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ORIGINAL ARTICLE

External root resorption of the second molar associated with mesially and horizontally impacted mandibular third molar: evidence from cone beam computed tomography

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Abstract
Objectives The aim of the present study was to assess the incidence and risk factors of ERR in second molars with mesially and horizontally impacted mandibular third molars using cone beam computed tomography (CBCT) images from patients in a Chinese tertiary referral hospital.
Materials and methods A total number of 216 patients with 362 mesially and horizontally impacted mandibular third molars who were treated at our institution from 2014 to 2015 was retrospectively included. The ERR in second molars was identified on CBCT multiplanar images. The associations between incidence of ERR and multiple clinical parameters were statistically analyzed by Chi-square test. Moreover, the risk factors for ERR in second molars were further assessed by multivariate regression analysis.
Results The overall incidence of ERR in second molars was 20.17 % (73/362) as detected on CBCT images. The presence of ERR significantly associated with patients age and impaction depth of mandibular third molars. However, no significant relationship was found between ERR severity and impaction depth or ERR location. Multivariate regression analyses further revealed age over 35 years and impaction depth as important risk factors affecting the ERR incidence caused by mesial and horizontal impaction of mandibular third molar.
Conclusions ERR in second molar resulted from mesially and horizontally impacted mandibular third molar is not very rare and can be reliably identified via CBCT scan.
Clinical relevance Given the possibility of ERR associated with third molar impaction, the prophylactic removal of these impacted teeth could be considered especially for those patients with over 35 years and mesially and horizontally impacted teeth.

Keywords External root resorption · Mandibular impacted third molar · Radiographic analysis · CBCT

Introduction

The mandibular third molars are the most frequently impacted teeth largely due to lack of adequate space in the lower jaw or barriers in its eruption trajectory. These impacted teeth usually result in several types of pathological conditions including pericoronitis, swelling, odontogenic cysts or tumors, bone loss as well as root resorption of the adjacent teeth, thus leading to impaired oral functions and discomfort [1–3]. Among them, external root resorption (ERR) in the second molars resulted from impacted third molars is an insidious clinical entity, and not easily and timely diagnosed in the clinic until dental pulpitis or periapical inflammation of the affected second molars occur [4, 5]. Moreover, the presence of ERR significantly undermines normal functions and health of the adjacent second molars, and might necessitate the effective treatments of these affected teeth such as root canal therapy, root resection or tooth extraction, if not properly managed [6, 7]. Therefore, identifying the risk factor of ERR caused by impacted third

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molars and preventing its occurrence is beneficial to preserve the second molars as well as keep health of local structures.

ERR is a pathological process that occurs on the outer surface of the permanent tooth which is commonly believed to be induced by local inflammation or mechanical stress [6, 8]. Accumulated evidence has indicated that several etiologic factors are associated with ERR of permanent teeth including periodontal infection, trauma, orthodontic tooth movement, tooth auto-transplantation or replantation, and mechanical pressure from the impacted tooth or tumor [9, 10]. Notably, progressive pressure resorption on the distal of the adjacent second molar is one of the most prevalent complications resulted from impacted mandibular third molar with the prevalence ranging from 0.3 to 24.2 % [2, 4, 11, 12]. Considering the vast amount of impacted third molars in the population, the number of this pathological resorption cannot be rare. However, ERR is difficult to be diagnosed because its progress remains asymptomatic unless the dental pulp or periodontal is involved or clinical symptoms are present. Currently, accurate and timely diagnosis of ERR largely depends on various radiographic examinations, while direct visualization and histological examinations are not commonly feasible [5, 6, 13]. Previously, the periapical and panoramic radiographs were used to identify the presence of ERR on the distal of the mandibular second molars adjacent to impacted third molars and showed a relatively low prevalence [4, 11]. Due to their two-dimensional nature and unequal magnification as well as possible image distortions, these periapical or panoramic radiographs cannot adequately meet the clinical demand to precisely detect ERR presumably due to relatively high false-positive and false-negative ratios, thus having relatively low diagnostic values [5, 14]. Recently, the advent of cone beam computed tomography (CBCT) in dentistry enable clinicians to visualize the dental and maxillofacial structures more precisely and clears from both multiple planes and three-dimensional views [15]. It has various advantages such as high spatial resolution, low radiation dosage as well as multiplanar images free of overlapping as compared to other dental radiography [16]. So, CBCT scan has been widely used to detect different kinds of dental pathological conditions including small and less accessible root resorption caused by adjacent impacted maxillary canines or third molars [5, 14]. Oenning and his colleagues have reported that mesially inclined third molars have the greatest potential to stimulate ERR in second molars as evaluated by CBCT [14]. Moreover, the incidence of ERR in second molars was 5.31 % detected by panoramic radiographs while 22.88 % by CBCT in the same patient cohort, thus supporting the sensitivity and superiority of CBCT in detecting ERR as compared to panoramic radiography [5]. However, until now, the data regarding the ERR of second molars associated with impacted lower third molars have mainly been derived from case reports or retrospective studies with a limited number of cases in which most ERR cases were diagnosed via panoramic or periapical radiographs [4, 7, 11, 17]. The incidence and risk factors of such ERR identified by CBCT scan in a large patient cohort have not been well established yet.

