RESEARCH

Correlation of panoramic radiography and cone beam CT findings in the assessment of the relationship between impacted mandibular third molars and the mandibular canal

F S Neves*, T C Souza, S M Almeida, F Haiter-Neto, D Q Freitas and F N Bóscolo

Department of Oral Diagnosis, Division of Oral Radiology, Piracicaba Dental School, State University of Campinas, Piracicaba, São Paulo, Brazil

Objectives: The aim of this study was to assess the reliability of four panoramic radiographic findings, both individually and in association, in predicting the absence of corticalization between the mandibular canal and the third molar on cone beam CT (CBCT) images.

Methods: The sample consisted of 72 individuals (142 mandibular third molars) who underwent pre-operative radiographic evaluation before extraction of impacted mandibular third molars. On panoramic radiographs, the most common signs of corticalization (darkening of roots, diversion of mandibular canal, narrowing of mandibular canal and interruption of white line) and the presence or absence of corticalization between the mandibular third molar and the mandibular canal on CBCT images were evaluated.

Results: Darkening of roots and interruption of white line associated with the absence of corticalization between the mandibular third molar and the mandibular canal on CBCT images were statistically significant, both as isolated findings ($p=0.0001$ and $p=0.0006$, respectively) and in association ($p=0.002$). No statistically significant association was observed for the other panoramic radiographic findings, either individually or in association ($p > 0.05$).

Conclusion: Darkening of roots and interruption of white line observed on panoramic radiographs, both as isolated findings and in association, were effective in determining the risk relationship between the tooth roots and the mandibular canal, requiring three-dimensional evaluation of the case.

Dentomaxillofacial Radiology (2012) **41**, 553–557. doi: 10.1259/dmfr/22263461

Keywords: third molar; inferior alveolar nerve; cone beam computed tomography; panoramic radiography

Introduction

Extraction of third molars is a routine procedure in maxillofacial surgery, whether for prophylactic or for orthodontic reasons. Usually there is little risk to adjacent structures, although in some cases there may be complications owing to the intimate relationship between the roots of the third molars and the mandibular canal and/or the mandibular lingual cortex.

Third molars have a high incidence of impaction associated with many conditions such as pericoronitis, caries on the distal surface of the second molar, pain,

external root resorption and odontogenic cysts or tumours.^{1,2} Difficulties in the eruption of the third molars, particularly in the mandible, are attributed to a lack of space caused by late formation and the phylogeny of the mandible.¹

An imaging exam is undoubtedly an essential tool for diagnosis and surgical management because it provides valuable information about the tooth position, the number/morphology of the roots and, especially, the relationship of the tooth to adjacent structures. Studies suggest that seven specific signs observed on panoramic radiograph (darkening of roots; deflection of roots; narrowing of roots; bifid root apex; diversion of canal; narrowing of canal; interruption in the white line of the canal) are reliable ways to assess the relationship between the third molar and the mandibular

*Correspondence to: Dr Frederico Sampaio Neves, Piracicaba Dental School, State University of Campinas, Department of Oral Diagnosis, Av. Limeira, 901, P.O. Box 52, 13414-903 Piracicaba, São Paulo, Brazil. E-mail: fredsampaio@yahoo.com.br

Received 4 September 2011; revised 24 September 2011; accepted 27 September 2011

canal.^{3,4} However, the presence or absence of these radiographic signs does not always determine the possibility of injury to the inferior alveolar nerve (IAN). This indicates that panoramic radiograph does not have a high diagnostic accuracy when used in the assessment of risk in surgical extractions of lower third molars.⁵

Cone beam CT (CBCT) is a radiographic method that has been used in several areas of dentistry because it shows three-dimensional (3D) images of dental structures in addition to providing clear structural images with high contrast. It is being used increasingly in many dental specialties, including orthodontics,^{6,7} orthognathic surgery^{8,9} and implant dentistry.¹⁰ Increasingly, CBCT is replacing medical CT because it provides adequate image quality associated with a lower exposure dose.^{11,12} Other advantages of CBCT are the low cost of the examination compared with CT, fast scanning time, lower number of artefacts and real-time image analysis.^{13,14}

The present study may provide information for maxillofacial surgeons who need to decide whether CBCT is required in addition to pre-operative panoramic radiography in mandibular third molar extractions. Therefore, the aim of this study was to assess the reliability of four panoramic radiographic signs, as both isolated findings and in association with each other, in predicting the absence of corticalization between the mandibular canal and the third molar on CBCT images.

