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ORIGINAL ARTICLE

Risk assessment of inferior alveolar neurovascular bundle by multidetector computed tomography in extractions of third molars

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Abstract
Purpose This study aimed to assess the reliability of multidetector computed tomography (MDCT) in determining the surgical risk of the inferior alveolar neurovascular bundle in extractions of third molars.
Methods The sample comprised thirty-three individuals (63 third molars) who underwent preoperative evaluation by MDCT before extraction of impacted mandibular third molars. MDCT was used to determine the relationship between the roots of the third molars and the mandibular canal, and the course of the mandibular canal. Inferior alveolar nerve (IAN) exposure and the presence of hemorrhage were analyzed after removal of the teeth. IAN neurosensory deficit was recorded after 7 days. Clinical and MDCT findings were compared using Fisher's exact test ($P < 0.05$).
Results There was a statistically significant association between IAN exposure and the tomographic relationship between the roots of third molars and the mandibular canal ($P = 0.015$). Conventionally, all cases of IAN neurosensory deficit and hemorrhage occurred when the roots of the third molar presented in an at-risk relationship with the mandibular canal, however, this association was not statistically significant ($P > 0.05$). A statistically significant association was found between the lingual course of the mandibular canal and IAN exposure ($P = 0.03$).
Conclusions MDCT is an effective tool for determination of the surgical risk to the inferior alveolar neurovascular bundle in extraction of mandibular third molars.

Keywords Mandibular canal · Third molar · Computed tomography · Inferior alveolar nerve

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Introduction

Extraction of third molars is a routine procedure in maxillofacial surgery, whether for prophylactic or orthodontic reasons. Usually there is few risk to adjacent structures, though in some cases there may be complications because of the intimate relationship between the roots of the third molar and the mandibular canal and/or 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 cysts or odontogenic tumors [15, 18]. Difficulties in the eruption of third molars, particularly mandibular, are attributed to late formation and the phylogeny of the mandible, which result in lack of space for normal eruption [15].

Several postoperative complications can arise after extraction of third molars. The most common are alveolar osteitis (2.7–6.3 %) [3, 8, 13], acute or chronic infection (2.2–3.7 %) [3, 10], inferior alveolar nerve (IAN) (0.35–8.4 %) [3, 4, 6, 9, 13, 30] and lingual nerve (0.1–5.7 %)

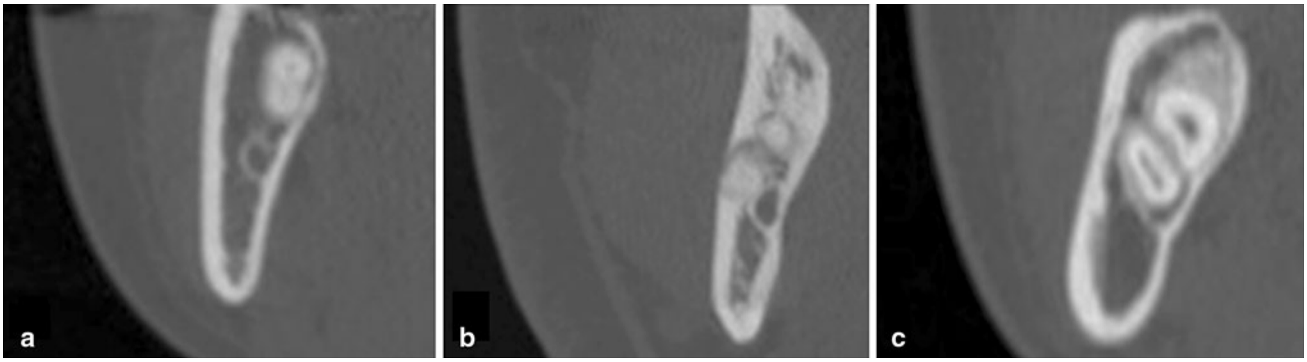

Fig. 1 MDCT images showing the relationship between the roots of third molars and the mandibular canal: **a** absence, **b** proximity and **c** at-risk

[4, 6, 9, 13, 30] paresthesia. In most cases, IAN paresthesia is temporary and recovers within 6 months, but it may be permanent and lead to functional and aesthetic problems [30].

