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ORIGINAL ARTICLE

Do anatomical variations of the mandibular canal pose an increased risk of inferior alveolar nerve injury after third molar removal?

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Abstract

Objectives The present study aimed to assess whether anatomical variations of the mandibular canal are associated with neurosensory disturbances of the inferior alveolar nerve (IAN) following mandibular third molar removal.

Methods Two observers compared the detection of third molar root-nerve relations and bifurcations of the mandibular canal on panoramic radiographs and CBCT images of 201 patients undergoing removal of 357 mandibular third molars. Potential neurosensory disturbances of the IAN were surveyed ten days after surgery. Fisher's Exact was performed to correlate presence of canal variations to postoperative neurosensory disturbances. Positive and negative predictive values (PPV, NPV) and likelihood ratios (LR +, LR–) were calculated.

Results Thirteen patients reported postoperative altered sensation of the lower lip, with 2 of them having mandibular canal bifurcations on the ipsilateral side of the injury. Fisher's Exact showed that the studied mandibular canal variations were not related to postoperative neurosensory disturbances. CBCT was superior in visualization of anatomical variations of the mandibular canal. Prevalence of bifurcations was 14% on CBCT and 7% on panoramic radiographs. In both imaging modalities and for all parameters, PPVs were low (0.04 – 0.06) and NPVs were high (0.92 – 0.98), with LR ranging around 1.

Conclusion In the present study, the assessed mandibular canal variations had limited predictive value for IAN neurosensory disturbances following third molar removal.

Clinical relevance While a close relation between the third molar and the mandibular canal remains a high risk factor, mandibular canal variations did not pose an increased risk of postoperative IAN injury after third molar removal.

Keywords Bifurcations · Inferior alveolar nerve · Mandibular canal · Retromolar canal · Third molar

Introduction

While third molar removal is one of the most commonly performed procedures by dentists and oral and maxillofacial surgeons, as with any type of surgery, peri- and postoperative complications can occur. One of the possible complications following mandibular third molar (M3) removal is damage to the inferior alveolar nerve (IAN), resulting in temporary or permanent disturbance in sensory function. These injuries translate as numbness (dys- or paresthesia) of the lower lip and chin or even complete loss of sensory function (anesthesia) [1]. Although in literature the reported incidence of (especially permanent) injuries of the IAN following third removal is comparatively rare, third molar removal is still the main cause of this trigeminal neuropathy [2–4]. Caution for risk factors of postoperative IAN injury is therefore vital, listed among which are surgeon's inexperience, age of the

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patient, surgical instruments causing direct injury, and most importantly, the anatomical relation of the third molar roots and the mandibular canal. This relation can be radiographically assessed using panoramic radiography (PAN), and in cases of suspected risk, additional cone-beam computed tomography (CBCT) imaging [4].

Another risk factor that is often disregarded in radiographic assessment is the presence of anatomical variations of the IAN, defined as bifurcations of the mandibular canal (BMC) (such as side branches and loops), and retromolar canals (RMC) [5–8]. Analysis of the contents of accessory canals showed that they contain a neurovascular bundle coming from the IAN [5, 9, 10]. Given this neurovascular content, anatomical variations of the mandibular canal might be of clinical relevance during dental procedures [9, 11–14]. However, little research has been done on the potential correlation between mandibular canal variations and the occurrence of postoperative IAN injury after third molar removal.

Therefore, the primary aim of the present study was to investigate a potential relation between mandibular canal variations and neurosensory disturbances of the IAN following mandibular third molar removal. As a subobjective, it was assessed whether CBCT enabled enhanced risk prediction in terms of IAN injury, as compared to PAN.

Materials and methods

Patients were selected from the M3BE database, a Belgian prospective epidemiological study in which patients undergoing third molar removal were followed up until 10 days postoperatively. The study was approved by the Ethics Committee Research of the University Hospitals of Leuven (Belgium) (B322201525552), and was carried out according to the ICH-GCP principles and the Declaration of Helsinki (2013). Patients had to be ≥ 18 years, undergoing mandibular third molar removal, and as part of diagnosis and surgical planning, PAN and CBCT images were acquired on the same day.

