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ORIGINAL ARTICLE

External root resorption in maxillary and mandibular second molars associated with impacted third molars: a cone-beam computed tomographic study

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Abstract

Objective To separately investigate the prevalence and risk factors of external root resorption (ERR) in maxillary and mandibular second molars (M2s) adjacent to impacted third molars (M3s).

Materials and methods CBCT scans involving 184 maxillary and 323 mandibular impacted M3s were included. Age, gender, the impaction status of M3, the presence, severity, and location of ERR in M2 were assessed. Risk factors were identified by multivariate logistic regression analyses.

Results The prevalence of ERR was 32.6% in maxillary and 52.9% in mandibular M2s ($P < 0.001$). Mesio-angulated and deeply impacted M3s were identified as risk factors for both ERR in maxillary and mandibular M2s ($P < 0.05$). Besides, age over 25 increased the risk of ERR in maxillary M2s ($P < 0.05$). ERR in maxillary M2s was overall more severe than that in mandibular M2s ($P < 0.001$). For maxillary M2s, ERR mostly occurred at the apical third, while the mandibular M2s ERR was most frequently detected at the cervical third.

Conclusions ERR occurring in M2s adjacent to impacted M3s is common, especially in mandibular M2s. ERR in maxillary M2s cannot be neglected because of its relatively high severity. Mesial angulation and impaction depth of M3 are significantly associated with ERR in M2s. For ERR in maxillary M2s, age is another predictive parameter.

Clinical relevance Considering the presence of ERR is associated with M3s' impaction, watchful monitoring or prophylactic removal of impacted M3s should be deliberated especially for the patients over 25 years and with mesially inclined and deeply positioned M3s.

Keywords External root resorption · Impacted third molar · Second molar · Cone-beam computed tomography

Introduction

Impacted third molars (M3s), which fail to completely erupt into functional position due to either lack of space or development in an abnormal position, may bear pathological changes including periodontitis, caries, and development of cysts or tumors [1]. They were also associated with caries in the distal surface of adjacent second molars (M2s), external root resorption (ERR) of M2s, and damage to the distal periodontal tissue of M2s [2, 3].

External root resorption (ERR) was defined as the loss of hard dental tissue (i.e., cementum and dentin) on the external surface of a permanent tooth, primarily as a result of the action of odontoclastic cells [4]. Occurrence of root resorption required two phases: chemical or mechanical injury to the protective tissues and stimulation by

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infection or pressure [5]. ERR in M2s occurring at the site of contact with adjacent impacted M3s indicated that the pressure exerted by the latter took part in the process of this type of resorption [6], which was usually aseptic [5]. Therefore, unlike caries or periodontitis, this kind of damage to M2s associated with M3s could not be prevented by good oral hygiene. The lack of pathognomonic symptoms and its hidden position could result in belated diagnosis of ERR [7], which highlights the significance of identifying the risk factors for ERR in M2s associated with impacted M3s.

The literature regarding ERR in M2s associated with impacted M3s were mainly case reports or retrospective studies based on periapical or panoramic radiographs, reporting the ERR prevalence ranging from 0.3 to 24.2% [8–11]. However, two-dimension (2D) radiography, with superimposition of images of anatomical features located at different distances from the X-ray source, may give rise to relatively high false positive or negative interpretation of hard tissue loss, leading to inaccurate diagnosis of ERR [12]. Nowadays, cone-beam computed tomography (CBCT), with distinct advantages of three-dimension (3D) visualization free from overlaps, had been widely applied in dental practice [7]. Several recent studies have found that the prevalence of ERR based on CBCT assessment can be 1.3–4.3 times more than those based on panoramic radiographs [13, 14]. In particular, the prevalence of ERR in M2s based on assessment of CBCT images ranged 20.2–54.9% [12–17].

