MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2018; 24: 26-36
DOI: 10.12659/MSM.905475

Received: 2017.05.24
Accepted: 2017.06.23
Published: 2018.01.02

The Risk Factors that Can Increase Possibility of Mandibular Canal Wall Damage in Adult: A Cone-Beam Computed Tomography (CBCT) Study in a Chinese Population

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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Source of support: This study is supported by Health and Family Planning Commission of Sichuan Province Research Fund (16PJ267)

Background: The objective of this study was to analyze the factors that can increase the possibility of mandibular canal (MC) defect in Chinese people, to evaluate the risk of nerve impairment, and to choose the proper operative method to reduce the risk of mandibular alveolar nerve injury during the extraction of mandibular third molar (MTM).

Material/Methods: A total of 954 patients (1,304 MTMs) who underwent orthopantomography (OPG) and cone-beam computed tomography (CBCT) between July 2014 and December 2014 were included in this study. The age and gender of patients, impacted type (high impaction, moderate impaction, and low impaction), Winter classification of MTM, position of MTM relative to MC, vertical classification of MTM and MC, and the feature images of OPG were collected and compared to the imperfection of the MC wall in CBCT images.

Results: The wall situation of MC was significantly correlated with the age of the patient, the depth of the molar, the position of the roots, and six imaging appearances on OPG. There was no significant difference based on gender.

Conclusions: Most incomplete walls of MCs could be inferred by OPG. However, images based on CBCT could clarify the defect of the MC and also could clearly display the spatial relationship between the root and inferior alveolar canal.

MeSH Keywords: **Cone-Beam Computed Tomography • Mandibular Nerve • Molar, Third • Radiography, Panoramic**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/905475

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Background

Mandibular third molars (MTMs) exist in 90% of the general population, with 33% having at least one impacted MTM [1]. Recent studies have reported that impacted third molars might cause a series of complications such as caries, germination disorders, repeated episodes of pericoronitis, periodontal lesions of the second molar, orthodontic problems, and even follicular cysts [2–4]. Considering the massive complications caused by impacted third molars, surgical removal of them may be the best option [5]. However, most patients complain about discomfort after surgery such as swelling, pain, bleeding, trismus, dry socket, dehiscence during primary wound healing, or even numbness of the lower lip caused by inferior alveolar nerve (IAN) injury [3,4]. Several studies have reported that the incidence of IAN injury is between 0.4% to 8.4% [6–8], with no recovery from the injury reported in approximately 0.12% to 0.30% of cases [8,9]. A previous study reported that cases of IAN damage were caused more frequently by MTM extraction surgery than by dental implantation or orthognathic surgery [10]. The spatial relationship between the MTM root and the mandibular canal (MC) is the most significant risk factor for IAN injury [11–15].

Therefore, it is vital for surgeons to understand the relationship between the MTM and the MC wall defect before surgery, which might help inform IAN damage risk assessment and surgical operation planning, as well as risk communication with patients before surgery.

The periapical radiograph and orthopanoramic radiographs (OPG) are the most commonly used clinical x-ray examinations now in China. The inferior alveolar canal can be seen as a radiolucent line with two thin cortical borders in OPG and periapical films. In some conditions, such as osteoporosis, imaging detection of the inferior alveolar canal may be difficult due to its lack of well-defined cortical boundaries. When MTM roots are overlapping with the MC, the image also may be unclear [16]. Sometimes the roots bend distally or mesially, and in this scenario, the OPG image could guide the operation design, and the surgeons could extract the roots following the bend direction. However, when the roots bend buccally or lingually, the OPG image would not be helpful, as without a visual aid, a blind extraction or forceful extraction may injure to the IAN.

Cone-beam computed tomography (CBCT) has been considered a precise measurement tool since late 1990s [17]. It can display the three-dimensional (3D) spatial relationship between the MTM and the MC; and compared to traditional CT, CBCT has a higher resolution and lower radiation exposure [18–21]. Several studies have reported on the relationship between MTM roots and the inferior alveolar canal; however, published studies about how to extract a tooth with minimally invasive techniques using CBCT are scarce. The aforementioned research studies did not include Chinese populations.

