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Original Article

Classification of impacted mandibular third molars using cone beam computed tomography based on neurological risks: N.R.C.

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Abstract – Introduction: Considering the close proximity of the third molar roots and the mandibular canal, also the location of the lingual nerve and its anatomic variations, both nerves may be injured during extraction. The aim of this observational study was to optimize a classification of the relationship between the third molar and its neuroanatomical environment, mandibular canal and lingual bone plate, which is inspired from the neurological risks involving cone beam CT (CBCT) images, and to apply this classification to our sample. **Materials and methods:** A retrospective, observational study was performed involving 100 CBCT (171 mandibular third molars). Two medical doctors, qualified in human anatomy, independently evaluated all CBCT using coronal oblique sections. The classification was approved by agreement between both observers. After that, it was applied to our sample by one of them. The SPSS software, version 21.0 (SPSS® Inc., Chicago, Illinois, USA) was used for the statistical analysis. **Results:** The final consensual classification presented three Classes (A, B, L) with their four subclasses (from 1 to 4). The rare cases found in our sample were grouped separately under the name of "uncommon", and were divided into four specific subclasses. The status of the lingual bone plate was assessed by the presence or the absence of a fenestration or a cortical thinning. In the current study, when the mandibular canal presented a direct contact with the third molar with a reduced calibre, lingual course was the most frequent anatomical situation in both genders (males 66.7%/ females 70.5%). There is not a significant correlation between the proximity of the third molar to the mandibular canal neither with age nor with gender. In contrast, the proximity to the third molar is significantly associated with the course of the canal. The highest significance was found with the lingual course. Statistical analysis showed a nonsignificant correlation between the status of the lingual bone plate and the age then the gender. **Discussion and conclusion:** The use of the proposed classification (NRC) could be a support for clinical practice. We suggested a common language among operators and during collaboration with radiologists in order to facilitate the clinical discussion and to correlate the surgery outcomes to the CBCT classes for more adjustment of the surgical procedures.

Introduction

An impacted tooth is defined as a tooth which is completely or partially unerupted. Due to its positioning facing another tooth, bone or soft tissue, its further eruption is implausible [1]. The surgical extraction of impacted third molars is a common procedure in oral surgery. However, several complications can occur postoperatively. It has been found that an impacted third molar extraction is the essential cause of permanent inferior alveolar nerve (IAN) sensory deficiency, overcoming both implants and orthognathic surgery as etiologic factors [2].

As a result of the close proximity of the third molar roots and the mandibular canal, the IAN may be injured during extraction; this could lead to a temporary or permanent numbness or hypoesthesia in the lower lip [3]. Jerjes *et al.* [4] concluded that the main factor in IAN injury is the surgeon's experience followed by the tooth status and the anatomical relationship between the mandibular third molar and the mandibular canal. The location of the lingual nerve, which lies in the soft tissues close to the lingual plate of the mandibular third molar socket, and its anatomic variations put the nerve at risk of damage [5]. Sensory deficits and taste disturbance may be present.

This complication occurs at 0.26–8.4% prevalence for IAN deficit and at 0.1–22% prevalence for lingual nerve deficit [6–9].

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Knowledge of the exact relationship between the third molar and the mandibular canal is a crucial factor since this data provides information about the regions where safe removal of bone should be carried out and the risk zones where appropriate care is essential [10].

The aim of this observational study was to announce a classification of the relationship between the third molar and its anatomical environment, mandibular canal and lingual bone plate, which is inspired from the neurological risks involving coronal oblique sections, and to apply this classification to our sample. This classification could be used in clinical practice as a shared language between radiologists and dental surgeons and among dental surgeons.