The prevalence and associated factors of ERR in mandibular M2s adjacent to impacted M3s have been extensively reported [9, 12, 14–16], while the knowledge of ERR in maxillary M2s remained limited. According to a few CBCT studies, the prevalence of ERR in mandibular M2s was significantly higher than that in maxillary M2s [13, 17]. However, when risk factors for the presence of ERR in M2s were assessed, the cases in maxillary and mandibular M2s had to be pooled together for analysis due to the limited sample sizes in the previous studies [6, 8, 13, 17]. Considering the differences of bone structures, tooth anatomies, and M3s eruption trajectories between the upper and lower jaws, which may result in the discrepant prevalence of ERR, separate evaluation of the risk factors for ERR in maxillary and mandibular M2s might be more reliable.

Therefore, the objective of this retrospective research, based on CBCT scans, was to analyze the prevalence of ERR in maxillary and mandibular M2s adjacent to impacted M3s, and to identify the risk factors for the presence of ERR in M2s from upper and lower jaws respectively. Besides, the severity of ERR in maxillary and mandibular M2s was also investigated.

Materials and methods

Sample selection

The study was reviewed and approved by the Ethics Committee of the Guanghua School and Hospital of Stomatology, Sun Yat-sen University (ERC-2017-09). Seven hundred and twelve CBCT images were randomly selected from an archive of 3500 radiographs with a field of view (FOV) of 16 × 7 cm and a voxel size of 0.20 mm, which were just enough to display the complete upper and lower dentition and were of sufficiently high resolution. These CBCT radiographs had been taken for diagnostic purposes before treatment at various departments, including endodontics (most), surgery, and orthodontics, in the Hospital of Stomatology, Sun Yat-sen University between January 2010 and January 2018.

The included CBCT scans must adequately display the relation between the impacted M3 (i.e., M3 without a functional position) and the adjacent M2 in the FOV. The exclusion criteria were as follows: the M3s or M2s associated with cystic lesions, the M3s or M2s presenting extensive carious lesions or malformations, the M3s with less than two thirds of the root developed, images with artifacts due to the presence of high-density materials or other reasons that obscured the areas of local anatomy and structures [12].

Via screening with the inclusion/exclusion criteria mentioned above, CBCT data of 276 patients (124 males and 152 females), with a mean age of 34 years (range from 16 to 81 years), involving 507 M2s adjacent to impacted M3s (184 in maxilla and 323 in mandible; 266 at the left and 241 at the right) were collected and assessed.

Radiographic assessment

The images were obtained by a CBCT scanner (DCTPRO, VATECH, Yongin-Si, Republic of Korea). The operating parameters were set at 90.0 kVp and 9.0 mA with a scanning time of 24 s. The measurements were evaluated by using the Ez3D 2009 software (Vatech Corporation, Hwaseong-si, Gyeonggi-do, Republic of Korea).

According to the classification by Pell and Gregory [18], the impaction depth of the M3 was categorized as follows: class A, the highest portion of the M3 was above or level with the occlusal plane of the M2; class B, the highest portion of the M3 was between the occlusal plane and the cervical line of the M2; and class C, the highest portion of the M3 was below the cervical line of the M2 (Fig. 1a, b). The mesial angulation of the M3 was determined by measuring the angle at which the occlusal plane of the M2 and the occlusal plane of the M3 intersected [19] (Fig. 1c). Here, the M3 was defined as distally, vertically, mesially, and horizontally impacted when the mesial angulation was < − 14°, − 14–15°, 16–75°, and > 75°, respectively. The distance between the mesial cementoenamel