The objective of this study was to analyze the factors that increase the possibility of a MC defect in Chinese people and determine if CBCT can show the shape of the root and the relationship of the root to the MC to better guide surgery.

Material and Methods

This study was approved by the Institutional Review Board of Sichuan University, Chengdu, China, and all participants signed an informed consent agreement. We followed the American Dental Association Council on Scientific Affairs advisory to use CBCT only when the diagnostic yield will benefit patient care, enhance patient safety, or improve clinical outcomes significantly. The study included 954 patients with 1,304 MTMs who underwent radiology examination between July 2014 and December 2014. Patients were enrolled in the study if the met the following inclusion criteria: 1) imaging included the MTM apical region and the MC; 2) patients were older than 18 years of age; 3) the MTM roots were completely developed; 4) radiographic imaging was distinct, with no image distortion or deflection.

Patients who did not meet all the aforementioned inclusion criteria were excluded from the study. If the OPG or CBCT images were obviously not clear, or if there was metal (such as implant) interference in the viewing area, the patients were not considered for the study. Furthermore, patients were excluded if they had mandibular lesions (trauma, cysts, tumors, osteomyelitis, etc.) around the MTM and MC.

All OPG images in this study were collected using OP/OC200 D digital panoramic/cephalometric x-ray and supporting CliniView7.1 software (Instrumentarium Dental, PaloDEx Group Oy, Finland). All CBCT images used in this study were collected using Japanese Morita 3D Accuitomo (Mortia Co., Japan). All patients receive a panoramic examination in a full adult projection (OP/OC200 D). All CBCT scans were taken by an experienced radiologist using an Accuitomo 3D device (Morita, Kyoto, Japan) under an extended field of view mode (100×100 mm). The scanning time was 17.5 seconds, with 85 kV tube voltage and 4 mA tube current, a 0.25 mm voxel size, and i-Dixel was used to view the images.

The OPG and CBCT images were collected without detail information regarding the patients (only gender was known) and the images were evaluated by two oral radiologists independently; the MC wall defect and the relationship between the MTM and MC were recorded. When disagreement existed, consensus was reached by discussion between the two observers. Inter-observer agreement was evaluated using kappa statistics.

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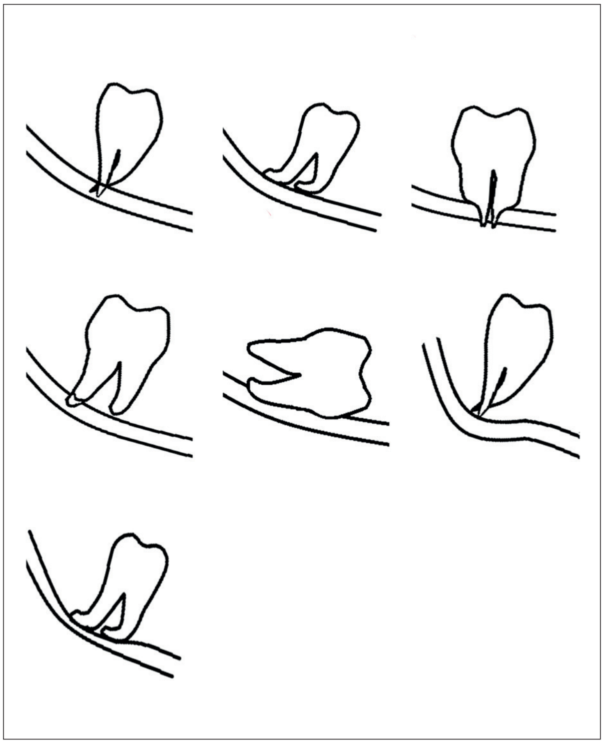

Figure 1. Seven features on the OPG: (**A**) darkening of root; (**B**) deflection of root; (**C**) narrowing of root; (**D**) bifid apex of root; (**E**) interruption of white line of canal; (**F**) diversion of canal; (**G**) narrowing of canal.