Materials and methods

A retrospective, observational study was performed involving 100 CBCT (171 mandibular third molars). The sample was collected from a private clinic of radiology, between 2015 and 2016. All the CBCT images were acquired with a CBCT unit GALILEOS Sirona comfort. Performance features are shown in Table I. All patients were candidates for a surgical procedure of lower third molars removal and the panoramic image was suggestive of a close relationship between the impacted tooth and the mandibular canal (Overlapping between both structures). Exclusion criterion was the presence of an osteolytic image related to the third molar.

Two medical doctors, qualified in human anatomy, independently evaluated all CBCT using coronal oblique sections. The section showing the closest relationship between third molar roots and mandibular canal was chosen for the classification. To assess the status of the lingual bone plate, a scanning of the sections was performed. Galileos viewer* software was used for scanning. The slice thickness of contiguous sections was 1 mm.

The classification was approved by agreement between both observers. They agreed that this classification has to obey to the following criteria helping surgeons to deal with the surgical approach, figuring all possible relationships between the two anatomical structures as well as the status of the lingual bone plate, predicting the risk of IAN injuries, reflecting all scientific knowledge regarding CBCT images signs that are correlated to an IAN lesion, and finally being easily learnable and usable.

The established classification was applied to our sample by one observer. After that, 30 CBCT were randomly chosen to be reassessed by the second observer to inspect the inter-observer concordance.

The present study was operated in agreement with the guidelines of the Helsinki Declaration.

Statistical analysis

In this study, all the classifications were carried out by the same observer. In order to evaluate the inter-observer agreement, in the whole classification, in classes, subclasses and the status of the lingual plate, a randomized subsample of 30 CBCT was selected and re-examined after a period of 4 weeks by the second observer. The Cohen's kappa test was used for this purpose.

Table I. Overview of the performance features of GALILEOS Sirona comforts unit.

Imaging volume	15.4 cm spherical imaging volume collimated 15 cm × 8.5 cm (UJ/lJ)
3D resolution: isotropic voxel size	0.25/0.125 mm
Scan time/exposure time	14 s/2–6 s
X-ray generator	
KV	98
MA	3–6
Effective dose	16–90 μSv (Ludlow)
(ICR P 2007)	Standard: 75 μSv
minimum space need (depth × width × height)	1.600 mm × 1.600 mm × 2.250 mm
Patient positioning	Standing/seated chin rest/bite block for head support and head fixation

The Student's *t*-test was used to assess the relationship between the status of the lingual bone plate and the age.

The Pearson's chi-square test was used to evaluate the association between the status of the lingual bone plate and the gender, then the correlation between the gender and the classes. The same test was also used to evaluate the correlation between the proximity of the mandibular canal to the third molar and the age, gender then classes.

Probability values of less than 0.05 were considered statistically significant.

The SPSS software, version 21.0 (SPSS® Inc., Chicago, Illinois, USA) was used for the statistical analysis.

Results

The sample consisted of 43 males and 57 females with ages ranging from 21 to 61 years.

The adopted classification

The final consensual classification in the buccolingual view was defined and detailed in Figures 1 and 2. To make our classification easily learnable and usable, we divided it into three Classes (A, B, L) (Fig. 1) with their four subclasses (from 1 to 4) (Fig. 2).

The rare cases found in the literature as well as in our sample were grouped separately under the name of "uncommon", and were divided into four specific subclasses (Table II).

The status of the lingual bone plate was assessed by the presence or the absence of a fenestration or a cortical thinning (index "F" mean the presence of a fenestration or thinning of the lingual bone plate) (Figs. 3 and 4).

In the subclasses, subclass 3 and subclass 4 were considered as "with proximity".