Imaging is an essential tool for diagnosis and surgical management, because it provides valuable information about the position of the tooth, the number/morphology of the roots and especially the relationship with the mandible and the anatomic structures. Studies suggest that seven specific signs observed in the panoramic radiograph (e.g. darkening of roots, deflection of roots, narrowing of roots, bifid root apex, diversion of canal, narrowing of canal, interruption in white line of canal) are reliable in assessing the relationship between third molars and the mandibular canal [2, 25]. However, the presence or absence of these radiographic signs does not always determine the possibility of injury to the IAN, indicating that the panoramic radiograph does not have high diagnostic accuracy in the assessment of risk in surgical extractions of lower third molars [1, 5].

Multidetector computed tomography (MDCT) is considered one of the most valuable imaging modalities for preoperative procedures, because it allows the acquisition of fast, reliable and reproducible images. Each slice can be viewed individually in the three planes (axial, coronal, sagittal), and overlapping of surrounding anatomical structures can be eliminated. Other advantages, such as the possibility of three-dimensional reconstruction of the evaluated structure and optimal contrast resolution, allow differentiation between tissues, so that the information obtained is utilized more efficiently compared with conventional radiographic techniques [26]. Computed tomography was for a long time considered a high-dose technique, but with the development of MDCT and low-dose protocols tailored for the diagnostic task, doses below 0.15 mSv are achievable [12]. Only a few studies have compared MDCT and clinical findings after extraction of lower third molars [11, 22, 27], therefore the aim of this study was to assess the reliability of MDCT in determining the surgical risk of the inferior alveolar neurovascular bundle in extractions of third molars.

Materials and methods

This study was carried out with the approval of the FOP/UNICAMP Ethical Committee (127/2009) and informed consent was obtained from all individuals. The study population was composed of all patients presented to the private radiological center (Salvador, Bahia, Brazil) for evaluation and management of lower third molars between June 2009 and November 2010. The sample consisted of 33 individuals (63 third molars) who underwent preoperative evaluation by computed tomography before extraction of impacted mandibular third molars, as requested by the maxillofacial surgeon, when the third molar was superposed with the mandibular canal. Individuals who had radiological evidence of intraosseous pathologies (cysts or tumors) associated with the third molars, or who had any loss of sensation in the facial region before the surgical procedure were excluded from the study. All subjects were informed of possible complications due to the third molar surgery.

The tomographic images were obtained using a multidetector helical computed tomography unit (CT Helical Synergy, General Electric Company, Milwaukee, WI, USA). The examination was performed with the patient in supine position (slice thickness 0.625 mm and increment of 0.625 mm, field of view of 15.8 cm, bone window, 120 kV and 200 mA). Each examination was evaluated on a workstation (21 inch LCD monitor with 1,280 × 1,024 resolution), under dim light conditions, by 2 radiologists with more than 10 years of experience in computed tomography. The images were evaluated in all the three planes, with the possibility of manipulating the brightness and contrast. When there was a disagreement between the two observers, consensus was reached by discussion.

In the tomographic images, the relationship between the roots of third molars and the mandibular canal was determined according to the following classification:

1. Absence of relationship: tooth roots clearly separated from the mandibular canal (Fig. 1a).

Table 1 Weighted kappa values according the MDCT findings

MDCT findings	Weighted kappa	*P* value	95 % CI	Agreement
Relationship between third molar and mandibular canal	0.65	<0.0001	0.4743–0.8334	Good
Course of the mandibular canal	0.79	<0.0001	0.6807–0.9065	Excellent

CI confidence interval

2. Proximity relationship: the lamina dura of the roots and the mandibular cortex were indistinct, without restricting mandibular canal space (Fig. 1b).
3. At-risk relationship: the tooth roots invade and restrict the mandibular canal space (Fig. 1c).