Two experienced oral radiologists evaluated the two sets of radiographs. PAN were acquired using the VistaPano S Ceph device (Dürr Dental, Bietigheim-Bissingen, Germany; kV 73, mA 11–12) and CBCT using the Newtom VGi evo (QR, Verona, Italy; voxel size 0.2, kV 110, mA 4–5, rotation 360°). Training sessions were organized prior to the start of the observations in which a random selection of radiographic images (PAN + CBCT) from the M3BE database were collectively examined. Exclusion criteria were: poor resolution or poor-quality images, supernumerary teeth, bone pathology associated with the third molar area (e.g. odontomas, tumors, and bone metabolism disease), and other lesions that could modify the path of the mandibular canal.

Four radiographic variables were evaluated:

- Third molar orientation: vertical, mesial, horizontal, distal or buccolingual;
- Close relation of third molar roots with the mandibular canal (M3-IAN; yes/no) based on the presence of Rood & Shehab markers (root darkening, deflection or narrowing; bifid root apex/apices; canal interruption, diversion or narrowing);
- Presence of bifurcations (BMC) of the mandibular canal (independent of width);
- Presence of retromolar canals (RMC).

The course of the BMC, when present, was further classified on CBCT into BMC in mandibular corpus (with or without confluence), BMC in mandibular ramus (with or without confluence) or RMC (BMC in retromolar area). The course of the RMC was further classified according to von Arx (2011): vertical (with or without accessory canal), oblique, or horizontal (with or without accessory canal) [7]. The anatomical variations were scored by means of a Likert five-point scale: (1) definitely present, (2) probably present, (3) uncertain, (4) probably absent, and (5) definitely absent, which was made binary for further analysis. Moreover, to be able to account potential nondetection of anatomical variations to the poor visibility of the mandibular canal on the images, the cortical borders of the canal were assessed as continuously visible, intermittently visible (interruption of one cortical border) or not visible (interruption of two cortical borders on PAN; and canal not traceable from mandibular foramen to mental foramen on CBCT).

After third molar removal, neurosensory disturbances were prospectively surveyed on day 10 postoperatively. Questions inquired after:

- Presence of altered sensation in the lower lip;
- On which side (left or right);
- Type: numbness, tingling, altered feeling upon touch, other;
- Constant or episodical nature of these symptoms.

Data were analyzed in MedCalc Statistical Software version 19.1.6 (MedCalc Software Ltd, Ostend, Belgium). Interobserver reliability was calculated using Cohen's kappa. The numbers of false positive and false negative observations on PAN were calculated, with CBCT considered as the reference standard. The relation between the presence of accessory canals and postoperative neurosensory disturbances of the IAN was checked using Fisher's Exact. Likewise, the effect of sex on the occurrence of anatomical variations and IAN neurosensory disturbances was assessed. P-values < 0.05 were considered significant. For each PAN and CBCT assessed parameter, the positive predictive value (PPV) for prediction of a postoperative neurosensory disturbances was calculated as true positives divided by the sum of true and false positives. This means the number of teeth with risk factor and postoperative neurosensory disturbance divided by the total number of teeth with risk factor. The negative predictive value (NPV) was calculated as true negatives divided by the sum of true and false negatives, meaning the number of teeth without postoperative neurosensory disturbance and without risk factor divided by the total number of teeth without risk factor.

To assess the odds that a neurosensory disturbance actually occurred if a given parameter was observed on PAN and/or CBCT, positive likelihood ratio (LR + = sensitivity/(1–specificity)) was calculated. To assess the likelihood of a patient reporting postoperative neurosensory disturbances when a priori diagnosed without a risk factor, the negative likelihood ratio was calculated (LR– = (1–sensitivity)/specificity). The higher LR +, the better the risk factor in estimating postoperative neuropathy, and the lower the LR–, the better absence of a risk factor rules out the neuropathy.

Results

Radiographic assessment and agreement PAN vs. CBCT

In total, 357 third molars were removed in 201 patients (83 males; 118 females; mean age 26.4 (± 8.6) years) during 226 surgeries. Accordingly, 357 hemimandibles were evaluated (181 left and 176 right). Hemimandibular prevalence of total BMC (including RMC) was 7.5% on PAN and 14.2% on CBCT ($n = 50$) (Table 1). Hemimandibular prevalence of RMC alone was 6.5% on PAN and 7.9% on CBCT ($n = 28$).