The purpose of this retrospective study was to evaluate the prevalence of ERR on the root distal aspect of the second molars caused by mesially and horizontally impacted mandibular third molars using CBCT scan and to identify the associated predisposing risk factors for ERR.

Patients and methods

This was a retrospective cohort study of patients who were treated at the Department of Oral and Maxillofacial Surgery, Affiliated Hospital of Stomatology, Nanjing Medical University, for surgical removal of impacted mandibular third molars between Jan. 2014 and December 2015. The research protocol was reviewed and approved by the Ethics and Research Committee of Nanjing Medical University. Written informed consent was obtained from all enrolled patients. Given the possibility of pressure resorption of second molars occurred when they were in close contact with impacted teeth and highest potential of mesial inclination to stimulate ERR [14], only patients with mesioangular or horizontal impacted mandibular third molars were included here. These enrolled teeth with mesioangular and horizontal impaction were identified with panoramic radiography and/or CBCT scans and diagnosed based on Winter's classifications similarly as reported before [5, 14, 18]. The exclusion criteria were as follows: the impacted molars associated with cystic or tumor lesions, tumors or bone defects extending to the posterior mandible, the impacted molars with less than two thirds of root, the adjacent second molars showing extensive carious lesions, crowns or distal fillings as well as root canal therapies, the second molars extracted or simultaneously impacted, low quality of CBCT image due to the presence of high-density materials or other reasons which jeopardized unambiguous view of local anatomy and structures. The detailed screen and inclusion/exclusion of patients were described in Fig. 1.

The presurgical CBCT images were obtained with a CBCT unit (New Tom, Verona, Italy) with medium volume and high resolution. The operating parameters were 7.3 mA and 110 kV with a 0.5-mm fixed focal spot and 18 × 16 cm field of view. The CBCT images were analyzed with the NNT software program (version 4.6, New Tom, Verona, Italy) from horizontal, coronal and sagittal planes independently by two observers with high expertise (Dr. Dongmiao Wang and Dr. Xiaotong He). Here, the presence of ERR was defined as clear loss of substance on the distal surface of the adjacent second molar root, which was similar as previous Al-Khateeb's description [1]. The dental caries on second molars and ERR was differentially diagnosed based on their radiographic