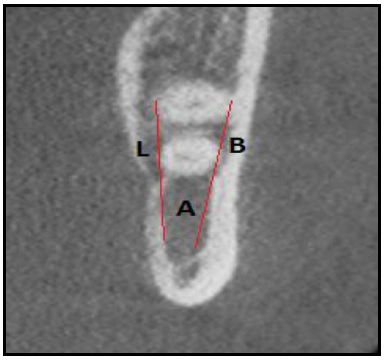
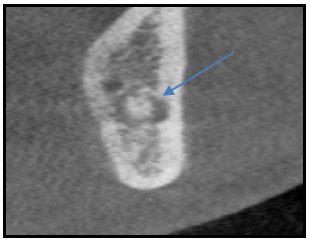
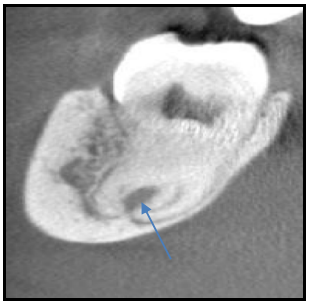


Fig. 1. Bucco-lingual position of mandibular canal regarding third molar roots on CBCT. Classes: A: Apical, B: Buccal, L: Lingual.

Table II. Uncommon class.

U1 The apex is totally surrounded by the cortical lining of the mandibular canal.	
U2 The mandibular canal runs between the roots with no close or fused apexes.	
U3 The mandibular canal runs between roots with close or fused apexes.	
U4 Plexiform canal: there is no discernible radiological canal.	

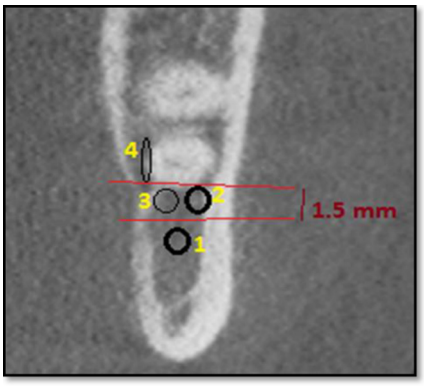


Fig. 2. Different situations and aspects of the mandibular canal: Subclasses. (1) The mandibular canal is distant more than 1.5 mm from the roots. (2) The mandibular canal is distant less than 1.5 mm from the roots with the total presence of its cortical lining. (3) The mandibular canal is distant less than 1.5 mm from the roots with total or partial loss of its cortical lining with preserved calibre. (4) Direct contact with a reduced calibre of the mandibular canal.

Statistical results

The study sample consisted of 171 impacted third molars (99 from women and 72 from men) from 100 patients (57 women and 43 men) with a mean age of 29.75 years (SD 8.762).

Tables III and IV show the distribution of the classes and subclasses in males and females. Class U is the less represented class in both genders (males: 2.8%/females: 12.1%). Subclass 4 has a limited representation in Class A, especially for males (2/9.5%).

When the mandibular canal runs lingually (Class L), the distance to the third molar is always less than 1.5 mm (no subclass 1), in both genders.

When the mandibular canal presented a direct contact with a reduced calibre (subclass 4), lingual course (Class L) was the most frequent anatomical situation in both genders (males 66.7%/females 70.5%).

Table V shows the distribution of the classes in male and female groups. The presence of Class U is significantly more frequent in the female group (p value = 0.002).

In the evaluation of the classes, subclasses and the status of the lingual bone plate on CBCT images, inter-observer reliability ranged from moderate to excellent (K value range: 0.598–0.967) (Tab. VI).

Statistical analysis showed a nonsignificant correlation between the status of the lingual bone plate and the age (Tab. VII) then the gender (Tab. VIII).

Tables IX and X show that there is not a significant correlation between the proximity to the mandibular canal neither with age nor with gender. In contrast, Table XI shows that the proximity to the mandibular canal is significantly associated with the classes, with the highest significance for Class L ($p < 0.001$).

Fig. 3. Fenestration of the lingual plate.

Fig. 4. Thinning of the lingual plate.

Table III. Distribution of classes and subclasses in males.