Detected canals were further classified according to their appearance on CBCT: 5 BMCs in corpus (1 with confluence, 4 without); 17 BMCs in ramus (2 with confluence, 15 without); and 28 RMCs (17 vertical, 7 oblique, and 4 horizontal). The visibility of the mandibular canal was compromised in 40.0% of the PAN images, with interruption of one cortical border in 34.5%, and interruption of two cortical borders in 5.5%. On CBCT, these numbers diminished to 29.7% and 0.6%, respectively.

The interobserver reliability was on average 0.73, with values ranging from 0.24 – 0.74 on PAN and 0.81 – 1 on CBCT. In particular, agreement was low for detection of mandibular canal variations on PAN (0.24).

False positive and false negative observations on PAN are displayed in Table 2. Values were low for M3-IAN relation, but were high for detection of anatomical variations. In total, 64.1% and 62.4% of BMC and RMC observations were falsely positive. On the other hand, 72.9% and 68.6% of BMC and RMC observations were falsely negative, meaning that they remained undetected on PAN (Fig. 1).

Table 1 Observations on panoramic radiographs and CBCT. ($n = 357$ hemimandibles)

	PAN		CBCT	
	N	%	N	%
Orientation				
Vertical	123	34.5	121	33.8
Mesial	184	51.4	189	52.8
Horizontal	40	11.1	44	12.2
Distal	10	2.7	1	0.3
Buccolingual	2	0.4	4	1.0
Relation M3 – IAN				
Yes	344	96.4	313	87.7
No	13	3.6	44	12.3
Bifurcations				
Yes	26	**7.5**	50	**14.2**
No	321	92.5	301	85.8
Retromolar canals				
Yes	23	**6.5**	28	**7.9**
No	329	93.5	325	92.1

PAN = panoramic radiography; *CBCT* = cone-beam computed tomography; *M3* = third molar; *IAN* = inferior alveolar nerve; Numbers for bifurcations and retromolar canals do not add up to $n = 357$ because of some unclear observations

Postoperative neurosensory disturbances in relation to the radiographic findings

Thirteen patients reported neurosensory disturbances in the lower lip on day 10 after surgery (4 right; 7 left; 2 bilateral), totaling 15 mandibular sides. Accordingly, the incidence of self-reported neurosensory disturbances in the lower lip was 6.5% of patients and 4.2% of hemimandibles. Numbness was reported 6 times, whereof 2 times in combination with tingling. One patient reported sole tingling and one patient experienced sensory disturbances upon touch. Six of these sensory disturbances were reported being of constant nature, 2 were episodical. In 5 patients, details on nature of the altered sensation were

Table 2 False positive and false negative detections on panoramic radiographs. 62.4% to 64.1% of the observed anatomical variations of the mandibular canal were falsely positive, and 68.6% to 72.9% of variations remained undetected (false negative)

	False positive	False negative
Relation M3 – IAN	35	3
%	10.1	1.0
Bifurcations	17	37
%	64.1	72.9
Retromolar canal	14	19
%	62.4	68.6

Fig. 1 Panoramic radiograph of a patient with a clear retromolar canal on the left side, confirmed by CBCT (circle close-up). The retromolar canal on the right side was less visible on the panoramic radiograph, but does show clearly on CBCT

Table 3 Positive and negative predictive values and likelihood ratios (between parentheses) of the assessed risk factors for suffering IAN injury after mandibular third molar removal

Predictive values for IAN injury for the risk factors assessed on		
	PAN	CBCT
Relation M3 – IAN		
PPV (LR +)	4% (0.97)	4% (1.07)
NPV (LR–)	92% (1.90)	98% (0.53)
Bifurcations		
PPV (LR +)	0% (0)	6% (1.43)
NPV (LR–)	95% (1.09)	96% (0.93)

PAN = panoramic radiography; *CBCT* = cone-beam computed tomography; *M3* = third molar; *IAN* = inferior alveolar nerve

missing. All 13 patients had a close relation of the third molar roots with the IAN. Two patients suffering postoperative neurosensory disturbances had an anatomical variation of the mandibular canal in the ipsilateral side of the injury (Fig. 2). Fisher's Exact showed that neither sex, nor anatomical variations of the mandibular canal were significantly associated with postoperative neurosensory disturbances of the IAN (sex $p = 0.786$; BMC $p = 0.438$; RMC $p = 0.616$). The effect of sex on the occurrence of variations was borderline significant for BMC ($p = 0.050$) with higher prevalence in men, but remained insignificant for RMC ($p = 0.251$).