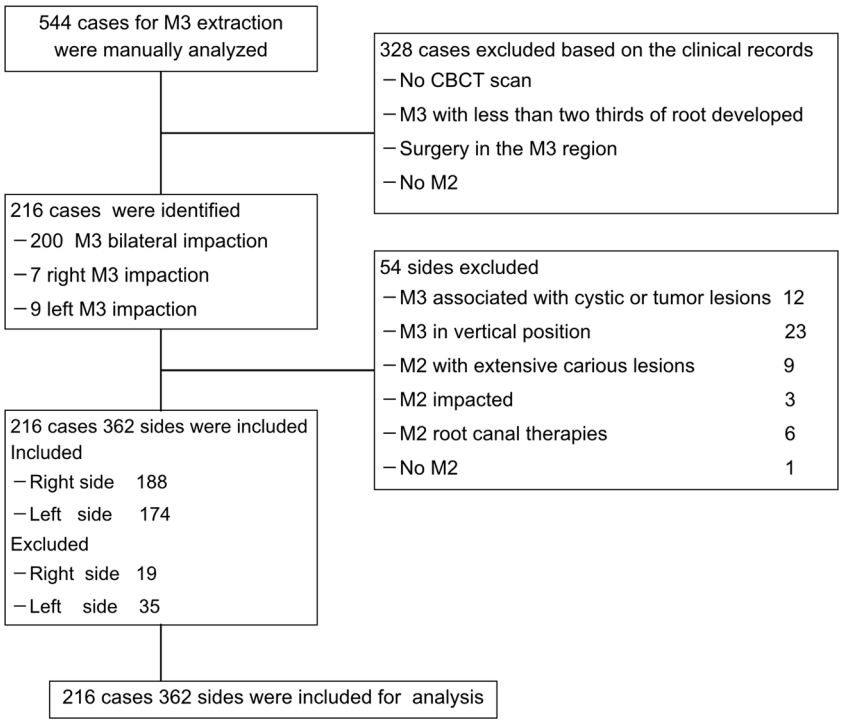

Fig. 1 Patient screen and inclusion protocol

appearance. When the radiolucency has irregular morphology and there is a clear gap between second molars and dental crown of third molar, this lesion was diagnosed as caries as shown in Fig. 2. To verify our methods to identify ERR by CBCT images analyses, the intra-observer agreement was statistically assessed by the consistency among the EER results from randomly selected 10 patients whose images were repeatedly examined by the same observer (Dr. Dongmiao Wang) in consecutive 3 weeks. In addition, the inter-observer agreement was evaluated by the consistency between two examiners (Dr. Dongmiao Wang and Xiaotong He) who independently assessed the ERR presence. When different ideas concerning the radiographic findings on CBCT images occur, they should discuss with another independent observer (Dr. Yanling Wang) and then obtain the final consensus. The location of the ERR in relation to the long axis of the second molar was categorized as three groups: cervical, middle and apical third of the root as shown in Fig. 3. Moreover, the severity of ERR was graded into the four categories as suggested by Ericson and Kurol [19] as follows, no resorption: intact root surface, the cementum layer may be lost; slight resorption: resorption up to half of the dentine thickness; moderate resorption: resorption of the dentine midway to the pulp or more, the pulp lining being unbroken; severe resorption: root resorption with the pulp exposed (Fig. 4). In addition, the impaction depths of the mandibular third molars were evaluated according to the Pell-Gregory classification [20]. The impaction depths of the mandibular third molars were categorized as indicated in Fig. 5. and classified as A, B, C. Class A was defined when the highest portion of the third molar was above or parallel with the occlusal plane of the second molar, while class B was defined when the highest portion of the third molar is between the occlusal plane and cervical line of the second molar. Class C was classified when the highest

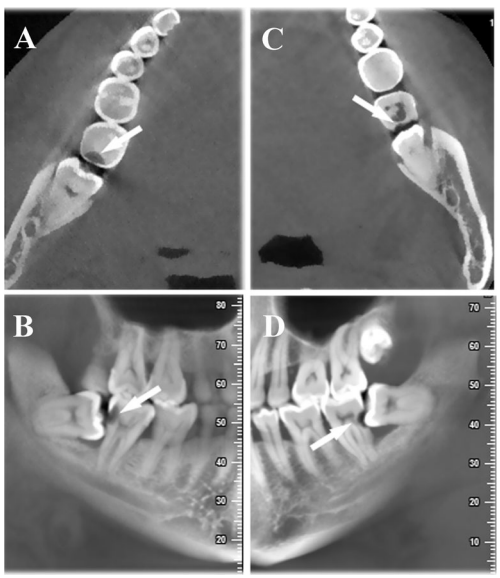

Fig. 2 Dental caries and ERR on second molar identified on CBCT images. **a**, **b**: Distal caries is found in second molar as the radiolucency has irregular morphology and margins. A clear gap exists between the dental crown of the impacted third molar and the distal aspect of the second molar. **c**, **d**: ERR on the second molar is detected in the cervical region and this radiolucency is closely contacted with the dental crown of the impacted third molar. Lesions in the figures were indicated by *white arrows*

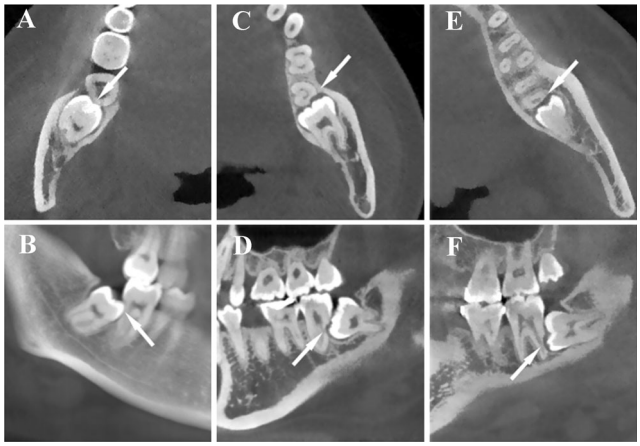

Fig. 3 The locations of ERR on the second molar identified by CBCT scan. ERR is found at the cervical region (**a**, **b**), middle part (**c**, **d**), and apical region (**e**, **f**) of the second molar root

portion of third molar was below the cervical line of the second molar.

