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Risk Factor in Endodontic Treatment: Topographic Evaluation of Mandibular Posterior Teeth and Lingual Cortical Plate Using Cone Beam Computed Tomography (CT)

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: Topographic relationships of mandibular posterior teeth with mandibular cortical plate are extremely important both in terms of infection spread and endodontic and surgical procedures to be performed. The aim of this study was to determine the relationship between root apex of the mandibular posterior teeth and lingual plate of the mandible.

Material/Methods: CBCT data of 138 patients were retrospectively analyzed. The topographic relationship between root apex and lingual plate was classified as non-contact, contact, or perforation. Morphology of the mandibular lingual plate was classified into the 4 types (convex, parallel, undercut, slanted) and recorded for each tooth region. The prevalence of each group was calculated.

Results: In 6.2% of all mandibular posterior teeth, the lingual plate was perforated by at least 1 root of the corresponding tooth. The teeth with the highest perforation rate were the third molar tooth (31.6%) and the second molar tooth (14.7%). The most common mandibular lingual plate morphology type was "undercut type" (61.3%) in the molar teeth region, while "parallel type" (55.7%) was most common in the premolar teeth region.

Conclusions: In conclusion, a high percentage of mandibular second and third molars root apex have topographically close relationships to the lingual plate of the mandible. Hence, endodontic consultants must be aware by this anatomical relationship and be aware of possible complications during endodontic and surgical procedures using radiographical modalities.

MeSH Keywords: Cone-Beam Computed Tomography • Endodontics • Intraoperative Complications • Mandible • Subcutaneous Emphysema • Tooth Root

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Background

The upper border between the internal and external surfaces of the mandible form the alveolar processes, supporting the mandibular teeth. The alveolar processes consist of the buccal and lingual plates, which are located on the external and internal aspects of the bone, and inter-dental and inter-radicular septa, which separate each tooth and root [1]. Of all the bones, the alveolar process structure and morphology are considered "unique" due to connection to the teeth, which are housed in the osseous crypts, called alveoli [2].

The anatomy of mandibular structures can influence the spread of odontogenic infection. The main causes of odontogenic infections are non-vital teeth, pericoronitis, tooth extractions, periapical granulomas that cannot be treated, and infected cysts [3]. Endodontic infection is one of the most frequent causes of odontogenic infection, thus it is important to understand the relative position of the apices of the mandibular posterior teeth inside the mandible.

According to current anatomical knowledge, mandibular posterior teeth are positioned lingually in the mandible corpus, thus the spread of odontogenic infection arising from these teeth is more likely to occur on the lingual side than the buccal side [4]. Moreover, in some cases, this lingual positioning of teeth results in apical fenestrations, which represent interruptions of the mandibular lingual cortical plate contour [5,6]. The close proximity of the root apices of posterior teeth to the cortical bone may lead the infection to penetrate into the adjacent facial spaces [7]. Involvement of submandibular and sublingual spaces causes severe symptoms such as neck rigidity, trismus, dysphagia, respiratory distress, sialorrhea, and pyrexia. In addition, the submandibular space is regarded as a space in which inflammation spreads through the space to the deep head and neck spaces, such as the parapharyngeal space. If the infection spreads to the parapharyngeal space, rapid airway obstruction may occur, resulting in a life-threatening condition [4].

Besides the infection spread, this close relationship can lead to complications during tooth extraction, including fracture of the lingual plate [8,9] and displacement of roots or root fragments into adjacent fascial spaces [10,11]. If there is an apical fenestration as the protrusion of the apical end of the root through the cortical plate, the displacement of endodontic materials such as irrigation solutions, medicaments, sealers, or broken instruments during root canal treatment may occur. Furthermore, apical fenestrations are one of the risk factors for the iatrogenic subcutaneous emphysema in endodontic treatments [8–11].

Although the thickness of the buccal bone over the mandibular roots has been investigated in several studies [12–14], little is known about the topographic relationship between mandibular posterior teeth and the lingual cortical plate. The aim of the present study was to measure the thickness of the lingual plate at the level of the root apex of mandibular premolar and molar teeth and to clarify the topographic relationship between the root apex and lingual plate using cone beam computed tomography (CBCT) images.