To determine the predictive value of PAN and CBCT assessed parameters on the occurrence of postoperative IAN injury, PPVs and NPVs were calculated (Table 3). In both imaging modalities, PPVs were low (0 – 6%) and NPVs were high (92 – 98%). LR + were around 1 in both imaging modalities (PAN 0.97; CBCT 1.07). LR– ranged from 0.53 to 1.90.

Fig. 2 Panoramic radiograph (left) and CBCT image (right) of a patient presenting with postoperative neurosensory disturbances in the right lower lip and chin area. CBCT shows a retromolar canal in the ipsilateral side of the injury that remained undetected on the panoramic radiograph

Discussion

The present study aimed to assess the relation between mandibular canal variations and neurosensory disturbances following mandibular third molar removal. High heterogeneity exists among reported prevalence rates, with values for BMCs ranging from 2.0% to 8.3% on PAN, and 9.8% to 65% on CBCT [8, 15–17]. Similarly, reported ranges for RMCs are generally lower on PAN (3.1 – 5.8%) compared to CBCT (14.6 – 43.1%) [7, 12, 18, 19]. Lower prevalences for visualization of BMC and RMC on PAN, as compared with CBCT, were confirmed in the present study. Varying results among studies can be attributed due to a number of factors [5, 20]. Moreover, the imaging modality, exposure protocol and image quality are probably the most important contributors to these varying numbers. Prevalence of PAN-detected BMC range from 1% in earlier studies to 8% in later studies, due to improved quality of devices over time [16, 21]. With the 2D superposition of 3D facial structures, PAN images are obviously subject to effects of magnification distortion, superimposition of structures and patient positioning [12]. CBCT, on the other hand, is a 3D representation of the skull, providing an accurate and reliable visualization of anatomical structures, including location, shape, and relationship with adjacent structures [5, 22]. From the higher number of detected variations on CBCT ($n = 50$) and the low level of interrater agreement on PAN, we can conclude that CBCT was the most sensitive technique in detecting anatomical variations. In addition, PAN-based assessments resulted in high numbers of false positives and false negatives (Table 2). False positive assessments of BMCs on PAN might arise from the imprint of the mylohyoid nerve on the internal mandibular surface [17, 23]. Moreover, BMCs can remain undetected on PAN because of diminished corticalization of the mandibular canal in areas where bifurcations often occur. The results showed that the visibility of the mandibular canal was diminished in 40% of PAN images, which could have paved the way for false negative observations.

From the results in Table 2, we can conclude that Rood & Shehab's markers are reliable for determining presence of root-nerve relation, however, in selected cases, PAN leaves room for misinterpretation (10.1% false positive, 1.0% false negative), so that root-nerve relation can most precisely be evaluated on CBCT [24]. This is in line with other studies, and is the very reason why, in cases of suspected risk, preoperative protocols advocate additional CBCT assessment [1, 10, 19, 25]. Other parameters indicating elevated risk of neurosensory complications, but not included in the present study protocol, are the exact location of the IAN (buccal, lingual, and interradicular), aberrant root curvature and morphology, and horizontally positioned teeth [26].

The incidence of (temporary) neurosensory disturbances of the IAN (6.5% of patients; 4.2% of hemimandibles) fell within reported ranges (0.35 – 8%) [27, 28]. The results showed that the presence of anatomical variations of the mandibular canal was not significantly related to the occurrence of IAN injuries. Neither was there a distinct effect of sex on the occurrence of variations or IAN injuries. It is important to notice that patient outcomes were self-reported, and surveying might not be ideal for correctly assessing posttraumatic trigeminal neuropathies (PTTN). The method of measurement might influence the incidence, so a clinical diagnosis of PTTN could have resulted in lower numbers of PTTN [29]. However, since this study was performed on a subsample of the M3BE study, we had to adhere to its methodology. Moreover, in the current study special attention was given to the detection of RMCs. RMCs are the most frequently observed accessory canals in close proximity of the third molars, although an RMC lesion is not often related to a clinically relevant loss of sensitivity, especially not in the lower lip [6]. Yet, as hypoesthesia of the buccal gingiva in the lower molar region has been reported, it remains advocated to take retromolar canals cautiously into consideration when planning and performing mandibular third molar removal [6, 10].