All relevant data including the demographic and clinical data of patients included were collected. Associations between two categorical covariates were assessed by Chi-square test. The intra-observer and inter-observer agreement on CBCT findings was estimated by Cohen κ test. Multiple epidemiological, clinical as well as radiographic parameters were analyzed using logistic regression model to evaluate their predictive values for the prevalence of ERR in the second molars. Statistical analyses were performed using Stata 9.2 software program (Texas, USA) with indicated methods. $P < 0.05$ (two-sides) was considered statistically significant.

Results

Through data screen and analyses in our clinical patients registry as described in Fig. 1, we identified 216 patients satisfying the inclusion criteria from a total number of 544 patients who received impacted lower third molar extraction during last two years (2014–2015). As described in Table 1, the mean age was 30.45 years (range: 16–71 years), with 111 (51.39 %) males and 105 (48.61 %) females. In addition, these impacted third molars were categorized into 47 as Class A, 217 as Class B, and 98 as Class C, respectively. Furthermore, unilateral impaction of the mandibular third molar was present in 16 patients (7 at the right, 9 at the left), and the other 200 patients were presented with bilateral impactions. Among these, 54 sides (19 at the right, 35 at the left) were further excluded according to the exclusion criteria. Finally, the original CBCT data of these 216 patients involving 362 impacted mandibular third molars (188 at the right, 174 at the left) were retrieved and further assessed to identify the ERR in the second molars.

The presence of ERR on the distal of the second molar was identified in 50 patients with 73 teeth (23 at the right side, 24 at the left side, 13 at both sides) on CBCT images with overall prevalence 20.17 % (73/362). The κ test analyses revealed good intra-observer (κ = 0.8546, P = 0.002) and inter-observer reliability (κ = 0.8832, P = 0.009) regarding our method to identify the ERR through CBCT images, thus validating the reliably and reproducibility of our methods. Notably, as shown in Table 2, significant associations were found between ERR occurrence and age or impaction depth of lower third molar (P = 0.049, 0.048, Chi-square test), respectively. Particularly, class A and C impactions associated with higher ERR incidence as compared to those with class B impaction. In addition, no significant correlation was detected between the occurrence of ERR and patient gender or impaction sides ($P > 0.05$, Chi-square test). The detailed location and severity of the ERR on the distal surface of the second molars were list in the Table 3. Of all the 73 s molars with ERR, 55 were identified with slight resorption, 9 with moderate resorption and 9 with severe resorption, respectively. Moreover, 32 ERR were observed in cervical, 30 in middle and 11 in apical region of second molars. With regard to the

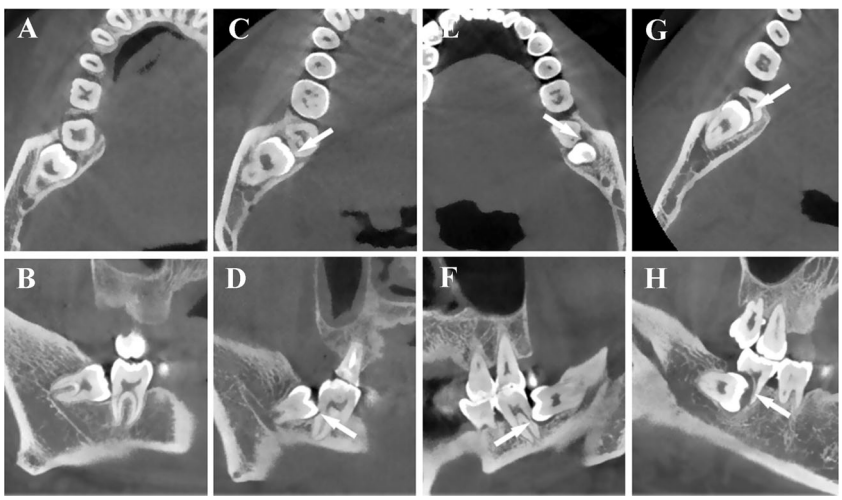

Fig. 4 The severity of ERR on the second molar identified by CBCT scan. No resorption (**a**, **b**), slight resorption (**c**, **d**), moderate resorption (**e**, **f**) as well as severe resorption (**g**, **h**) on the distal aspect of second molars are detected