The OPG images were classified as follow: 1) based on the Pell and Gregory classification, the OPG images were classified as high impaction, median impaction, or low impaction of the MTM, and 2) based on Winter classification, OPG images were classified as vertical impaction, horizontal impaction, mesioangular impaction, distoangular impaction, buccal impaction, lingual impaction, or inverted impaction of the MTM. In this study, the buccal and lingual impactions were classified as one group because they were hard to distinguish on OPG.

According to Rood and Shehab [22] and Bell [23], other imaging features on OPG should be considered, including apical shadow, deflection of root, narrowing of root, dark and bifid apex of root, interruption of white line of canal, diversion of canal, and narrowing of canal (Figure 1).

OPG images were classified into three groups based on roots: roots that had no contact with the canals; roots of the tooth just touching the upper white line; and roots superimposed on the outline of the neurovascular bundle, including interruption of white line (Figure 2).

Based on the Ghaeminia classification [24], the relationship of the root and the MC were classified into four types: buccal, lingual, inferior, and inter-radicular (Figure 3).

Based on whether the wall of the MC was intact or not, the images were divided into two groups: the wall of canal was intact and the wall was defective (Figure 4).

Based on the integrity of the MC wall, these images were classified into two groups: the root of the MTM in the MC and the root of the MTM out of the MC (Figure 5).

The original CBCT image data, which observed the MTM root and the MC contact, was imported into Mimics15.0 software (Figure 6). Then a 3D geometric surface model of the teeth and IAN was established using the 3D calculator. The 3D relationship from all angles could be observed by rotating the model.

The data was analyzed using SPSS 22.0; categorical data with chi-square test were compared (significance level α=0.05)

Results

There were 1,304 MTMs from 954 patients (476 women and 478 men) who met the inclusion criteria. The age range was 18 to 78 years with the mean age of 40.26 years. The kappa (K) value was calculated for inter-observer agreement. The K value was 0.80 in this study.

According to the Winter classification, MTMs were vertical impacted in 676 cases (51.8%). The top three types of impaction by Winter classification in this study were the mesioangular in 269 cases (20.6%), the horizontal in 265 cases (20.3%), and the distoangular in 70 cases (5.4%). High impaction in 858 cases (65.8%) was the most common impaction type using Pell and Gregory classification (Table 1).

Of the 1,304 CBCT images, the wall of the MC was intact in 1,041 cases (79.8%). Of the 263 cases with defective canals, the root was inserted into the canal in 89 cases (6.8%). Of the 1,304 CBCT images, the roots of 745 MTMs were located above the MC (57.1%); in 93 cases (7.1%) they were located on the buccal side; in 458 cases (35.1%) they were located on the lingual side, and the MC was located inter-radicular of the MTM in eight cases (0.6%).

Of the 745 cases with roots located above the MC, most walls of the MC were intact (716 cases, 96.1%). Of the 93 cases with roots located buccal to the MC, only six cases had intact canals (6.5%). Of the 458 cases with the root located on the lingual side of the MC, 319 cases had intact roots (69.7%). Of the eight cases with the MC located inter-radicular of the MTM, all eight cases had defects on the wall of the MC.

The four groups were analyzed according to the position relationship between the root and MC using chi- square tests, with

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Figure 2. Three types of the relationship between the MTM and MC in OPG image: (**A**) root of tooth with no contact with the canal; (**B**) root of tooth just touching upper white line; (**C**) root of tooth superimposed on outline of neurovascular bundle.

p=0.000 <0.05. There was significant differences among all the groups, excepted for cases with the root located buccal compared to those with the root surrounding the canal (Table 2).

Of the 1,304 images, 665 cases were male and the others were female. MCs were intact in 543 images of the 665 males, while 122 of 639 images were intact in the females. There was no significant difference in the spatial relationship of MTM and MC, or the integrity of MCs between genders (Table 3).