			Classes				Total
			B	A	L	U	
Subclasses	Subclass 1	Count	3	4	**0**	–	7
		% within Subclass	42.9%	57.1%	0%	–	100%
	Subclass 2	Count	5	10	1	–	16
		% within Subclass	31.3%	62.5%	6.3%	–	100%
	Subclass 3	Count	12	12	2	–	26
		% within Subclass	46.2%	46.2%	7.7%	–	100%
	Subclass 4	Count	5	**2**	**14**	–	21
		% within Subclass	23.8%	9.5%	**66.7%**	–	100%
	Class U	Count	–	–	–	2	2
		% within Subclass	–	–	–	–	–
Total		Count	25	28	17	2	72
		% within third molars of males	34.7%	**38.9%**	23.6%	**2.8%**	100%

Table IV. Distribution of classes and subclasses in females.

			Classes				Total
			B	A	L	U	
Subclasses	Subclass 1	Count	3	2	**0**	–	5
		% within Subclass	60.0%	40.0%	0.%	–	100%
	Subclass 2	Count	6	8	3	–	17
		% within Subclass	35.3%	47.1%	17.6%	–	100%
	Subclass 3	Count	2	17	2	–	21
		% within Subclass	9.5%	81.0%	9.5%	–	100%
	Subclass 4	Count	3	10	**31**	–	44
		% within Subclass	6.8%	22.7%	**70.5%**	–	100%
	Class U	Count	–	–	–	12	12
		% within Subclass	–	–	–	–	–
Total		Count	14	37	36	12	99
		% within third molars of females	14.1%	37.4%	36.4%	**12.1%**	100%

Table V. Distribution of classes according to gender.

			Class				Total
			B	A	L	U*	
Gender	F	Count	14	37	36	**12**	99
		% within gender	14.1%	37.4%	36.4%	12.1%	100%
	M	Count	25	28	17	**2**	72
		% within gender	34.7%	389%	23.6%	2.8%	100%
Total		Count	39	65	53	14	171
		% within total	22.8%	38%	31%	8.2%	100%

* *p* value = 0.002 (chi-square test).

Table VI. The Cohen *K* values for inter-observer agreement.

	Cohen *K* values	*p*
Entire classification	0.598	<0.001
Classes	0.967	
Subclasses	0.540	
Status of the lingual plate	0.816	

Table VIII. Correlation between the status of the lingual bone plate and gender.

	Without thinning or fenestration *N* = 129	With thinning or fenestration *N* = 42	Total	*p* value
Female	73 (73.7%)	26 (26.3%)	99 (100%)	0.545
Male	56 (77.8%)	16 (22.2%)	72 (100%)	

Table VII. Correlation between the status of the lingual bone plate and age.

	Without thinning or fenestration *N* = 129	With thinning or fenestration *N* = 42	*p* value
Age (mean ± SD)	28.2 (±6.7)	30.9 (±10.06)	0.115

Table IX. Correlation between the proximity to the mandibular canal (in Classes: A, B, and L) and age.

	Without proximity (subclasses 1 and 2) *N* = 45	With proximity (subclasses 3 and 4) *N* = 112	*p* value
Age	29.6 (±8.1)	28.7 (±7.8)	0.566

Table X. Correlation between the proximity to the mandibular canal (in Classes: A, B, and L) and gender.

	Without proximity (subclasses 1 and 2) *N* = 45	With proximity (subclasses 3 and 4) *N* = 112	*p* value
Female	22 (25.3%)	65 (74.7%)	0.297
Male	23 (32.9%)	47 (67.1%)	

Table XI. Correlation between the proximity to the mandibular canal (in Classes: A, B, and L) and classes.

			Without proximity (subclasses 1 and 2) *N* = 45	With proximity (subclasses 3 and 4) *N* = 112	Total	*p* value
Class	B	Count	17	22	39	0.041
		% included in class	43.6%	56.4%	100,0%	
	A	Count	24	41	65	0.016
		% included in class	36.9%	63.1%	100.,0%	
	L	Count	4	49	53	<0.001
		% included in class	7.5%	92.5%	100.,0%	
Total		Count	45	112	157	
		% included in class	28.7%	71.3%	100.0%	

Discussion

In order to limit the number of complications during mandibular third molar extraction, several classifications have been developed. The first classifications that were developed estimate the difficulty of the surgical procedure and aim to create an optimal treatment plan. The most popular are Winter's [11], Pell and Gregory's [12] and Peterson [13].