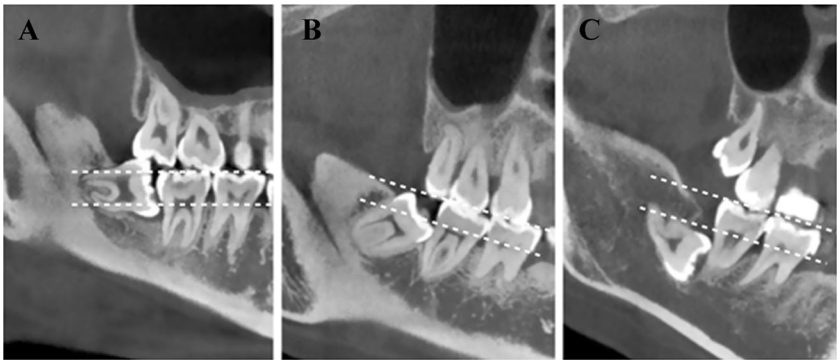

Fig. 5 The Pell-Gregory classification of impacted mandibular third molars. Three types of mandibular third molar impaction, class A (**a**), B (**b**), and C (**c**), are detected based on the impaction depth similar to the Pell-Gregory classification [20]. The *upper white dotted line* indicates the occlusal plane of the second molar. The *lower white dotted line* indicates the cervical line of the second molar, which is parallel with the upper one

impaction depth of these mandibular third molars, 14 ERR were found with class A-impacted third molars, 35 with class B, and 24 with class C. However, there was no significant correlation between the ERR location and ERR severity ($P = 0.115$) as well as the impaction depth and ERR severity ($P = 0.638$). To further strengthen clinical significance of these radiographic ad clinical data concerning ERR associated with mesially and horizontally impacted third molars, we performed multivariate analyses via logic regression assay to identify the risk factors for possible ERR using the gender, age as well as impaction depth as parameters. As indicated in Table 4**,** age over 35 was identified as an independent risk factor for ERR occurrence with adjusted odds ratio 2.47 ($P < 0.05$). Moreover, as compared with class A impaction, the patients with class B impaction tend to have less risk of ERR on second molars with adjusted odds ratio 0.41 ($P < 0.05$).

Discussion

ERR on the adjacent second molar associated with impacted mandibular third molar is not rare and sometime neglected until these resorption penetrates into the pulp and induces inflammation [2, 4]. Previous studies have revealed the incidence of ERR on second molar adjacent to impacted lower third molar ranging from 0.3 to 24.2 % by different radiographic methods [4, 11]. Moreover, the incidence of ERR on the second molars was even much higher (49.43 %) as detected by CBCT in 116 patients with mesially inclined impacted maxillary and mandibular third molars [14]. Here, we selected 211 patients with 356 mesioangular and horizontal impacted mandibular third molars from a total number of 544 patients based on our preset inclusion criteria. Through our radiographic analyses on CBCT multiplanar images, we found that the overall incidence of ERR on second molars adjacent to mesially and horizontally inclined impacted mandibular molars was 20.17 %, which was generally in line with previous findings [5, 11]. The incidence reported here is much lower as

Table 1 Descriptive clinical data of impacted mandibular third molars

Variable		No. (%)
Age (years)	Mean 30.45 (16–71 years)	
Gender	Male	111 (51.39 %)
	Female	105 (48.61 %)
Impaction depth	Class A	47 (12.98 %)
	Class B	217 (59.94 %)
	Class C	98 (27.07 %)
Impaction type	Right side	7 (3.24 %)
	Left side	9 (4.17 %)
	Bilateral side	200 (92.59 %)

Table 2 The prevalence of ERR on the distal surface of the mandibular second molar and its associations with clinical parameters

	ERR presence ($n = 73$)	ERR absence ($n = 289$)	P value
Age (years)			*0.049*
16–24	19	111	
25–35	27	108	
≥ 35	27	70	
Gender			0.163
Male	33	157	
Female	40	132	
Impaction depth of M3			*0.048*
Class A	14	33	
Class B	35	182	
Class C	24	74	
Impaction side of M3			0.616
Left	37	137	
Right	36	152	

The numbers in italics indicate statistically significant data

Table 3 Relationships between ERR severity, location in the second molar and the impaction depth of the mandibular third molar

	Slight	Moderate	Severe	Total	*P* value
Impaction depth					0.638
Class A	12	2	0	14	
Class B	26	4	5	35	
Class C	17	3	4	24	
Location of ERR					0.115
Cervical	29	1	2	32	
Middle	19	6	5	30	
Apical	7	2	2	11	

compared with Oenning et al.'s recent report which is the only clinical and radiographic study with regard to ERR in second molars associated with mesially inclined impacted third molars as detected via CBCT in the literature [14]. We reasoned that this discrepancy might associate with different sample size, patient selection bias, and varied inclusion criteria. A large amount of patients with the same inclusion criteria from multiple centers might be required to further establish the incidence of ERR on second molars associated with mesially impacted mandibular third molars.