In addition, the course of the mandibular canal in relation to the roots of the third molar was classified as buccal, lingual, inferior or interradicular on MDCT images.

After the MDCT examination, the surgical procedure (by five maxillofacial surgeons) consisted of local anesthesia, incision of soft tissue, bone exposure and tooth removal. Ostectomy and tooth section were used in all cases of an at-risk relationship based on the MDCT images. After tooth removal, direct inspection of the alveolus was performed and classified as:

1. Visualization of the alveolus floor impossible.
2. Visualization of the alveolus floor, without IAN exposure.
3. Visualization of the alveolus floor, with IAN exposure.

In addition, the presence of hemorrhage due to injury in the inferior alveolar artery and/or vein was evaluated. Following the protocol used by Poort et al. [24] for extraction of third molars, the occurrence of IAN neurosensory deficit was recorded after 7 days, by asking the patient about the presence of tingling or numbness in the lip and chin. If the individual reported the presence of altered sensation, objective assessment was performed by response to a light touch with a finger and direct sense by stroking lightly with a probe. Such cases were clinically followed for 6 months. No cases of permanent neurosensory deficit occurred.

Data were analyzed using SAS software 9.1 (SAS Institute, Cary, NC, USA). The weighted kappa statistic was used to calculate interobserver agreement (0.40, poor agreement; 0.40–0.59, moderate agreement; 0.60–0.74, good agreement; 0.75–1.00, excellent agreement). Comparison between clinical and MDCT findings was performed using the Fisher's exact test, with $P < 0.05$.

Results

The sample was composed of 14 males (42.4 %) and 19 females (57.6 %) and the age ranged from 16 to 55 years (mean 26.4 years). For the two variables ("Relationship between third molar and mandibular canal" and "Course of the mandibular canal") analyzed in MDCT images, weighted kappa values of 0.65 and 0.79 were obtained, showing a good and excellent interobserver agreement, respectively (Table 1).

Table 2 summarizes the clinical findings according to the relationship between the roots of the third molars and the mandibular canal. In 20 cases, the alveolus floor could not be visualized. Regarding the exposure of the IAN, in 29 cases the IAN was not exposed and the IAN was exposed in 14 cases. The relationship between the roots of the third molars and the mandibular canal was classified as absent in 4 cases (6.4 %), proximity in 7 cases (11.1 %) and at-risk in 52 cases (82.5 %).

In all 14 cases where IAN was exposed during surgery, the preoperative assessment by MDCT images classified the relationship between the roots of the third molars and the mandibular canal as at-risk. There was a statistically significant relationship between IAN exposure and the relationship between the roots of the third molars and the mandibular canal ($P = 0.015$) (Table 2).

IAN neurosensory deficit and hemorrhage occurred in 6 cases (9.5 %) and 5 cases (7.9 %), respectively. The presence of hemorrhage was recorded in two cases, simultaneous with IAN neurosensory deficit. There was no statistically significant association between IAN neurosensory deficit and hemorrhage when compared with the relationship between roots of the third molars and the mandibular canal ($P > 0.05$). However, in all cases the roots of the third molars were in an at-risk relationship with the mandibular canal (Table 2).

Table 3 shows that the interradicular course of the mandibular canal was more common (23 cases) followed by a lingual course (22 cases). Most of the cases of hemorrhage (4 cases) and IAN neurosensory deficit (5 cases) occurred when the course of the mandibular canal was lingual to the third molar. In such cases, a statistically significant association was observed with IAN exposure ($P = 0.03$).