Since a preoperative evaluation of the exact relationship between the roots of the mandibular third molar and the IAN would aid in predicting, and potentially avoiding sensory impairment [14], newer classifications focusing on the relationship between the third molar and the mandibular canal have been presented [3,15–17]. The newer classifications have some drawbacks. In fact, they are a little blurry and they examined the general course of the mandibular canal not the closest relationship, given that the course of the mandibular canal in relation to the third molar could have various situations [17]. Moreover, these classifications do not present all the anatomical situations and they are adapted to the main objective of their studies. Therefore, they were oriented classifications. Consequently, our proposed classification evaluated the closest relationship and aimed at presenting all possible relations.

Panoramic radiographs are the initial tool for the assessment of this relationship. Due to the evidence that they only produce a two-dimensional image of a three-dimensional anatomical reality, it has been advocated that if the radiological marker on the panoramic radiographs indicates that there is a close relationship between the third molar and the mandibular canal, further probing using computed tomography scans is indicated. However, one of the drawbacks of conventional CT is the patient's exposition to a higher radiation dose [18–22].

CBCT seems to give an optimal, low-dose, 3D imaging modality to assist in resolving the complexities of the relationship between the two anatomical structures.

In contrast to the IAN damage, the lingual nerve injury cannot be predicted by preoperative panoramic radiography [23,24]. Coronal sections of CBCT could accurately alert us of the status of the lingual bone plate which protects the lingual nerve during third molar extraction. Consequently, the presence of a perforation or a thinning should be noted in our classification.

To the best of our knowledge, no previous studies have noted this factor in their classifications.

The knowledge of the canal course to the third molar can suggest the surgical approach and the entity of forces to apply during luxation, tooth sectioning or ostectomy. Xu *et al.* [3] found that IAN impairments increased if the third molar intersect with the mandibular canal, particularly on its buccal side. On the contrary, Ghaeminia *et al.* [25] observed that in all the patients with sensory impairments, the mandibular canal was positioned lingual to the third molar roots as seen on CBCT images ($p < 0.02$). This background justifies the legitimacy to define whether the course and the closest relationship are in the buccal, apical or in the lingual side (Classes: B, A, and L).

In the subclasses, we evaluated, in addition to the cortical lining, the distance between the mandibular canal and the third molar roots. It has been reported that the most evident risk factor for IAN injury is the proximity of the third molar root to the mandibular canal [25]. The risk increases dramatically when there is a contact between an impacted molar and the mandibular canal [26,27]. Sammartino *et al.* [28] proposed a safety distance from the mandibular canal of 1.5 mm during implant placement to avoid indirect lesions of the IAN. Consequently, a cut-off of 1.5 mm was chosen in our classification as a safety distance to differentiate the cases with higher risk of lesion (distance $<$1.5 mm) from those with a lesser one (distance $>$1.5 mm).

The difference between subclass 2 and 3 is the presence or the absence of the cortical lining. The cortication status of the mandibular canal are reliable predictors for IAN injury during third molar surgery. The cases exhibiting absence of cortication should be recognized as presenting a high risk of IAN injury during third molar removal [29]. According to Monaco *et al.* [30], the risk of the IAN injury increased from 1–5% to 20–30% average when a mandibular canal cortical perforation was observed.

Tantanapornkul *et al.* [31] found that the frequency of dysesthesia was significantly higher in cases of nerve exposure. In a similar study, Nakamori *et al.* [32] found that the loss of the cortication of the mandibular canal was an important factor in post extraction nerve damage. The findings of these studies are similar to Park's results [33], a study that indicated that the loss of cortical lining integrity is associated with an increased risk of experiencing paresthesia after third molar extraction. Therefore, the notification of the cortical status is fundamental.