The conditions of the second molar, for example the existence of ERR or not, largely influence the treat decision-making about the adjacent impacted third molar [6, 21]. Precise information regarding the actual presence of ERR is definitely required so that dentists may select the appropriate treatment modality. Until now, the accurate identification of ERR on permanent tooth primarily depends on radiographic examinations. Dental and panoramic radiography was commonly exploited to detect the ERR resulted from diverse pathological factors in the clinic [11]. However, these two-dimensional techniques have inherent weakness including more artifacts, image distortion and overlapping, which impede them to become routine approaches to identify ERR. Three-dimensional imaging techniques such as CT and CBCT have proved to be advantageous relative to the two-dimensional radiography to detect ERR as evidenced that much more ERR associated with unerupted maxillary canines and impacted third molars was found via CT/CBCT as compared with dental radiography [14, 22]. Furthermore, high image quality, multiplanar or 3-D views, few artifacts and relative low radiographic dosage make CBCT as a preferred imaging technique to detect ERR [23]. Here we defined ERR as substance loss in root surface and utilized the CBCT images from three planes to identify ERR on second molar. Previous reports have suggest that the presence of caries on distal root surface might complicate the identifications of ERR on the adjacent second molars especially when associate with those partially erupted third molars [24, 25]. In the present study, dental caries on second molars in proximity to impacted third molars were identified when radiolucency has irregular morphology, margins and communicates with oral environment, and there is a gap between second molars and crown of third molar as indicative of no direct contact (Fig. 2) [26]. Indeed, the overwhelming majority of ERR was situated at the site of contact between the root surface of second molar and the third molar crown. Although we cannot absolutely rule out the possibility of dental caries which were mistakenly counted as ERR, we believe that radiographic distinctions between ERR and dental caries is generally reliable with relatively high sensitivity and accuracy, especially when identified via CBCT on multiplanar images. This notion is also supported by

Table 4 Regression analyses of multiple clinical/radiographic parameters as risk factors for ERR incidence

Variable	ERR presence (%)	ERR absence (%)	*P* value	Crude OR (95 % CI)	*P* value	Adjusted OR (95 % CI)
Gender						
Male	33 (17.4)	157 (82.6)		1 (Reference)		1 (Reference)
Female	40 (23.3)	132 (76.7)	0.1645	1.44 (0.86,2.41)	0.1143	1.53 (0.90,2.60)
Age						
16–24	19 (14.6)	111 (85.4)		1 (Reference)		1 (Reference)
25–34	27 (20.0)	108 (80.0)	0.2489	1.46 (0.77,2.78)	0.1433	1.67 (0.84,3.31)
≥ 35	27 (27.8)	70 (72.2)	*0.0156*	2.25 (1.17,4.35)	*0.0132*	2.47 (1.21,5.04)
Impaction depth						
Class A	14 (29.8)	33 (70.2)		1 (Reference)		1 (Reference)
Class B	35 (16.1)	182 (83.9)	*0.0318*	0.45 (0.22,0.93)	*0.0181*	0.41 (0.19,0.86)
Class C	24 (24.5)	74 (75.4)	0.4978	0.76 (0.35,1.66)	0.1755	0.56 (0.24,1.30)

The numbers in italics indicate statistically significant data. The values in the second and third volumes indicate the proportions of patients who fall into categories of each variable, while the numbers in the fifth and seventh volumes indicate the results of 95 % CI (confidence intervals) in multivariate regression analyses

OR odds ratio, *CI* confidential intervals

previous finding that ERR diagnosed using conventional dental radiography was confirmed histologically [27].

Previous studies have revealed that incidence of ERR on the second molar associated with impacted third molar is related to patients gender, age, impaction type and depth, et al. [4, 11, 14]. Yamaoka M et al. reported a higher incidence of root resorption of mandibular second molar in men than women as detected via dental radiographs in 3174 individuals [4]. One explanation for the male preponderance of ERR was the sex hormones which were suggested as one of the predisposing factors for ERR [12]. However, our data and others do not support this as evidenced by the fact that no significant associations were found between ERR and gender [14]. Indeed, our data indicated that patients with age over 24 years had a relatively higher incidence with ERR, which was in agreement with previous findings [14]. Moreover, our data from multivariate regression analyses further revealed that the age especially over 35 was an independent risk factor for ERR. This is not unexpected because root resorption induced by mechanical pressure from impacted third molar might be a progressive process over time [8, 10]. The eruptive tooth movement does not stop after root formation was completed, and these impacted teeth continue to exert mechanical pressure on the adjacent second molars, therefore stimulating ERR formation and progression.