Material and Methods

The research protocol was reviewed and approved by the Ethics and Research Committee of the Faculty of Medicine (YDU/2017/47-405). The methods and protocols in the whole study were in accordance with the ethical principles of the Helsinki Declaration for research involving human subjects. Written informed consent was obtained from the patients before enrolment. CBCT scans carried out between January 2010 and May 2016 from the patient record database were selected. The indications for CBCT examinations were implant planning or oral surgery procedure planning, as well as impacted third molar and canine evaluation. Good-quality CBCT images that contained the bilateral posterior area with at least 1 of the premolars or molars (fully erupted teeth and fully formed apices) with a view of the entire tooth and surrounding alveolar bone in both sides were included. The exclusion criteria consisted of any pathology (including supernumerary teeth or misplaced teeth) or any syndrome anamnesis and the presence of orthodontic treatment history that might alter the relationship between the teeth and the lingual plate of the mandible. In total, 1027 mandibular posterior teeth (257 first premolar, 242 second premolar, 225 first molar, 224 second molar, and 79 third molar) in 138 patients (69 males, 69 females; age range 15–76 years; mean age 37.3 years) were obtained and analyzed retrospectively.

The CBCT scans were carried out using the NewTom 3G imaging system (Quantitative Radiology s.r.l., Verona, Italy) operating at 9-inch field of view (FOV) to include the mandibular anatomy. The unit was operated under a fixed 110-kVp setting, automated adjusted milliamperes, and a scan time of 36 s with 0.3-mm-thick axial slices and isotropic voxels. All exposures were performed by an experienced and licensed radiologist. The images of the scans were previously saved in a Digital Imaging and Communications in Medicine (DICOM) format.

CBCT images were analyzed with NNT software (NNT 5.3.2, QR NewTom Quantitative Radiology s.r.l., Verona, Italy) and it was used to reconstruct axial, coronal, and cross-sectional images to evaluate the mandibular teeth and their relationship with the mandibular lingual plate, by a trained observer with at least 10 years of experience using the CBCT device and its own software (UA, KO). All images were reconstructed on a 21.3-inch flat-panel color active matrix TFT medical display (Nio Colour 3MP, Barco, France), with a resolution of 3MP

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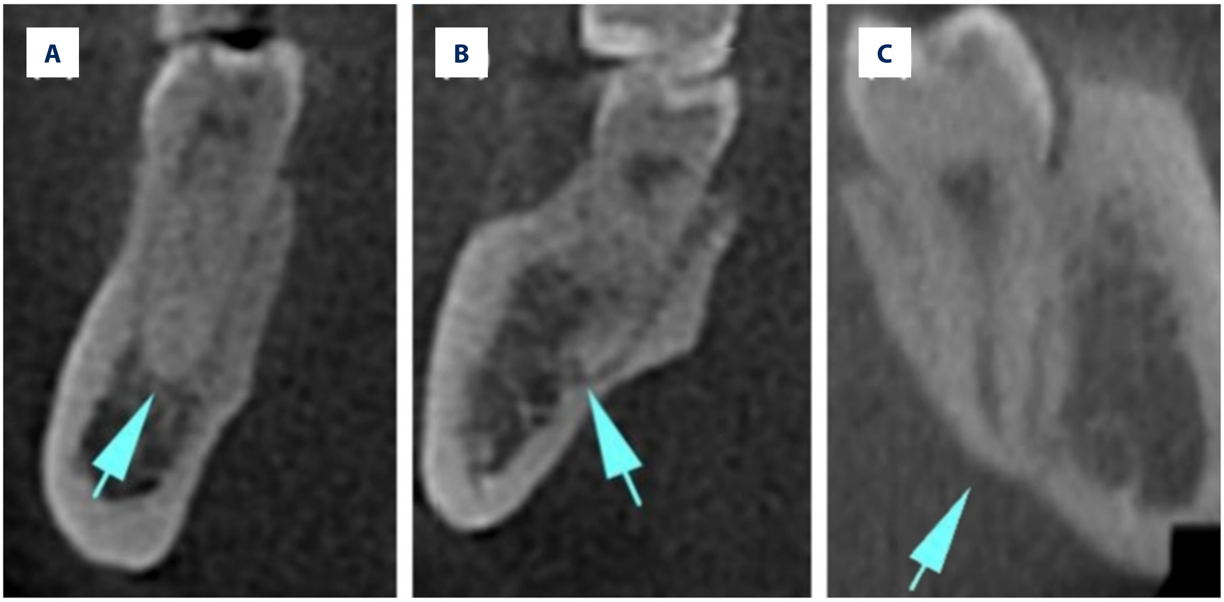

Figure 1. The topographic relationship between teeth and mandibular lingual plate (**A**) Type A, non-contact (**B**) Type B, contact (**C**) Type C, perforation.