Materials and methods

The present retrospective case-control study was carried out following approval of the FOP/UNICAMP Ethical Committee (057/2010), and informed consent was obtained from all volunteers. The sample consisted of 72 individuals (142 mandibular third molars) who underwent pre-operative radiographic evaluation before extraction of impacted mandibular third molars. Digital panoramic radiographs were obtained using an Orthopantomograph® OP100 D unit (Instrumentarium Corp., Imaging Division, Tuusula, Finland), operating at 66 kVp/2.5 mA and an exposure time of 17.6 s. 3D images were obtained using a Classic i-CAT CBCT unit (Imaging Sciences International, Inc., Hatfield, PA), operating at 120 kVp/8 mA, with a 0.25 mm voxel size and a field of view of 8 cm. Individuals with radiological evidence of intra-osseous pathologies (*e.g.* cysts or tumours) associated with the third molars were excluded from the study.

Panoramic radiography and CBCT images were evaluated independently by two radiologists with at least 2 years of experience in CBCT diagnosis, on a computer monitor (21 inch LCD monitor with 1280 × 1024 resolution), under dim lighting conditions. The images were evaluated with the use of the “zoom” tool and manipulation of brightness and contrast. Any disagreements were resolved subsequent to the initial observation, when each observer discussed his findings with the other in order to reach a final evaluation. After 30 days, 40 panoramic radiographs and CBCT images had been re-evaluated.

On the panoramic radiographs, the relationship between the mandibular third molar and the mandibular canal was evaluated according to the criteria established by Rood and Shehab.³ In the present study, we used the most common signs (darkening of roots, diversion of mandibular canal, narrowing of mandibular canal and interruption in white line) associated with a higher risk of IAN injury^{15–18} (Figure 1). On the CBCT images, the presence or absence of corticalization between the mandibular third molar and the mandibular canal was evaluated using cross-sectional images. Absence of corticalization was defined as a loss of cortical lining between the tooth root and the mandibular canal (Figure 2).

Data were analysed using BioEstat software v. 5.0 (Ayres Company, Pará, Brazil). The kappa statistic was used to calculate intra- and interobserver agreement (less than or equal to 0.40, poor agreement; 0.40–0.59, moderate agreement; 0.60–0.74, good agreement; 0.75–1.00, excellent agreement). Comparison between panoramic and CBCT findings was performed using Fisher’s exact test, with a significance level of $p < 0.05$.

Results

The sample was composed of 28 males (38.9%) and 44 females (61.1%); ages ranged between 18 and 39 years (mean 27.2 years). Statistically significant differences were not observed for gender or age ($p > 0.05$). The intra- and interobserver agreement kappa values for the panoramic radiographs were 0.77 (Observer 1: first vs second evaluation), 0.84 (Observer 2: first vs second evaluation) and 0.76 (first evaluation: Observer 1 vs Observer 2). For the CBCT images, the kappa values were 0.79 (Observer 1: first vs second evaluation), 0.86 (Observer 2: first vs second evaluation) and 0.82 (first evaluation: Observer 1 vs Observer 2). For both image modalities, the agreement was excellent.

Table 1 summarizes the panoramic and CBCT findings according to the relationship between the roots of the third molars and the mandibular canal. Only darkening of roots and interruption in white line, as both isolated findings ($p = 0.0001$ and $p = 0.0006$, respectively) and in association with each other ($p = 0.002$), demonstrated a statistically significant association with the absence of corticalization between the mandibular third molar and the mandibular canal in CBCT images. No statistically significant association was observed for the other panoramic radiographic signs, either as isolated findings or in association with each other ($p > 0.05$).

Discussion

An accurate radiographic diagnosis is essential to evaluate and predict the possible outcome related to

Figure 1 Cropped panoramic radiographs showing (a) darkening of roots, (b) diversion of mandibular canal, (c) narrowing of mandibular canal and (d) interruption in white line

the extraction of impacted third molars. Periapical radiography (obtained using the parallel technique), panoramic radiography and CT offer an increasing level of image definition and enable the maxillofacial surgeon to make a more accurate diagnosis.