It is well established that the position, angulation and depth of impacted third molars have a significant effect on the associated pathological features and associated with clinical symptoms [11, 28]. Due to the presence of the mesially and horizontally impacted third molars as the primary cause of ERR in second molars [5, 14], the impacted mandibular third molars with mesioangular and horizontal inclinations were included here and the prevalence of ERR on second molar was analyzed. The overall incidence of ERR in our patient cohort is 20.17 %, relatively higher than that in some previous reports but similar with the others [11, 14]. For example, Knutsson et al. reported that ERR on second molar was identified in only 1 % cases by conventional radiography [28]. However, a greater incidence of such ERR was observed by periapical radiographs or CBCT images, respectively [4, 11, 14]. We believe that mesial and horizontal inclinations of impacted third molars have relatively large contact area between the second and third molars, which tends to more pressure resorption. In support of this, our data indicate that the patients with class A (29.8 %) impaction have the most high incidence of ERR in second molars, followed by class C (24.5 %) and B (16.1 %). Consistently, our data from multivariate regression analyses further support this idea as evidenced that class B impaction have less risk to result in ERR incidence as compared with class A and C impactions. These findings suggest that cervical area of the root surface and root apical region might be susceptible regions for ERR. These findings are in line with previous report that the apical region as the most susceptible region for ERR in individuals with completely unerupted third molars [11]. However, Oenning and his colleagues reported that teeth positioned in class A and B were associated with more ERR in second molars compared with class C [14]. We speculate that the difference of patient selection and radiographic techniques might account for this discrepancy. Further studies are needed to identify the vulnerable regions of root surface in second molar which predisposes to ERR incidence by impacted third molars in a large patient cohort.

Retaining or prophylactic extraction of the impacted third molars has been a hot subject of intensive debate [29, 30]. The complications associated with third molar removal have been well documented [31]. If the pathological conditions occur as a result of impacted third molars, the teeth removal is strongly indicated. However, for those asymptomatic third molars, no consensus for management has been reached until now. No sufficient evidence has been obtained to justify the prophylactic extraction of asymptomatic third molars [29]. The decision for impacted third molars may base on clinical assessment and patient preference and should weight the benefits and risks carefully. Our findings and others support that extraction of these impacted third molars is indicated when the diagnosis of ERR on second molars is confirmed by radiographic examinations. Upon the removal of third molars, the affected second molars may need restoration, endodontic or periodontal treatment or even root resection if necessary. Therefore, radiographic assessment like CBCT scan might be beneficial to timely and accurately diagnosis of ERR on the second molars caused by impacted mandibular third molars.

There are several advantages and limitations concerning our findings. The patients included here were strictly filtered and screened based on our inclusion and exclusion criteria to reduce the sample heterogeneity as much as possible. To the best of our knowledge, our sample size might be the largest one to evaluate second molar ERR by CBCT image analyses. However, data from a large amount of patients is still needed to further validate our findings. Moreover, the present study is a retrospective study with potential bias of sample selection. ERR is identified by CBCT scan only which lacks of adequate clinical or histological validations such as evidence from direct visualization or histological examination. To address this limitations, the longitudinal study of ERR by radiographic surveillance is warranted to provide convincing scientific evidence in support of our findings.

In conclusion, ERR in second molars resulted from mesially and horizontally impacted third molars is not a rare clinical condition and can be accurately identified by CBCT scan. The incidence of ERR significantly associates with patient age and impaction depth. The age with over 35 years is identified as an independent risk factor for ERR in the adjacent second molars. When direct contact between the second and impacted third lower molar is observed in the radiography, ERR on second molar should not be neglected and active surveillance or prophylactic extraction could be suggested in the clinic.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of our institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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