To assess the diagnostic power of PAN and CBCT assessed variables on the occurrence of postoperative IAN injury, PPVs and NPVs were calculated (Table 3). In both modalities and for all parameters, PPVs were low (PAN 4%; CBCT 4 – 6%) and NPVs were high (PAN 92 – 95%; CBCT 95 – 98%). While the former means that only 4% to 6% of patients diagnosed with M3-IAN relation will develop PTTN, the latter means that in the absence of a root-nerve relation or anatomical variation, more than 9 out of 10 patients did not experience IAN neurosensory disturbances. LR + were generally higher in CBCT, compared to PAN, whereas the LR– were lower. This could point out a slightly better diagnostic value of CBCT-assessed parameters compared to PAN-assessed parameters. Still, the LRs ranged around 1 in both imaging modalities (Table 3), resulting in little to no practical significance for the prediction of PTTN. Exceptions were bifurcations detected on CBCT (LR + 1.43), indicating a slight increase in the odds of developing PTTN when a bifurcation was detected on CBCT; and M3-IAN relation in CBCT (LR– 0.53), indicating that absence of a M3-IAN relation in CBCT (slightly) reduced the odds of developing PTTN.

Nevertheless, evidence is mounting that preoperative CBCT imaging does not reduce the incidence of IAN neurosensory disturbances after third molar removal. While some put forward the better visualization of the mandibular canal, it is to date not proven that CBCT results in more accurate prediction of intraoperative IAN exposure, let alone reduces the prevalence of iatrogenic nerve damage [4, 5, 29]. The visibility of the mandibular canal depends on multiple factors, among which are age, location (premolar vs. molar region), morphology of the (superior) wall of the canal (cortical, trabecular, irregular), and bone conditions such as osteoporosis [30]. Consequently, 3D visualization by CBCT will not always improve the visibility of the canal and the detectability of its accessory branches. Moreover, it has been shown that the visibility of the mandibular canal (in CBCT) is lower in females than in males [31]. Yet, for the detection of anatomical variations of the canal, no sex effect was observed in the present study. A systematic review by Haas et al. (2016) summarizes clearly that most studies on mandibular canal variations showed no statistically significant difference based on sex or age [5].

Furthermore, Guerrero et al. (2012) demonstrated that use of CBCT does not show a significant reduction in postoperative complications compared to PAN [1]. Likewise, Matzen et al. (2019) concluded that preoperative CBCT assessment does not affect postoperative outcome in terms of IAN injuries [29]. Factors that do have an impact on the risk of IAN neurosensory disturbances are duration of the surgical intervention and surgical technique [3]. This does not detract from the fact that surgeons can precisely plan the procedure based on 3D data (buccolingual view and number and position of roots), eventually resulting in shorter surgical time, and reduced postoperative discomfort and risk of complications.

It is generally accepted that the experience of the surgeon could affect patient postoperative morbidity as well. Less experienced surgeons are more likely to have longer and more traumatic surgeries, which can result in higher rates of postoperative neurosensory disturbances [32, 33]. Other studies, however, have failed to reveal any correlation between the experience of the surgeon and postoperative nerve complications [34]. In the M3BE project, the effect of surgical inexperience was considered limited. Resident-treated patients showed a slightly higher incidence of IAN neurosensory disturbances, but the difference was statistically insignificant [35]. Overall, it remains challenging to clearly distinguish the effects of surgical performance (experience) or preoperative imaging (CBCT) on the occurrence of complications [3].

In the present study, CBCT was superior in visualization of anatomical variations of the mandibular canal, as compared to PAN. However, in both imaging modalities, the assessed anatomical variations had limited predictive value for IAN neurosensory disturbances following third molar removal. While a close relation between the third molar and the mandibular canal remains a high risk factor, canal variations did not pose an increased risk of postoperative IAN injury after mandibular third molar removal.

Declarations

Ethical approval The study was approved by the Medical Ethical Committee of the University Hospitals of Leuven (Belgium) (B322201525552). All procedures performed in this study, involving human participants, were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consent was obtained from all individual participants included in the study.

Competing interests The authors declare no competing interests.

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