The patients were divided into three groups according to age: 18 to 30 years, 31 to 60 years, and 60-years and older). Intact MCs were found in 313 of 471, 603 of 693, and 125 of 140 in the three age groups, respectively. Of the 471 cases ranging from 18 to 30 years of age, the MC was intact in 313 cases (66.5%) and defective in 158 cases (33.5%). Of the 693 cases ranging from 31 to 60 years of age, the MC was intact in 603 cases (87.0%) and defective in 90 cases (13.0%). Of the 140 cases older than 60 years of age, the MC was intact in 125 cases (89.3%) and defective in 15 cases (10.7%). The integrity of the MC walls was compared among the three groups (Table 4). There were significant differences between the 18- to 30-year old group and the other two age groups.

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Figure 3. Ghaeminia classification in CBCT: (**A**) root located buccal of the canal; (**B**) root located lingual of the canal; (**C**) root located inferior of the canal; (**D**) MC located interradicular of the MTM.

Based on the relationship between the MTM root and the MC in OPG images, all the patients were divided into three groups: root had no contact with the MC (group A), root clung to the MC (group B), and the root overlapped with the MC (group C). The MCs were intact in 723 of 727 cases in group A (99.4%), 234 of 322 cases in group B (72.7%), and 84 of 255 cases in group C (47.5%). The rate of intact MC decreased when the root of the MTM was closer to the MC (Table 5, p=0.000 <0.05).

Based on OPG images, the MCs were intact in 793 of 858 high-impacted cases (92.4%), 171 of 284 median-impacted cases (60.2%), and 77 of 162 low-impacted cases (47.5%). The rate of intact MC decreased when the impact level was lower.

Based on the Winter classification, all the patients were divided into vertical, mesioangular, horizontal, inverted, distoangular, and buccal and lingually impaction groups. The MCs were intact in 616 of 676 cases in the vertical group (91.1%), 189 of 269 cases in the mesioangular group (70.3%), 159 of 269 cases in the horizontal group (60.0%), 11 of 14 cases in the invert group 78.6%), 59 of 70 cases in the distoangular group (84.3%), and seven of 10 cases in the buccal and lingually group (70%). There were significant differences between the

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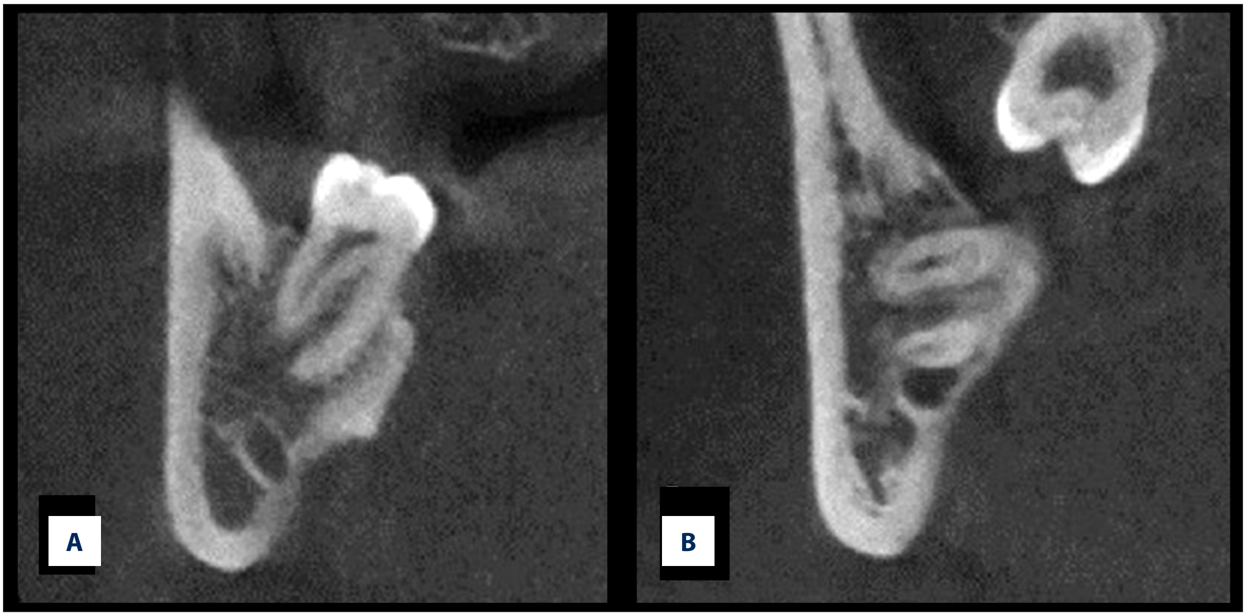

Figure 4. The wall situation of canal in CBCT images: (**A**) wall of canal is intact; (**B**) wall of canal is defective.