Discussion

In oral and maxillofacial surgery, panoramic radiography is the supplementary examination initially requested to assess impacted third molars and estimate the risk of damage to

Table 2 Association between the clinical findings during surgery and the relationship between the third molar and mandibular canal on preoperative MDCT imaging

	Absence of relationship, *n* (%)	Proximity relationship, *n* (%)	At-risk relationship, *n* (%)	Total, *n* (%)	*P* value
IAN exposure					0.015
Impossible to visualize the alveolus floor	1 (5)	0 (0)	19 (95)	20 (31.8)	
IAN not exposed	3 (10.4)	7 (24.1)	19 (65.5)	29 (46)	
IAN exposed	0 (0)	0 (0)	14 (100)	14 (22.2)	
Hemorrhage					>0.005
Absence	4 (6.9)	7 (12.1)	47 (81)	58 (92.1)	
Presence	0 (0)	0 (0)	5 (100)	5 (7.9)	
IAN neurosensory deficit					>0.005
Absence	4 (7)	7 (12.3)	46 (80.7)	57 (90.5)	
Presence	0 (0)	0 (0)	6 (100)	6 (9.5)	
Total, *n* (%)	4 (6.4)	7 (11.1)	52 (82.5)	63 (100)	

Table 3 Association between the operative complications during surgery and the course of the mandibular canal on preoperative MDCT imaging

	Buccal, *n* (%)	Lingual, *n* (%)	Inferior, *n* (%)	Interradicular, *n* (%)	Total, *n* (%)	*P* value
IAN exposure						0.03
Impossible to visualize the alveolus floor	4 (20)	7 (35)	3 (15)	6 (30)	20 (31.8)	
IAN not exposed	3 (10.4)	7 (24.1)	3 (10.4)	16 (55.1)	29 (46)	
IAN exposed	1 (7.1)	8 (57.2)	4 (28.6)	1 (7.1)	14 (22.2)	
Hemorrhage						>0.005
Absence	7 (12.1)	18 (31)	10 (17.3)	23 (39.6)	58 (92.1)	
Presence	1 (20)	4 (80)	0 (0)	0 (0)	5 (7.9)	
IAN neurosensory deficit						>0.005
Absence	8 (14)	17 (29.8)	10 (17.6)	22 (38.6)	57 (90.5)	
Presence	0 (0)	5 (83.3)	0 (0)	1 (16.7)	6 (9.5)	
Total, *n* (%)	8 (12.7)	22 (34.9)	10 (15.9)	23 (36.5)	63 (100)	

the IAN. When specific signs are detected, computed tomography is recommended for tridimensional evaluation [28] to assess the relationship of the third molars with anatomical structures, specially the maxillary sinus and mandibular canal, and provide a higher operative safety [2, 8, 21].

The anatomical proximity of the roots of the third molar and the mandibular canal can result in injuries to the IAN during extraction of the third molars. To avoid this problem, many studies have proposed risk factors based on the findings on panoramic radiographs [1, 5, 8, 10, 25], however, because radiographs are two dimensional, this does not provide specific diagnostic information about the anatomical relationship between the third molar and the mandibular canal.

Studies on the relationship between IAN exposure and the computed tomography findings have been proposed. Maegawa et al. [16] evaluated the correlation between the cortical integrity of the mandibular canal in the tomographic images and IAN exposure after the extraction of the third molar. In the MDCT images, the roots were seen in direct contact with the mandibular canal as observed by the loss of cortical integrity of the mandibular canal. IAN exposure occurred in 7 of 47 cases in which there was direct contact between the third molar roots and the mandibular canal.

Other studies, using cone beam computed tomography [20, 28] and MDCT [12, 27], reported a significant relationship between the roots of third molars and the mandibular canal and IAN exposure during the surgical procedure. The results observed in the present study are similar to the literature. Fourteen cases of IAN exposure were found, and in all cases the roots of the third molar presented in an at-risk relationship with the mandibular canal.