In our study, the distribution of the classes disclosed a prevalence of the apical course of the mandibular canal (38%). This result is in accordance with the majority of the consulted literature [17,34,35]. The *K* value revealed a moderate agreement for the entire classification (0.598), which could be explained by the fact that this classification was composed by three elements, so it is unexpected to have an excellent agreement. When the classification was tested by element, the concordance has become excellent for the classes and for the evaluation of the status of the lingual bone plate. A possible explanation of the moderate agreement for the subclasses could be explained by the subjectivity to assess the distance of 1.5 mm and to evaluate the cortical lining.

The unusual relationship between third molars and the mandibular canal shown in the literature and proved in our study was arranged in a specific class (uncommon "U") to facilitate the learning of the classification and not to complicate the most observed classes. This class was significantly correlated with gender ($p = 0.002$), it represented 12.1% of the female third molars (99 third molars). A large sample is needed to approve this finding. Clinically, for "uncommon" class, a coronectomy should be discussed (except for U4).

In Class L, subclass 1 (mandibular canal is distant more than 1.5 mm from the roots) was not represented for both genders. The reduced thickness of the lingual bone plate could explain this ascertainment.

A non significant correlation was found between the lingual bone plate status and the proximity to the mandibular canal with age ($p = 0.115$ and $p = 0.566$ respectively). This result suggested that there is not a specificity of IAN risk of damage in aged patients. However, in a literature review of prospective studies, it was found that age is linked to IAN and lingual nerve deficits and it was the first etiology even before deep impaction, specific radiographic signs, intra-operative IAN exposure and lingual split technique [36]. For Sarikov and Juodzbalys [37] more risks for subjects older than 24 years. Probably, other anatomic and physiologic factors could be involved in having these clinical findings.

A non significant correlation was also found between the lingual bone plate status and the proximity to the mandibular canal with gender ($p = 0.297$ for proximity/$p = 0.545$ for lingual bone plate status). The smaller amount of bone in females compared to males is mitigated by the smaller third molar size in females. Therefore, it was expected to have a nonsignificant relationship between proximity and lingual bone status with gender. Studies with larger sample sizes are required to confirm this observation.

The present study revealed a significant correlation between the three Classes (A, B, and L) and the proximity to the mandibular canal (subclass 3 and 4).

The lingual class showed the highest correlation ($p < 10^{-3}$). The reduced thickness of the lingual bone plate compared to the buccal plate could be an explanation of this ascertainment. This finding agrees with the observation of Maglione *et al.* [17] concluding that the patients at high risk of developing an IAN damage are patients with a lingual course of the mandibular canal. Particular attention should be taken for the cases with lingual course of the mandibular canal during CBCT examination and third molar removal.

Future research should aim at applying the proposed CBCT classification to a large sample with a better image resolution, then to correlate the classification to the surgical outcomes in terms of IAN and lingual nerve injuries.

Conclusion

The IAN or LN injury during third molar surgery can result in major morbidity and it negatively affects a patient's quality of life. Therefore, careful preoperative clinical and radiographic assessments of the risk factors are essential to minimize the risk of permanent nerve injury.

CBCT in the cross-sectional sections can accurately show the closest relationship between the impacted third molar and the mandibular canal, which can help surgeons plan the surgical procedure of impacted mandibular third molars with close relationship to the mandibular canal.

The use of the proposed classification (NRC) could be a support for clinical practice. We suggested a common language among operators and during collaboration with radiologists in order to facilitate the clinical discussion and to correlate the surgery outcomes to the CBCT classes for more adjustment of the surgical procedures.

Conflicts of interests: Neither the author nor any of the coauthors have any potential conflict of interests related to the publication of this paper.

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