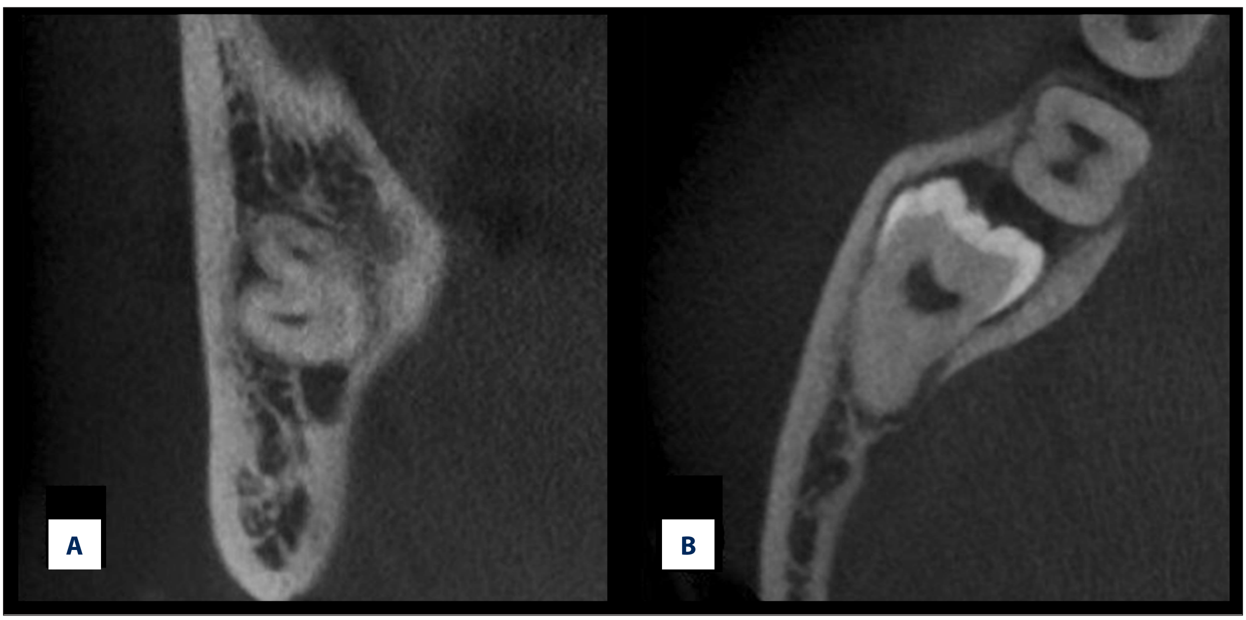

Figure 5. The root position relative to the canal in the examples that the canal wall is defective: (**A**) root did not enter the canal; (**B**) root inserted the canal.

vertical and mesioangular, the vertical and horizontal, and the distoangular and horizontal groups (Table 6).

There were 269 of 1,304 OPG images that had a broken white line at the canal border, while 217 of the 269 cases had defective MC by CBCT. There were 21 of 1,304 OPG images that had a diversion canal, all of which had defective MC in the corresponding CBCT images. Of the 28 cases with narrowing canals by OPG images, 18 had defective canals confirmed by CBCT.

Of the 19 cases with bent canals by OPG images, 13 were defective by CBCT images.

There were significant differences between OPG and CBCT images in aspects of interruption of the white line of canal, diversion of canal, narrowing of canal, and deflection of root, darkening of root, and narrowing of root (Table 7).