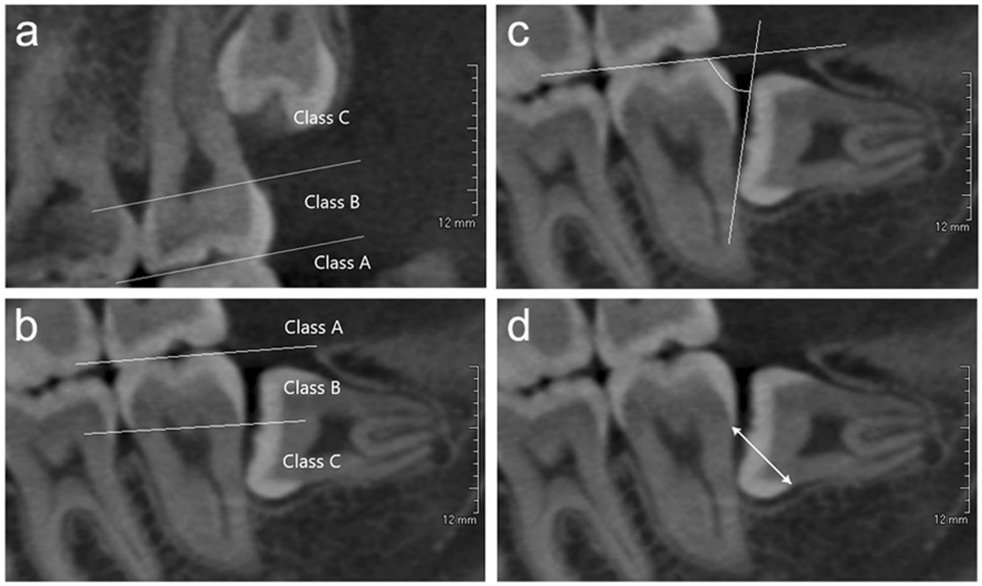

Fig. 1 Impaction status of the third molar (M3). **a**, **b** Impaction depth of the M3 according to the classification of Pell and Gregory [18]. **c** Mesial angulation of the M3 [19]. **d** Distance between the mesial cementoenamel junction (CEJ) of the M3 and the distal CEJ of the second molar (M2) [20]

junction (CEJ) of the M3 and the distal CEJ of the adjacent M2 (abbreviated as "CEJ distance") was measured according to Leone et al [20] (Fig. 1d). All the abovementioned variables describing the impaction status of the M3 were evaluated in the sagittal planes of CBCT scans. Among them, the mesial angulations of the M3 and the CEJ distance were both measured in three different sagittal planes, and then the average values were recorded [21]. In order to precisely describe the impaction status, the buccal/lingual inclination of the M3, which was evaluated in the coronal or axial planes, was also assessed.

The presence of ERR was defined as a clear loss of substance on the distal surface of the root of M2 due to direct contact between the M2 and the adjacent M3 [10]. The ERR was classified according to its location (cervical, middle, or apical third of the root) and severity (slight: involving less than half the dentin thickness; moderate: involving at least half the dentin; severe: involving the pulp cavity [22]) (Fig. 2).

All the images were independently evaluated by two observers (Danna Li and Yiwei Tao). If there was disagreement, it was resolved by discussion to consensus. Should the disagreement not be resolved, a third author Dr. Minyi Cui (radiologist) was consulted to come to agreement. In order to verify the reproducibility of our measurement of the above radiographic characteristics, the intra-observer agreement was assessed after the examination of 51 randomly selected cases (10% of the whole) was repeated by the same observer (Danna Li) with an interval of 1 month.

Statistical analyses

Statistical analyses were performed using SPSS software, version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). The inter-observer and intra-observer agreement on the measurement of the radiographic characteristics was estimated by Cohen's κ test (poor agreement, less than 0.40; moderate agreement, 0.40 to 0.59; good agreement, 0.60 to 0.74; excellent agreement, 0.75 to 1.00) [16]. Since wisdom teeth usually erupt from about 16 years, we grouped patients in 16–25, 26–35, and > 35 years with 10-year increments from 16 years [12]. Associations between the demographic (age and gender) or radiographic characteristics and the presence of ERR on the distal surface of M2 were assessed by Pearson χ^2 independence tests. Then, two multivariate logistic regression models were built to further evaluate predictive values of the screened factors for the prevalence of ERR in maxillary and mandibular M2s, respectively. The association between ERR severity and age was evaluated by Goodman and Kruskal's gamma correlation analysis. ERR severity among different groups classified according to the radiographic characteristics was compared by Mann-Whitney U test or Kruskal-Wallis test. The significance was set at $P < 0.05$.

