to extract the tooth or to provide a coronectomy[20] to prevent IAN injury. The patient can also be more adequately informed about his or her risk profile. In the authors' view, a CBCT image is specifically indicated when the panoramic radiograph shows that the apex of the third molar root touches or crosses the inferior border of the mandibular canal. Additional multicentre studies are required to determine cases in which panoramic radiographs are sufficient to prevent injury of the IAN or when additional CBCT imaging is needed.

Table 5. The bucco-lingual position of the mandibular canal with the third molar root as reported in the literature.

	no	Buccal	Lingual	Between roots	Inferior
Ghaeminia et al., 2009	53	17%	49%	15%	19%
Tantanapornkul *et al.* 2007	142	25%	26%	4%	45%
de Melo Albert *et al.* 2006	29	45%	48%		7%
Ohman *et al.* 2006	90	31%	33%	10%	26%
Monaco *et al.* 2004	73	25%	19%	5%	51%
Maegawa *et al.* 2003	47	51%	26%	4%	19%
Miller *et al.* 1990	31	45%	39%		16%

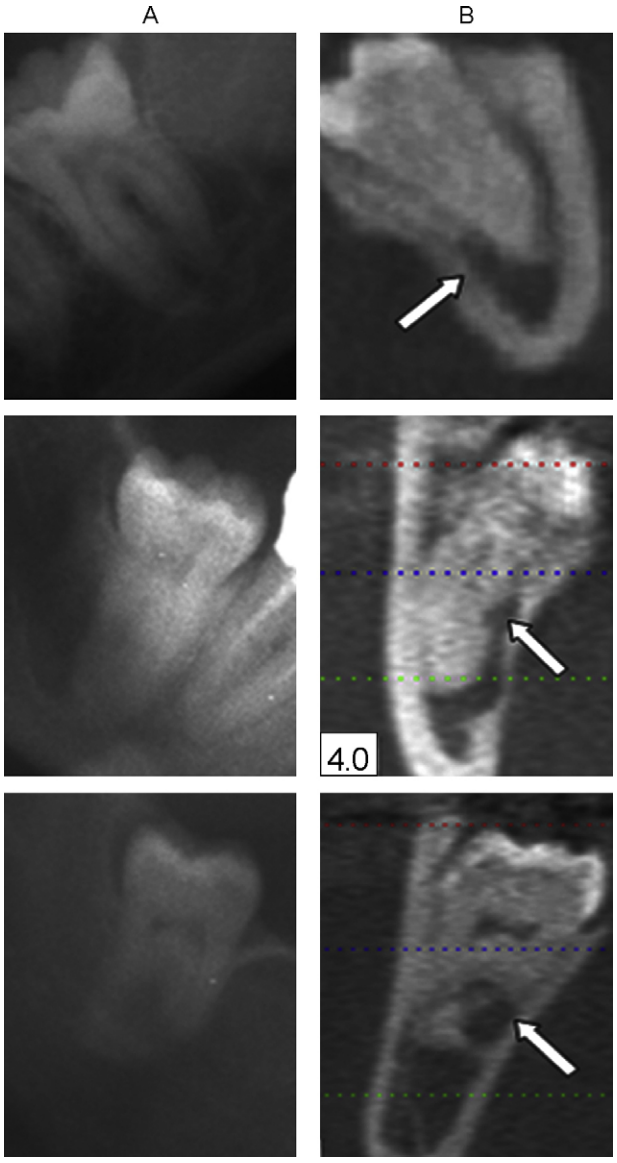

Fig. 4. Three cases are shown with darkening of the tooth root on panoramic radiographs (A). The corresponding coronal CBCT images show grooving of the tooth root (arrows) at the lingual side (B). In all these cases the IAN was exposed during surgery and postoperative sensory impairments occurred in all these patients. One patient continued to have some sensory impairment after 6 months.

Competing interests

None declared.

Funding

None

Ethical approval

Not required

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