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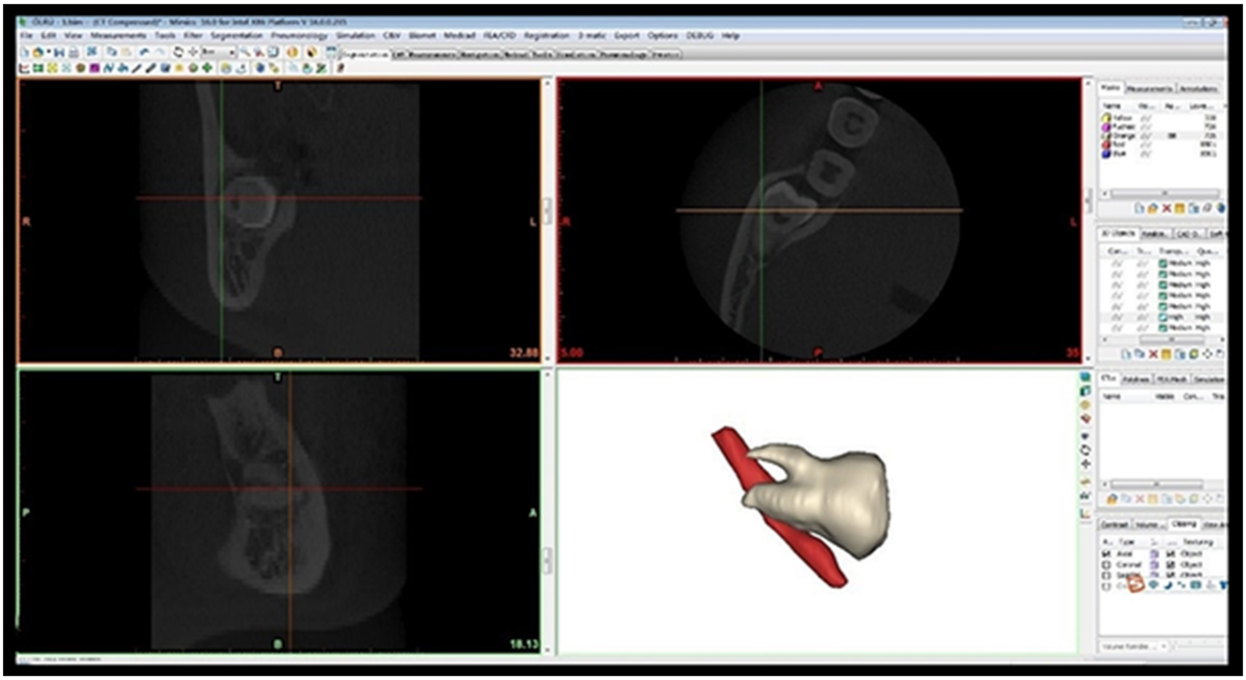

Figure 6. View of Mimics15.0.

Table 1. The impaction type of MTMs.

Pell & Gregory classification			Winter classification		
Impacted type	**Number**	**Percentages**	**Impacted type**	**Number**	**Percentages**
High impacted	858	65.8	Vertical	676	51.8
Median impacted	284	21.8	Horizontal	265	20.3
Low impacted	162	12.4	Mesioangular	269	20.6
Total	**1304**	**100.0**	Distoangular	70	5.4
			Inverted	14	1.1
			Buccolingual	10	0.8
			Total	**1304**	**100**

Table 2. The relationship between MC integrity and position of MTM roots.

Relationships between MTM roots and MCs	Intact canal	Detective canal	Total
Inferior*	716	29	745
Buccal*	6	87	93
Lingual*	319	139	458
Surrounding the canal*	0	8	8
Total	**1041**	**263**	**1304**

* P=0.000 <0.05.

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Table 3. The relationship between patients' gender and MC.

Sex	Position of the root relative to MC					Integrity of MC		
	Inferior	Buccal	Lingual	Surrounding the MC	Total	Intact canal	Defective canal	Total
Male*	388	39	233	5	665	543	122	665
Female*	357	54	225	3	639	498	141	639
Total	**745**	**93**	**458**	**8**	**304**	**1041**	**263**	**304**
P value	P=0.280 >0.05					P=0.094 >0.05		

Table 4. Canal situation of different age group.