In oral and maxillofacial surgery, panoramic radiography is a supplementary examination initially requested to assess impacted third molars and estimate the risk of IAN damage. However, this image modality has a distortion, so it does not always provide enough information to determine the actual risk level.

Several studies^{15,17–24} that evaluated the relationship between the mandibular canal and the third molar suggest pre-operative evaluation by CT when specific

signs are observed in panoramic radiography. In the present study, most panoramic radiographic signs were interruption of white line (20.4%) and darkening of roots (17.4%). These findings conform with those in other studies.^{5,16,17,21,25,26}

The anatomical proximity of the roots of the third molar and the mandibular canal can result in IAN injuries during the extraction of the third molars. To avoid this problem, many studies have proposed risk factors based on the findings of panoramic radiography.^{15,17–24} However, as a two-dimensional exam, it does not provide specific diagnostic information about the relationship between the third molar and the mandibular canal. Knowledge of this relationship

Figure 2 Cone beam CT cross-sectional images showing (a) presence and (b) absence of corticalization between the mandibular third molar and the mandibular canal

Table 1 Correlation between panoramic and CBCT findings

<i>Radiographic findings</i>	<i>Cases in panoramic radiography (n = 142)</i>	<i>Presence of corticalization in CBCT images (n = 142)</i>	<i>Absence of corticalization in CBCT images (n = 142)</i>	<i>p-value</i>
DR	25 (17.6)	6 (4.2)	19 (13.4)	0.0001
DMC	6 (4.2)	2 (1.4)	4 (2.8)	>0.05
NMC	5 (3.5)	4 (2.8)	1 (0.7)	>0.05
IWL	29 (20.4)	12 (8.5)	17 (12.0)	0.0006
DR + DMC	2 (1.4)	0 (0.0)	2 (1.4)	>0.05
DR + NMC	0 (0.0)	0 (0.0)	0 (0.0)	>0.05
DR + IWL	5 (3.5)	0 (0.0)	5 (3.5)	0.002
DMC + NMC	0 (0.0)	0 (0.0)	0 (0.0)	>0.05
DMC + IWL	2 (1.4)	0 (0.0)	2 (1.4)	>0.05
NMC + IWL	1 (0.7)	0 (0.0)	1 (0.7)	>0.05

CBCT, cone beam CT; DMC, diversion of mandibular canal; DR, darkening of roots; NMC, narrowing of mandibular canal; IWL, interruption in white line.

Values are given as number (percentage) unless otherwise indicated.

information allows for secure management in cases of severe impactions.

Several studies have demonstrated that the presence of two or more signs on a panoramic radiograph indicates an increased risk of IAN exposure^{15,18,20,24,27} or injury.^{5,16,19,24} However, comparison of CBCT findings with two panoramic radiographic signs in association has not been previously investigated. In the present study, darkening of roots and interruption in white line associated with the absence of corticalization between the mandibular third molar and the mandibular canal in CBCT images were statistically significant, as both isolated findings and in association with each other. In the study by Gomes *et al.*,⁵ no statistically significant association was observed between the presence of the seven panoramic radiographic signs and IAN paraesthesia after third molar extractions. However, Ghaemini *et al.*²⁷ observed that three panoramic radiographic signs (interruption of white line, darkening of roots and diversion of the mandibular canal) were significantly associated with IAN exposure. Clinical studies have demonstrated that the absence of corticalization between the tooth roots and the mandibular canal on spiral CT images¹⁵ and IAN exposure^{15,18} are significantly associated only with some panoramic radiographic signs—in particular, darkening of roots and interruption of white line. Szalma *et al.*¹⁶ identified three signs on panoramic radiograph that were significantly associated with IAN paraesthesia (interruption of white line, diversion of the mandibular canal and darkening of roots).

Monaco *et al.*²¹ determined the reliability of panoramic radiograph in evaluating the relationship between the mandibular canal and the roots of the third molar based on multidetector CT images. According to the authors, the 3D exam should be carried out when darkening of roots, narrowing of the mandibular canal and interruption of white line are observed on panoramic radiograph. In our results, we found that the

narrowing of the mandibular canal was not associated with higher risk of contact between the tooth roots and the mandibular canal, either as an isolated finding or in association with other panoramic radiographic signs, based on CBCT images.