(2048×1536 pixels), 0.2109 mm pixel pitch, and 30-bit depth. Observation conditions were standardized on the same computer terminal in a room with the lights dimmed, and the examiners were also permitted to use enhancements and orientation tools such as magnification, brightness, and contrast to improve visualization of the landmarks.

The apical positions of the evaluated teeth roots were categorized into 3 groups on the cross-sectional plane according to the classification described by Emes et al. [6]. Type A (non-contact) is defined as a space between the root surface and the inner boarder of lingual plate. Type B (contact) is defined as the root contacts with lingual plate directly and does not protrude into the outer border of lingual plate. Type C (perforation) is defined as the root perforates the outer border of the lingual plate and contacts with lingual soft tissue (Figure 1).

The measurements were made by both observers (UA, KO). Two measurements (in millimeters) were taken at the level of root apices of teeth and the mandibular lingual cortical plate. These measurements included: (a) the distance from the closest aspect of the root apex to the closest point of the lingual cortical plate for Type A and Type B groups and Type C is the perforated type; hence no measurements were done for this group; and (b) the thickness of lingual plate at the level of first measurement (Figure 2). All measurements were verified by using coronal and axial views.

The morphological shapes of lingual plate on the cross-sectional images of each tooth region from the first premolar to the third molar were classified as 4 subgroups according to the classification described by Wang et al. [15]: Type U, undercut on the lingual side; Type P, parallel to the buccal plate; Type S, slanted with buccolingual width reduced on the lingual side; and Type R, round shape on the lingual side (Figure 3).

Evaluations were performed by 2 observers. Both observers were previously calibrated for mandibular anatomy using CBCT in a special session by in independent clinician other than the observers of the study. The morphological shapes of the plate were classified independently. Any disagreement was resolved by discussion until a consensus was reached between the 2 observers.

For measurements, intra- and inter-examiner validation measures were conducted. To assess intra-observer reliability, the Wilcoxon matched-pairs signed rank test was used for repeat measurements. The inter-observer reliability was determined by the intra-class correlation coefficient (ICC) and the coefficient of variation (CV) [CV=(standard deviation/mean)×100%]. Values for the ICC range from 0 to 1. ICC values greater than 0.75 show good reliability, and the low CV demonstrates the precision error as an indicator for reproducibility. The data were statistically analyzed using SPSS16.0 for Windows (SPSS Inc, Chicago, IL) by 2-way ANOVA (age, sex) analysis of variance with Bonferroni post hoc test at $P<0.05$ to determine the effect of age and sex on the position of the root apices within the bone with respect to the lingual cortical plate, and the inner border morphology of the posterior mandible body.