Age group	Intact canal	Defective canal	Total
18~30*	313	158	471
31~60*	603	90	693
>60*	125	15	140
Total	**1041**	**263**	**1304**

* P=0.000, P<0.05.

Table 5. Canal's situation of the vertical relationship between MC and root.

Vertical relation between MC and root	Intact canal	Defective canal	Total
No contact*	723	4	727
Just touch upper white line*	234	88	322
Superimposed*	84	171	255
Total	**1041**	**263**	**1304**

* P=0.000 <0.05.

Table 6. The relationship between impaction type and MC integrity.

Pell & Gregory classification			Winter classification		
Impacted type	Intact canal	Defective canal	Impacted type	Intact canal	Defective canal
High impacted	793	65	Vertical	616	60
Median impacted	171	113	Horizontal	189	80
Low impacted	77	85	Mesioangular	159	106
Total	**263**	**1041**	Distoangular	11	3
			Inverted	59	11
			Buccolingual	7	3
			Total	**1041**	**263**
P value	P=0.000 <0.05			P=0.000 <0.05	

There were significant differences between vertical and mesioangular, vertical and horizontal, distoangular and horizontal groups.

Table 7. Canal's situation of the six OPG feature images.

OPG image		Intact canal		Defective canal		Total
Complete white line	Yes 1	989	(95.6%)	46	(4.4%)	1035
	No 1	52	(19.3%)	217	(80.7%)	269
Diversion of canal	Yes 2	0	(0.0%)	21	(100.0%)	21
	No 2	1041	(81.1%)	242	(18.9%)	1283
Narrowing of canal	Yes 3	10	(35.7%)	18	(64.3%)	28
	No 3	1031	(80.8%)	245	(19.2%)	1276
Deflection of root	Yes 4	6	(31.6%)	13	(68.4%)	19
	No 4	1035	(80.5%)	250	(19.5%)	1285
Darkening of root	Yes 5	2	(7.1%)	26	(92.9%)	28
	No 5	1039	(81.4%)	237	(18.6%)	1276
Narrowing of root	Yes 6	0	(0.0%)	2	(100.0%)	2
	No 6	1041	(80.0%)	261	(20.0%)	1302
Total		**1041**		**263**		**1304**

P(1)=0.000, P(2)=0.000, P(3)=0.000, P(4)=0.000, P(5)=0.000, P(6)=0.041.

Discussion

MTM extraction is a common oral and maxillofacial outpatient surgery. Nerve damage is the most severe postoperative complication after MTM extraction. There are numerous reasons that might cause the inferior alveolar nerve (IAN) damage [6,11]. It has been reported that temporary nerve injury is usually caused by partial MC wall defects and blood clot pressure on the nerve extraction. The probability of postoperative inferior alveolar neurovascular bundle exposure has been reported as 14.9% and 10.9% [23,25–27]. Park et al. [28] reported that a defect of the MC wall had a close relationship with postoperative IAN injury. Dentists can assess the risk by checking the integrity of the MC wall before surgery. CBCT can display the relationship of the MTM and MC from three planes (coronal, sagittal, and cross-sectional), and it has high resolution [29]. Hilgers reported that the accuracy of CBCT was superior to OPG [30]. For the cases that cannot be displayed clearly or that indicate that the relationship between the MTM and MC is close using OPG, CBCT can display the spatial relationship between the MTM and MC [31–33] and also reconstruct the 3D model with the image data using software, thus allowing the image to be observed more intuitively [34].

The coronal images provided by CBCT could be used to display the buccolingual relationship between the MTM and the MC, which is useful for surgical planning to reduce the risk of IAN injury [10]. Nakayama et al. [35] reported that contact of the MTM and the MC resulted in an increased risk for IAN exposure or injury. Thus, CBCT examination before the extraction makes physician-patient communication and risk assessment more effective.