In a few cases, darkening of the roots could be associated with thinning or perforation of the lingual cortical by the tooth roots, instead of being related to a “true contact” relationship between the mandibular canal and the tooth roots.^{22,28} In the present study, this relationship could not be assessed because the thinning or perforation of the lingual cortical by the tooth roots was not evaluated.

The results obtained in the present study corroborate with those of Nakagawa *et al.*,²⁹ in which absence of white line on panoramic radiograph was significantly associated with an increased risk of contact between the third molar and the mandibular canal on CBCT images; however, this relationship was not observed by Nakamori *et al.*²⁴

It has been observed that only 3D exams, *i.e.* CT^{15,17,22–24,26} and MRI,³⁰ are effective in determining the true relationship of the tooth roots and the mandibular canal. However, in view of the socioeconomic conditions of some developing countries, the high cost of those exams and the radiation dose (for CT only) makes the use of panoramic radiography clearly justified in the pre-operative evaluation in third molar surgery, despite the fact that its predictability is low with regards to the emergence of nerve lesions during the procedure.

In conclusion, panoramic radiography is an effective method for pre-operative assessment of mandibular third molars. Darkened roots and interruption of white line observed on panoramic radiographs, as both isolated findings and in association with each other, are effective in determining the risk relationship between the tooth roots and the mandibular canal, requiring 3D evaluation of the case.

References

1. Lysell L, Rohlin M. A study of indications used for removal of the mandibular third molar. *Int J Oral Maxillofac Surg* 1988; **17**: 161–164.
2. Marciani RD. Third molar removal: an overview of indications, imaging, evaluation, and assessment of risk. *Oral Maxillofac Surg Clin North Am* 2007; **19**: 1–13.