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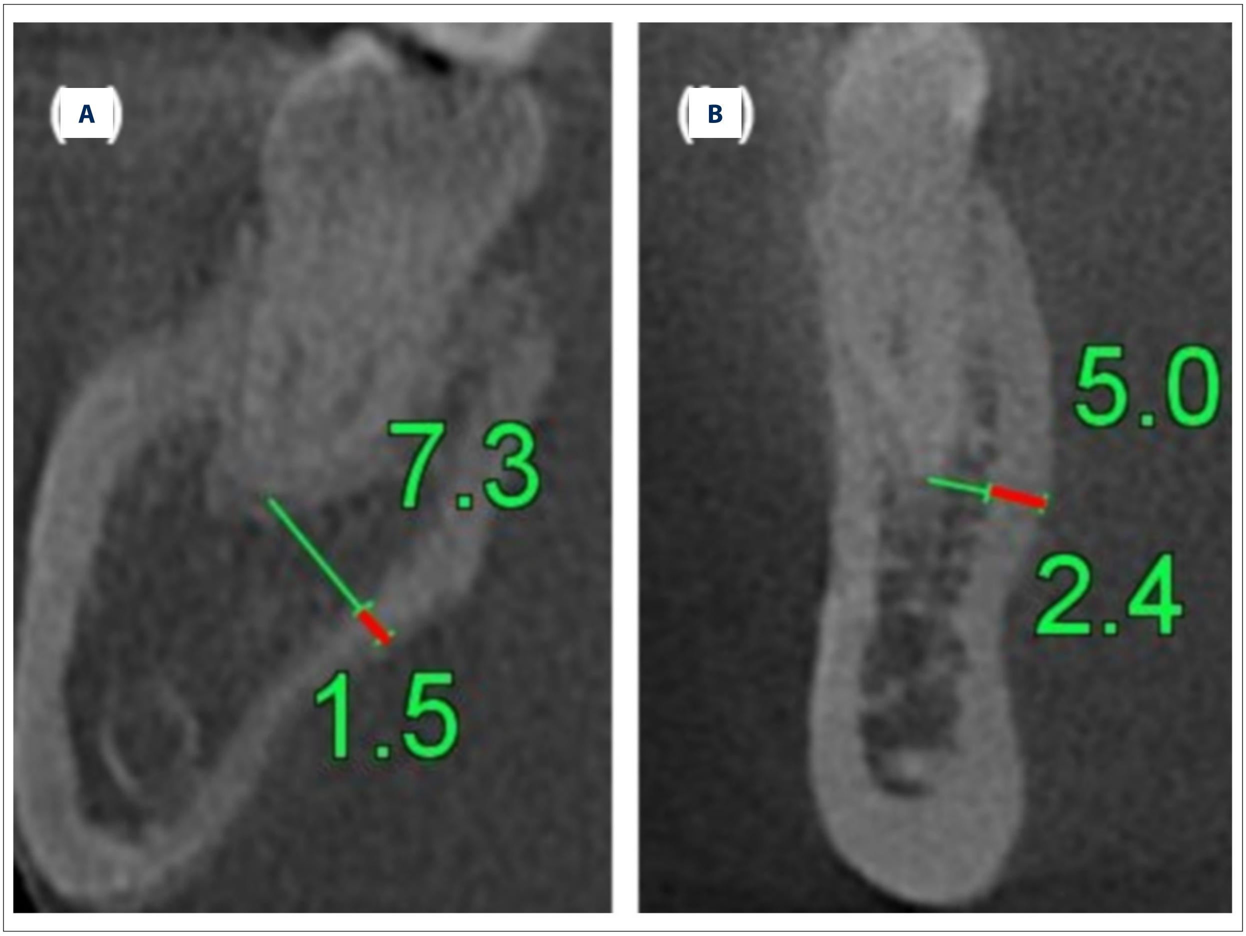

Figure 2. Examples of CBCT measurements of closest distances from the root apex to the lingual cortical plate and the thickness of lingual plate at the level of first measurement. (**A**) Exemplary measurements for mandibular second molar tooth and (**B**) Exemplary measurements for mandibular second premolar tooth.

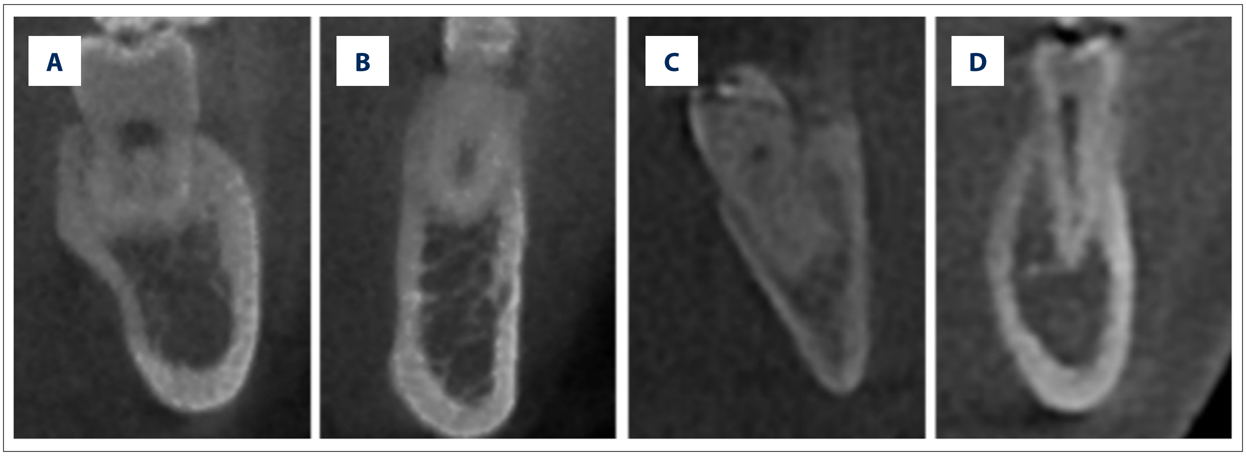

Figure 3. The morphological shapes of lingual plate: (**A**) Type U, undercut on the lingual side; (**B**) Type P, parallel to the buccal plate; (**C**) Type S, slanted with buccolingual width reduced on the lingual side; (**D**) Type R, round shape on the lingual side.