Results

The κ test revealed excellent inter-observer agreement (κ = 0.848–0.977, $P < 0.001$) and intra-observer reliability (κ = 0.754–0.970, $P < 0.001$).

The prevalence of ERR in maxillary M2s and mandibular M2s were 32.6% (60/184) and 52.9% (171/323), respectively ($\chi^2 = 19.538$, $P < 0.001$).

ERR in M2s and its associations with various demographic and radiographic characteristics are shown in Table 1. Pearson χ^2 independence tests indicated that age, mesial angulation of M3, and impaction depth of M3 and CEJ distance were related to the presence of ERR in maxillary M2s ($P < 0.05$). For mandibular M2s, significant associations were found between ERR and mesial angulation of M3, impaction depth of M3,

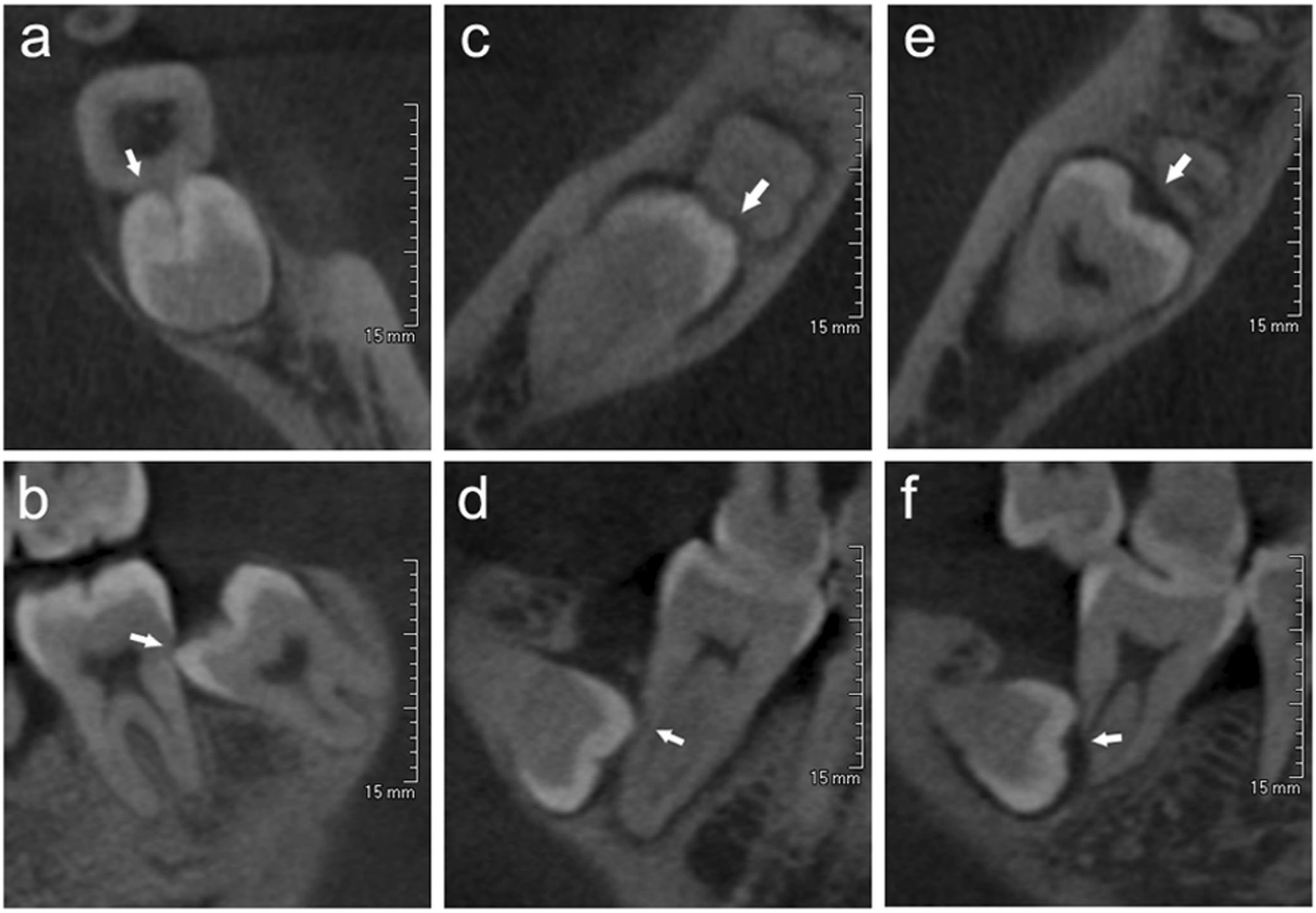

Fig. 2 The severity of external root resorption (ERR) on the distal surface of M2 identified by CBCT scans from axial and sagittal tomograms. **a**, **b** Slight resorption. **c**, **d** Moderate resorption. **e**, **f**: Severe resorption [22]

and buccal/lingual inclination of M3 and CEJ distance ($P < 0.05$). Compared to the other age groups, ERR in maxillary M2s was less found in patients aged 16–25 years (18.3%). 84.8% (156/184) of the impacted maxillary M3s were disto-angular or vertical (mesial angulation < − 14° and− 14–15°), while 80.5% (260/323) of the impacted mandibular M3s were mesially or horizontally inclined (mesial angulation 16–75° and > 75°). Notably, M3s with mesial angulation 46–75° were related to the highest prevalence of ERR in M2s (maxillary, 100%; mandibular, 78.1%), followed by those with mesial angulation 16–45°.