Direct exposure of the neurovascular bundle and/or contact between the tooth roots of the third molar and the mandibular canal based on tomographic images increase the incidence of IAN injuries in approximately 20 % [29]. However, this relationship is more often observed than the occurrence of IAN neurosensory deficit [16, 20, 28]. In this study, the roots of the third molars presented in an at-risk relationship with the mandibular canal in 52 cases, however, only 6 (11.5 %) progressed to IAN neurosensory deficit. Because cases of postoperative IAN neurosensory deficit are attributed to exposure of the IAN, we believe that the integrity of the mandibular canal cortex, based on MDCT images, can be a valuable indicator for the prognosis of IAN injuries.

According to Park et al. [22], if there is contact between the third molar and the mandibular canal but the cortex remains intact, there is a higher chance of IAN injury, due to destruction of the mandibular canal cortex by the forces or movements during extraction. However, according to our findings, in the cases which the roots of the third molar presented in proximity relationship with the mandibular canal, was not registered IAN exposure, IAN neurosensory deficit or hemorrhage.

Identification of the IAN can often be difficult due to factors such as the position of the tooth, deepness of the roots or hemorrhage, which prevents direct inspection within the alveolus floor, which was observed in the present study in 31.8 % of the sample.

Evaluating the relationship between the IAN neurosensory deficit and the integrity of the mandibular canal cortex in the MDCT images, it was observed that the occurrence of IAN neurosensory deficit was associated when the relationship between the roots of the third molar and the mandibular canal was classified as at-risk. These results corroborate with those of Nakamori et al. [19] and Park et al. [22]. Therefore, the information provided by MDCT is a good marker of the risks involving the surgical removal of third molars.

Several studies have suggested that the inferior position of the mandibular canal in relation to the third molar is the most common [17, 20, 28]. Lübbers et al. [14] found a higher prevalence of a buccal course of the mandibular canal. However, in agreement with other studies [6, 7, 20, 21], our findings show that an interradicular and lingual courses are the most common positions of the mandibular canal.

In the present study a statistically significant association was observed between the course of the mandibular canal and IAN exposure ($P = 0.03$), with most cases of IAN exposure occurring when the mandibular canal was located lingually (57.2 %). These results were also observed in other studies [6, 20, 21].

In the present study, only five cases of hemorrhage were found. However, there was no statistically significant association with MDCT findings. Nevertheless, it was observed that hemorrhage occurred when the relationship between the third molar and the mandibular canal was classified as at-risk (five cases) and the mandibular canal had a lingual course (four cases). Our findings are similar to those of Jhamb et al. [11], who evaluated 31 teeth and observed only 2 cases of hemorrhage; on which the CT images did not show integrity of the mandibular canal cortex.

Anatomically, the inferior alveolar vein is the most superior structure in the mandibular canal. After the extraction of a mandibular third molar, the presence of bleeding is a warning sign that the superior cortex of the mandible was breached, indicating damage to the alveolar inferior vein. More profuse hemorrhage usually indicates damage to the alveolar inferior artery, which has a lingual course in relation to the IAN [23].

In this study, most cases with clinical complications occurred when the mandibular canal had a lingual course. This relationship could be attributed to the fact that the surgeon invariably initiates the surgical approach on the buccal side, regardless of the course of the mandibular canal, to avoid injury to the lingual nerve. According to Ghaeminia et al. [7], when the surgeon knows that the IAN is positioned lingually, such injury can be prevented, for example, by luxating the crown in a lingual direction, thereby rotating the roots in the opposite direction from the mandibular canal.

In conclusion, MDCT is an effective tool for determination of the surgical risk to the inferior alveolar neurovascular bundle in extraction of mandibular third molars. The possibility of IAN neurosensory deficit and hemorrhage is higher if the MDCT images display an at-risk relationship between the roots of the third molar and the mandibular canal. The lingual course of the mandibular canal implies on an increased risk of IAN exposure.

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Conflict of interest The authors declare that they have no conflict of interest.

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