In this study, high impaction was the most common impact type, followed by moderate impaction and then low impaction. High impaction was the most unlikely type to have an incomplete MC wall. Our study results revealed that when the impaction position was lower in the mandible, the relationship between the MTM root and the MC became closer, while the MC was more likely to appear defective.

In this study, based on the Winter classification, vertical impaction was the most common type. It was followed by mesioangular impaction, horizontal impaction, distoangular impaction, inverted impaction, and buccolingual impaction. A MC defect most frequently happened with horizontal impaction; 40% of the horizontal impacted MTMs had defects on the walls of the MCs. Although vertical impaction was the most common impaction type of the MTM, it had a minimum risk for MC wall defects. Only 8.9% of the vertical impacted MTMs had defects on the walls of MC.

Nakagawa et al. [8] reported that there were significant differences with MC defects between males and females. The defect rate for females was higher. However, there was no significant difference between males and females found in our study. This study result was the same as the reported by Cheung et al. [36].

Our study suggested that patients between 18 and 30 years of age had the greatest chance of having a MC wall defect, while

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patients older than 60 years of age had a minimum risk. The reason for this difference might be that most patients have their MTMs removed when they are young.

A previous study reported that most MTM roots are located on the buccal side of the MC [33]. Whereas, another research report suggests that most MTM roots are located on the lingual side of the MC [24]. In our study, we found that most MTM roots were located superior to MC and all eight cases with roots surrounding the MC had defects on the wall of the MC. The next highest percentage was the roots located on the buccal side of the MC (93.5% of this type had defect on the wall of MC), followed by roots located on the lingual side of the MC (30.3% of this type had defect on the wall of MC), and roots located on the inferior of the MC (3.9% of this type had defect on the wall of MC). Our study results revealed that the two types (roots surrounding the MC and roots located on buccal side of the MC) were most likely to have defects on the MC wall, which was in agreement with a previous study [37]. The surgeon should avoid force on the buccal side and avoid pushing and scratching in these situations, in order to avoid nerve injury.

There were 727 cases that had MTM roots out of touch with the MC in the 1,304 OPG images. Most of these MCs had wall integrity, except for four special ones, suggesting that although the roots of the MTM had no contact with the MC in OPG image, we could not exclude the possibility of defective MC in rare cases. The reason for differences might be the shooting angle or the lower resolution of OPG images. Most of these cases had MC wall integrity; therefore, there was no need to have additional CBCT imaging studies. According to our study, as the vertical relationship between the MC and the MTM became closer and closer, the MC was more likely to have a defect, which was consistent with previous research [38].

Monaco et al. [31] reported that it was more likely to find a defective MC wall when there was narrowing of the root or interruption of white line of canal on OPG image. Nakagawa et al. [8] suggested that the cases with interruption of white line on OPG film had a greater chance of having a MC wall defect. The Bell study [23] indicated that it was more likely to have MC wall defects when there was root deflection or periapical lesions on OPG images.

CBCT is increasingly being used in many of dental specialties because of its high resolution of bone and teeth. Compared to OPG, CBCT is able to show the location, inclination, and morphology of impacted MTMs, as well as their distances from the MC more clearly. In addition to the use of CBCT technology in dental-maxillofacial imaging, it provides a number of potential advantages compared to CT, such as x-ray beam collimation to the area of interest, reduced effective dose, and less artifacts [39]. The radiation dose from CBCT is significant lower than conventional CT, yet higher than the dose from OPG. Exposure dose from CBCT has been reported to range from 45 μSy to 65 μSy. The reported exposure from a full-mouth series of analog radiographs is 150 μSy, and 54 μSy for an analog panoramic radiograph. In comparison, a roundtrip airplane flight from Paris to Tokyo exposes passengers to an effective dose of 139 μSy [40].

Conclusions

According to our research, cases with periapical lesions, bent roots interruption of white line, diversion of canal, and narrowing of canal on OPG images had a greater probability of having a defect on the wall. Surgeons should add CBCT examination for these patients to provide 3D imaging spatial relationship between the MTM and MC when they find these features in OPG images. Meanwhile, CBCT can help surgeons in surgical planning and reduce operation risk.

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