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Table 1. The topographic relationship between tooth types and mandibular lingual plate.

	n	Relationship between lingual plate and teeth					
		Type A (non-contact) n (%)		Type B (contact) n (%)		Type C (perforation) n (%)	
First premolar	257	254	(98.8)	3	(1.2)	0	(0)
Second premolar	242	238	(98.3)	4	(1.7)	0	(0)
First molar							
Mesial root	225	219	(97.4)	3	(1.3)	3	(1.3)
Distal root	225	213	(94.7)	9	(4)	3	(1.3)
Second molar							
Mesial root	218	164	(75.2)	40	(18.4)	14	(6.4)
Distal root	218	151	(69.3)	42	(19.3)	25	(11.4)
One root	6	3	(50)	2	(33.3)	1	(16.7)
Third molar							
Mesial root	75	37	(49.4)	28	(37.3)	10	(13.3)
Distal root	75	31	(41.4)	22	(29.3)	22	(29.3)
One root	4	2	(50)	1	(25)	1	(25)

Table 2. The number and percentage of teeth with at least one root perforates the outer boarder of lingual plate and contacts with lingual soft tissue.

	Total	Type C occurance	
		n	%
First premolar	257	0	0
Second premolar	242	0	0
First molar	225	6	2.7
Second molar	224	33	13.6
Third molar	79	25	31.6
Total	1027	64	6.2

Results

Intra-observer consistency

Repeated CBCT evaluation and measurements indicated no significant intra-observer difference for both observers (p>0.05). Overall intra-observer consistency for observer 1 was rated at 87.2% and 88.4%, while the consistency for observer 2 was 87.6% and 90.2% between the 2 evaluations and measurements, respectively. All measurements were found to be highly reproducible for both observers, and no significant difference was obtained from 2 measurements of the observers (p>0.05).

Inter-observer consistency

The ICCs between Observer 1 and Observer 2 ranged from 0.911 to 0.914. There was a high inter-observer agreement, while a high ICC and low CV demonstrated that the procedure was standardized between the evaluations and measurements of the observers. No statistical differences were found among observers' evaluations and measurements (p<0.05). The mean of both observer's evaluations and measurements were used for further analysis of distances.

Table 1 describes the topographic relationship between different tooth types and mandibular lingual plate. The perforation rate of the roots (Type 3) within the mandibula tended to

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Table 3. The distances between root apices and mandibular lingual plate (mm).

	Total	Mean	SD	Low range	High range
First premolar	257	5.17	1.38	0.8	11.2
Second premolar	242	5.43	1.53	0.5	9.7
First molar					
Mesial root	225	5.62	1.73	0.0	10.2
Distal root	225	4.99	1.84	0.0	10.0
Second molar					
Mesial root	218	2.96	1.77	0.0	8.2
Distal root	218	2.42	1.69	0.0	8.4
One root	6	2.73	2.65	0.0	6.2
Third molar					
Mesial root	75	1.99	1.72	0.0	8.5
Distal root	75	1.52	1.66	0.0	6.3
One root	4	1.15	1.01	0.0	2.1

Table 4. The thickness of lingual plate (mm).

	Total	Mean	SD	Low range	High range
First premolar	257	2.01	0.59	0.7	5.5
Second premolar	242	1.79	0.51	0.7	4.3
First molar					
Mesial root	225	1.68	0.58	0.7	5.5
Distal root	225	1.51	0.51	0.6	3.5
Second molar					
Mesial root	218	1.30	0.39	0.4	3
Distal root	218	1.27	0.36	0.5	2.8
One root	6	1.46	0.51	0.9	2.1
Third molar					
Mesial root	75	1.23	0.36	0.6	2.1
Distal root	75	1.25	0.38	0.4	2.3
One root	4	1.37	0.67	0.5	2.1

increase toward the posterior area of the mandible body. While the premolars and the first molar had a relatively distant relationship, a close relationship was observed in any particular third molar. About one-third of third molars had an exposed root that protruded beyond the bone (Table 2).