References

1. Al-Khateeb TH, Bataineh AB (2006) Pathology associated with impacted mandibular third molars in a group of Jordanians. J Oral Maxillofac Surg 64(11):1598–1602
2. van der Linden W, Cleaton-Jones P, Lownie M (1995) Diseases and lesions associated with third molars. Review of 1001 cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 79(2):142–145
3. Guven O, Keskin A, Akal UK (2000) The incidence of cysts and tumors around impacted third molars. Int J Oral Maxillofac Surg 29(2):131–135
4. Yamaoka M, Furusawa K, Ikeda M, Hasegawa T (1999) Root resorption of mandibular second molar teeth associated with the presence of the third molars. Aust Dent J 44(2):112–116
5. Oenning AC, Neves FS, Alencar PN, Prado RF, Groppo FC, Haiter-Neto F (2014) External root resorption of the second molar associated with third molar impaction: comparison of panoramic radiography and cone beam computed tomography. J Oral Maxillofac Surg 72(8):1444–1455
6. Fuss Z, Tsesis I, Lin S (2003) Root resorption—diagnosis, classification and treatment choices based on stimulation factors. Dent Traumatol 19(4):175–182
7. Holcomb JB, Dodds RN, England MC (1983) Endodontic treatment modalities for external root resorption associated with impacted mandibular third molars. J Endod 9(8):335–337. doi:10.1016/S0099-2399(83)80149-6
8. Benenati FW (1997) Root resorption: types and treatment. Gen Dent 45(1):42–45
9. Pandis N, Nasika M, Polychronopoulou A, Eliades T (2008) External apical root resorption in patients treated with conventional and self-ligating brackets. Am J Orthod Dentofac Orthop 134(5):646–651. doi:10.1016/j.ajodo.2007.01.032
10. Larson TD (2010) Causes and treatment of root resorption. Northwest Dent 89(3):45–47
11. Nemcovsky CE, Libfeld H, Zubery Y (1996) Effect of non-erupted 3rd molars on distal roots and supporting structures of approximal teeth. A radiographic survey of 202 cases. J Clin Periodontol 23(9):810–815
12. Nitzan D, Keren T, Marmary Y (1981) Does an impacted tooth cause root resorption of the adjacent one? Oral Surg Oral Med Oral Pathol 51(3):221–224
13. Nakata K, Naitoh M, Izumi M, Ariji E, Nakamura H (2009) Evaluation of correspondence of dental computed tomography imaging to anatomic observation of external root resorption. J Endod 35(11):1594–1597
14. Oenning AC, Melo SL, Groppo FC, Haiter-Neto F (2015) Mesial inclination of impacted third molars and its propensity to stimulate external root resorption in second molars—a cone-beam computed tomographic evaluation. J Oral Maxillofac Surg 73(3):379–386
15. Guerrero ME, Shahbazian M, Elsiena Bekkering G, Nackaerts O, Jacobs R, Horner K (2011) The diagnostic efficacy of cone beam CT for impacted teeth and associated features: a systematic review. J Oral Rehabil 38(3):208–216
16. Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS (2015) Technical aspects of dental CBCT: state of the art. Dentomaxillofac Radiol 44(1):20140224
17. Oles RD (1979) Root resorption associated with impacted third molars. Oral Surg Oral Med Oral Pathol 48(3):281
18. Winter GB (1926) Impacted mandibular third molars. American Medical Book Co., St Louis, pp. 241–279
19. Ericson S, Kurol J (2000) Incisor root resorptions due to ectopic maxillary canines imaged by computerized tomography: a comparative study in extracted teeth. Angle Orthod 70(4):276–283
20. Pell GJ, Gregory BT (1933) Impacted mandibular third molars: classification and modified techniques for removal. Dent Digest 39:330–338
21. Nunn ME, Fish MD, Garcia RI, Kaye EK, Figueroa R, Gohel A, et al. (2013) Retained asymptomatic third molars and risk for second molar pathology. J Dent Res 92(12):1095–1099
22. Alqerban A, Jacobs R, Souza PC, Willems G (2009) In-vitro comparison of 2 cone-beam computed tomography systems and panoramic imaging for detecting simulated canine impaction-induced external root resorption in maxillary lateral incisors. Am J Orthod Dentofac Orthop 136(6):764 e1-11; discussion -5
23. De Vos W, Casselman J, Swennen GR (2009) Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg 38(6):609–625
24. Kang F, Huang C, Sah MK, Jiang B (2016) Effect of eruption status of the mandibular third molar on distal caries in the adjacent second molar. J Oral Maxillofac Surg 74(4):684–692
25. Katkar RA (2015) Mesially inclined third molars may or may not be associated with external root resorption in adjacent second molars. J Evid Based Dent Pract 15(3):131–133
26. Falci SG, de Castro CR, Santos RC, de Souza Lima LD, Ramos-Jorge ML, Botelho AM, et al. (2012) Association between the presence of a partially erupted mandibular third molar and the existence of caries in the distal of the second molars. Int J Oral Maxillofac Surg 41(10):1270–1274
27. Nemcovsky CE, Tal H, Pitaru S (1997) Effect of non-erupted third molars on roots of approximal teeth. A radiographic, clinical and histologic study. J Oral Pathol Med 26(10):464–469
28. Knutsson K, Brehmer B, Lysell L, Rohlin M (1996) Pathoses associated with mandibular third molars subjected to removal. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 82(1):10–17
29. Dodson TB (2012) Surveillance as a management strategy for retained third molars: is it desirable? J Oral Maxillofac Surg 70(9 Suppl 1):S20–S24
30. Mettes TG, Nienhuijs ME, van der Sanden WJ, Verdonschot EH, Plasschaert AJ (2005) Interventions for treating asymptomatic impacted wisdom teeth in adolescents and adults. Cochrane Database Syst Rev 2:CD003879
31. Lopes V, Mumenya R, Feinmann C, Harris M (1995) Third molar surgery: an audit of the indications for surgery, post-operative complaints and patient satisfaction. Br J Oral Maxillofac Surg 33(1):33–35