3. Rood JP, Shehab BAAN. The radiological prediction of inferior alveolar nerve injury during third molar surgery. *Br J Oral Maxillofac Surg* 1990; **28**: 20–25.
4. Blaeser BF, August MA, Donoff RB, Kaban LB, Dodson TB. Panoramic radiography risk factors for inferior alveolar nerve injury after third molar extraction. *J Oral Maxillofac Surg* 2003; **61**: 417–421.
5. Gomes AC, Vasconcelos BGE, Silva EDO, Caldas AF, Neto IVP. Sensitivity and specificity of pantomography to predict inferior alveolar nerve damage during extraction of impacted lower third molars. *J Oral Maxillofac Surg* 2008; **66**: 256–259.
6. Holberg C, Steinhäuser S, Geis P, Rudzki-Janson I. Cone-beam computed tomography in orthodontics: benefits and limitations. *J Orofac Orthop* 2005; **66**: 434–444.
7. Kau CH, Richmond S, Palomo JM, Hans MG. Three-dimensional cone beam computerized tomography in orthodontics. *J Orthod* 2005; **32**: 282–293.
8. Cevidanes LH, Bailey LJ, Tucker GR Jr, Styner MA, Mol A, Phillips CL, et al. Superimposition of 3D cone-beam CT models of orthognathic surgery patients. *Dentomaxillofac Radiol* 2005; **34**: 369–375.
9. Cevidanes LH, Bailey LJ, Tucker SF, Styner MA, Mol A, Phillips CL, et al. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. *Am J Orthod Dentofacial Orthop* 2007; **131**: 44–50.
10. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Invest* 2006; **10**: 1–7.
11. Suomalainen A, Kiljunen T, Käser Y, Peltola J, Kortensniemi M. Dosimetry and image quality of four dental cone beam computed tomography scanners compared with multislice computed tomography scanners. *Dentomaxillofac Radiol* 2009; **38**: 367–378.
12. Loubele M, Jacobs R, Maes F, Denis K, White S, Coudyzer W, et al. Image quality vs radiation dose of four cone beam computed tomography scanners. *Dentomaxillofac Radiol* 2008; **37**: 309–318.
13. Ziegler CM, Woertche R, Brief J, Hassfeld S. Clinical indications for digital volume tomography in oral and maxillofacial surgery. *Dentomaxillofac Radiol* 2002; **31**: 126–130.
14. Miracle AC, Mukherji SK. Cone beam CT of the head and neck, part 1: physical principles. *AJNR Am J Neuroradiol* 2009; **30**: 1088–1095.
15. Jhamb A, Dolas R, Pandilwar P, Mohanty S. Comparative efficacy of spiral computed tomography and orthopantomography in preoperative detection of relation of inferior alveolar neurovascular bundle to the impacted mandibular third molar. *J Oral Maxillofac Surg* 2009; **67**: 58–66.
16. Szalma J, Lempel E, Jeges S, Szabó G, Olasz L. The prognostic value of panoramic radiography of inferior alveolar nerve damage after mandibular third molar removal: retrospective study of 400 cases. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **109**: 294–302.
17. Khan I, Rajshekhar H, Grade P, Grade KS. Correlation of panoramic radiographs and spiral CT scan in the preoperative assessment of intimacy of the inferior alveolar nerve canal to impacted mandibular third molars. *J Craniofac Surg* 2011; **22**: 566–570.
18. Szalma J, Lempel E, Jeges S, Olasz L. Darkening of third molar roots: panoramic radiographic associations with inferior alveolar nerve exposure. *J Oral Maxillofac Surg* 2011; **69**: 1544–1549.
19. Blaeser BF, August MA, Donoff RB, Kaban LB, Dodson TB. Panoramic radiographic risk factors for inferior alveolar nerve injury after third molar extraction. *J Oral Maxillofac Surg* 2003; **61**: 417–421.
20. Bell GW. Use of dental panoramic tomographs to predict the relation between mandibular third molar teeth and the inferior alveolar. Radiological and surgical findings, and clinical outcome. *Br J Oral Maxillofac Surg* 2004; **42**: 21–27.
21. Monaco G, Montecvecchi M, Bonetti GA, Gatto MR, Checchi L. Reliability of panoramic radiography in evaluating the topographic relationship between the mandibular canal and impacted third molars. *J Am Dent Assoc* 2004; **135**: 312–318.
22. Mahasantipiya PM, Savage NW, Monsour PAJ, Wilson RJ. Narrowing of the dental canal in relation to the lower third molars. *Dentomaxillofac Radiol* 2005; **34**: 154–163.
23. Öhman A, Kivijarvi K, Blomback U, Flygare L. Pre-operative radiographic evaluation of lower third molars with computed tomography. *Dentomaxillofac Radiol* 2006; **35**: 30–35.
24. Nakamori K, Fujiwara K, Miyazaki A, Tomihara K, Tsuji M, Nakai M, et al. Clinical assessment of the relationship between the third molar and the inferior alveolar canal using panoramic images and computed tomography. *J Oral Maxillofac Surg* 2008; **66**: 2308–2313.
25. Jerjes W, El-Maaytah M, Swinson B, Upile T, Thompson G, Gittelmon S, et al. Inferior alveolar nerve injury and surgical difficulty prediction in third molar surgery: the role of dental panoramic tomography. *J Clin Dent* 2006; **17**: 122–130.
26. Tantanapornkul W, Okochi K, Fujiwara Y, Yamashiro M, Maruoka Y, Ohbayashi N, et al. A comparative study of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **103**: 253–259.
27. Ghaeminia H, Meijer GJ, Soehardi A, Borstlap WA, Mulder J, Bergé SJ. Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography. *Int J Oral Maxillofac Surg* 2009; **38**: 964–971.
28. Tantanapornkul W, Okochi K, Bhakdinaronk A, Ohbayashi N, Kurabayashi T. Correlation of darkening of impacted mandibular third molar root on digital panoramic images with cone beam computed tomography findings. *Dentomaxillofac Radiol* 2009; **38**: 11–16.
29. Nakagawa Y, Ishii H, Nomura Y, Watanabe NY, Hoshida D, Kobayashi K, et al. Third molar position: reliability of panoramic radiography. *J Oral Maxillofac Surg* 2007; **65**: 1303–1308.
30. Ferreti F, Malventi M, Malasoma R. Dental magnetic resonance imaging: study of impacted third molars. *Dentomaxillofac Radiol* 2009; **38**: 387–392.