As shown in Table 3, the distances between root apices and mandibular lingual plate gradually decreased from the first premolar to the third molar. Second and third molars had significantly shorter distances in this respect ($p<0.05$). Interestingly, distal roots of molars had shorter distances than mesial roots, although the difference was not statistically significant ($p>0.05$). Similarly, the thickness of mandibular lingual plate also gradually decreased from the first premolar to the third molar and resulted in the thinnest lingual plate observed in the third molar region (Table 4).

The morphological shapes of lingual plate showed differences by region (Table 5). The most common mandibular lingual plate morphology was Type U (undercut type) (61.3%) in the molar teeth region, while Type P (parallel type) (55.7%) was most common in the premolar teeth region ($p<0.05$). Additionally, there was a strong correlation between the morphology of the

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Table 5. The morphological shapes of lingual plate on the cross-sectional images of each tooth region.

	n	Lingual plate morphology			
		Type U n (%)	Type P n (%)	Type R n (%)	Type S n (%)
First premolar	257	25 (9.7)	139 (54.1)	93 (36.2)	0 (0)
Second premolar	242	36 (14.9)	139 (57.4)	67 (27.7)	0 (0)
First molar	225	136 (60.4)	65 (28.9)	12 (5.3)	12 (5.3)
Second molar	224	150 (67.0)	18 (8.0)	0 (0)	56 (25)
Third molar	79	38 (48.1)	1 (1.3)	0 (0)	40 (50.6)

Table 6. The topographic relationship between lingual plate and teeth by age groups and gender.

Age Groups/ gender	n	Relationship between lingual plate and teeth		
		Type A (non-contact) n (%)	Type B (contact) n (%)	Type C (perforation) n (%)
15–25	47	472 (81.4)	60 (10.3)	48 (8.3)
26–45	45	461 (84.5)	64 (11.7)	21 (3.8)
46–76	46	379 (90.5)	30 (7.2)	10 (2.3)
Female	69	641 (83.7)	83 (10.8)	42 (5.5)
Male	69	671 (86.1)	71 (9.1)	37 (4.8)

lingual plate and the occurrence of the Type C relationship of roots and lingual plate. Type U and Type P lingual plate morphologies were positively associated with the possibility of the Type C relationship ($p<0.05$).

Table 6 shows the prevalence of different types of relationship between teeth and lingual plate by age groups and sex. The only significant difference was between the age 15–25 and 46–76 years groups. The age 15–25 years group was significantly more likely to have Type C (perforation) relationship when compared with the age 46–76 years group ($p<0.05$). There was no statistically significant difference between males and females ($p>0.05$).

Discussion

The current study evaluated the spatial position of the root apices of mandibular posterior teeth relative to the inner edge of the mandible. According to the literature, there is a limited number of relevant studies, mostly focused on impacted third molars in terms of extraction complications [6,15,16]. Some early studies on dry human skulls [2,5,17–19] aimed to assess the prevalence and distribution of root fenestrations in teeth. Reported prevalences ranged from 1% to 17% with variations between ethnic groups, while the buccal bone fenestrations are also included in this percentage. Moreover, several investigations have found defects only on the buccal aspect of teeth. Elliott and Bowers [19] reported only 1 unspecified lingual fenestration in a mandibular third molar. Edel [18] reported 2 lingual root fenestrations in mandibular incisors because of inclined roots. Nimigean et al. [2] examined 3646 teeth but reported no palatal or lingual root fenestrations. However, Rupprecht et al. [5] found a significant number of alveolar defects (5.5%) on the lingual or palatal aspect of the jaws. Even so, mandibular lingual root fenestrations are generally considered as a rare condition. However, root fenestration has a wider definition than the "Type 3 relationship" used in the present study, described as a circumscribed defect of the cortical plate that exposes the underlying root surface, and may even exist in the middle region of roots. Thus, the reported prevalence rates of fenestrations are not exactly comparable to the Type 3 relationship rates in our study.

Prior to the availability of three-dimensional (3D) imaging techniques, such as CBCT, visualization of labiolingual depth or lingual bone plate thickness was not possible because of image superimposition associated with conventional radiographs, and there was no accurate, noninvasive method for assessing the intimate anatomical relationship of the roots to the lingual plate, apart from cadaveric dissections [20,21]. This limitation was overcome by CBCT. The advent of CBCT imaging allows clinicians to see high-definition cross-sectional view of

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the mandible to locate key anatomic features with a far lower dosage of radiation than is used with medical CT imaging, and is closer to the range of standard periapical radiography [22]. It has also allowed precise measurements from the external surfaces of the mandible to the mandibular canal and teeth [20].