As the factor "CEJ distance" was significantly correlated with the factor "mesial angulation of M3" ($R^2 = 0.480$, $P < 0.001$) (Fig. 3), CEJ distance was not included in the multivariate logistic regression models.

As shown in Table 2, age over 25 years was identified as a risk factor for ERR in maxillary M2s (26–35 years: OR 4.29; over 35 years: OR 3.06; both $P < 0.05$). M3s with mesial inclinations of 16–75° (i.e., mesially impacted) were 9.66 times more likely to cause ERR in maxillary M2s when compared with those outside of this range ($P < 0.05$). Moreover, class B and C impacted M3s presented higher risk to cause ERR in maxillary M2s when compared with class A impacted M3 s (OR 6.80 and 11.24, respectively; both $P < 0.05$).

For ERR in mandibular M2s, mesial angulation of M3 over 15° (i.e., mesially and horizontally impacted) was associated with the increased risk ($P < 0.05$) (Table 3). Especially, the M3s with mesial inclination between 46 and 75° were highly likely to result in ERR of M2s (OR 49.41; $P < 0.05$). In addition, the risk of ERR in mandibular M2s associated with impacted M3s in depth of class C was 3.09 times higher than that resulted from class A and B impacted M3s ($P < 0.05$) (Table 3).

Distributions of ERR severity were different between maxillary (55.0% slight, 8.3% moderate, 36.7% severe) and mandibular M2s (77.8% slight, 18.7% moderate, 3.5% severe). M2s ERR in maxilla was overall more severe than that in mandible (Mann-Whitney U test, mean rank = 141.09, 107.20; $P < 0.001$).

The severity of ERR in maxillary M2s increased with age, so did that in mandibular M2s ($G > 0$; both $P < 0.001$) (Table 4). ERR severity of maxillary M2s was statistically different among groups according to its location, mesial angulation, and impaction depth of M3 ($P < 0.05$) (Table 5).