In the literature, a number of possible factors have been implicated in the etiology of root fenestrations, including tooth size and root curvature, tooth malposition, endodontic and periodontal disease, trauma, bruxism and strong occlusal forces, orthodontic tooth movement, and thin cortical bone [2,5,23–25]. In the present study, some exogenous factors such as orthodontic treatment and dental pathologies were eliminated to better clarify the effect of age, sex, and mandibular morphology on the relationship of roots and the inner border of the mandible. In this study, the oldest age group (46–76 years) was significantly less likely to have a Type C (perforation) relationship. These results are in accord with recent studies indicating that the frequency of root fenestrations decreases with age [5,17,26]. It is difficult to explain this observation, but it might be related to tooth eruption throughout life as a result of attrition and wear, and it might lead to more central positioning of root apices in the mandible. It is noteworthy that several studies have shown that the craniofacial complex continues to change and adapt throughout life [27,28]. Some authors speculated that older people are more likely to have undergone extraction, especially teeth with bone defects such as root fenestrations [26]. This might lead to a low prevalence in elderly people. Most studies, including the present one, found that sex difference did not affect the prevalence of root fenestrations [26].

It is well established that endodontic materials should be restricted to the root canals without extrusion into periapical tissues during endodontic treatment [29,30]. However, overextension of root canal materials may take place unintentionally due to overinstrumentation or perforation of the root canals [29]. This is of major concern when the teeth being treated are in close proximity to anatomically neighboring structures such as the maxillary sinus, mandibular canal, or facial spaces. Dental practitioners are conscious of the need to consider the risks of inferior alveolar nerve injuries when planning the endodontic treatment in the posterior mandibular teeth [31]. However, there is tends to be less or limited emphasis on the risks of complications related to lingual plate perforation. Based on the results of this study, the root apex of mandibular second and third molar teeth are topographically closed to the lingual plate of mandible, which is not rare, as previously expected. Therefore, it appears that more care and attention must be paid during endodontic treatment of these teeth.

The intimate relationship of mandibular teeth and lingual plate may increase the risk for hemorrhagic complications and nerve damage. Weinstock and Clarkson reported a case of life-threatening hemorrhagic complication during endodontic treatment, as a result of the perforation of the lingual plate and laceration of the lingual vessels, causing a rapidly developing expanding swelling of the neck [32]. An anatomic study showed that terminal tributaries from the submental and sublingual arteries run in close proximity to the lingual plate [33]. Devine et al. presented a lingual nerve injury caused by an expanding periapical lesion of the mandibular first molar [34].

Subcutaneous emphysema is a known but rare complication of both dental and surgical procedures. It occurs when gas or air dissects along fascial planes and into subcutaneous spaces of the head and neck. It may spread into the mediastinum via the parapharyngeal, retropharyngeal, and carotid sheath spaces, and may lead to mediastinal emphysema (ME), also known as pneumomediastinum. In the cases associated with root canal treatment, hydrogen peroxide irrigation, the use of conventional high-speed handpieces during access preparation, and the use of compressed air to dry canals have been reported to cause subcutaneous emphysema [35–37]. In most cases, tight periapical tissues resist the spread of air. However, the presence of an apical fenestration (Type C) can decrease the resistance beyond the apical foramen, resulting in air being forced further into neighboring subcutaneous tissues. Particularly, in non-vital teeth with a periapical bone defect, the risk of emphysema is still present, even if there is a Type A or Type B relationship with the root apex and lingual plate. Apical periodontitis may disrupt the bone barrier around the tooth apex, and then air was able to spread into the subcutaneous tissues, even during the access cavity preparation. There have been several case reports of subcutaneous emphysema following endodontic treatment of mandibular posterior teeth [37,38], and some of them presented orbital, pneumomediastinal, and cervicofacial subcutaneous emphysema, which are serious and life-threatening complications [36,39,40].

Results of the present study show that the close relationship of the second and third molar teeth to the lingual plate poses a risk for endodontic and surgical procedures. However, in order to confirm our findings further, more data are required from studies in larger and more diverse populations.

Conclusions

In conclusion, in many patients, the root apex of mandibular second and third molars have a topographically close relationship to the lingual plate of the mandible, and this should be considered when performing endodontic and surgical procedures, as well as in the assessment of the pathology of this region.

Conflict of interest

None.

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