Table 1 The prevalence of ERR on distal surface of M2s and its associations with the demographic/radiographic characteristics

Variables	Maxillary ($n = 184$)				Mandibular ($n = 323$)			
	Total	ERR presence		*P* value	Total	ERR presence		*P* value
		Yes (%)	No (%)			Yes (%)	No (%)	
Age (years)				*0.001**				0.780
16–25	82	15 (18.3)	67 (81.7)		112	57 (50.9)	55 (49.1)	
26–35	49	22 (44.9)	27 (55.1)		108	60 (55.6)	48 (44.4)	
≥ 36	53	23 (43.4)	30 (56.6)		103	54 (52.4)	49 (47.6)	
Gender				0.702				0.520
Male	68	21 (30.9)	47 (69.1)		157	86 (54.8)	71 (45.2)	
Female	116	39 (33.6)	77 (66.4)		166	85 (51.2)	81 (48.8)	
Mesial angulation of M3				< *0.001**				< *0.001**
< − 14°	97	21 (21.6)	76 (78.4)		21	1 (4.8)	20 (95.2)	
− 14–15°	59	17 (28.8)	42 (71.2)		42	4 (9.5)	38 (90.5)	
16–45°	19	13 (68.4)	6 (31.6)		55	29 (52.7)	26 (47.3)	
46–75°	9	9 (100.0)	0 (00.0)		114	89 (78.1)	25 (21.9)	
> 75°	–	–	–		91	48 (52.7)	43 (47.3)	
Impaction depth of M3				< *0.001**				*0.008**
Class A	32	2 (6.2)	30 (93.8)		99	60 (60.6)	39 (39.4)	
Class B	66	19 (28.8)	47 (71.2)		175	79 (45.1)	96 (54.9)	
Class C	86	39 (45.3)	47 (54.7)		49	32 (65.3)	17 (34.7)	
Buccal/lingual inclination of M3				0.519				*0.010**
No	56	17 (30.4)	39 (69.6)		177	104 (58.8)	73 (41.2)	
Buccal	102	32 (31.4)	70 (68.6)		40	13 (32.5)	27 (67.5)	
Lingual	26	11 (42.3)	15 (57.7)		106	54 (50.9)	52 (49.1)	
CEJ distance (mm)				< *0.001**				< *0.001**
≤ 6	107	19 (17.8)	88 (82.2)		104	32 (30.8)	72 (69.2)	
6.1–9	49	23 (46.9)	26 (53.1)		126	87 (69.0)	39 (31.0)	
> 9	28	18 (64.3)	10 (35.7)		93	52 (55.9)	41 (44.1)	

* Statistically significant ($P < 0.05$ by Pearson χ^2 independence test between categorical variables)

Notably, the ERR location was differently distributed in maxillary and mandibular M2s. More than half of maxillary M2s ERR were located at the apical third of the root (31/60), while the mandibular M2s ERR was mostly detected at the cervical (83/171) and middle thirds (66/171). For both maxillary and mandibular M2s, ERR occurring at apical third of the root was the most severe (Tables 5 and 6).

Discussion

The factors associated with ERR in maxillary and mandibular M2s have not yet been respectively identified, though ERR was more frequently detected in mandibular M2s than maxillary ones on both panoramic radiographs and CBCT images [13, 17]. This is the first study to separately analyze the effect of impacted M3s on ERR in maxillary and mandibular M2s based on CBCT examination. The risk factors of M2s ERR associated with impacted M3s were characterized.

In the present investigation, the prevalence of ERR associated with impacted M3s was 32.6% in maxillary and 52.9% in mandibular M2s, which was generally agreed with previous CBCT findings (from 20.2 to 54.9%) [12–17]. The difference between the prevalence of ERR in upper and lower M2s could be partially explained by the fact that the most common impaction type of maxillary M3s was the disto-angular and vertical, while that of mandibular M3s was the mesio-angular and horizontal (Table 1). Mesio-angular and horizontal impaction of M3 has been identified as a risk factor of ERR in adjacent M2s [8, 13–15, 17]. In addition, the distal portions of upper and lower M2s differed in configuration, so their susceptibility to the pressure caused by impacted M3s may be different even when the upper and lower M3s were in the same impaction status.

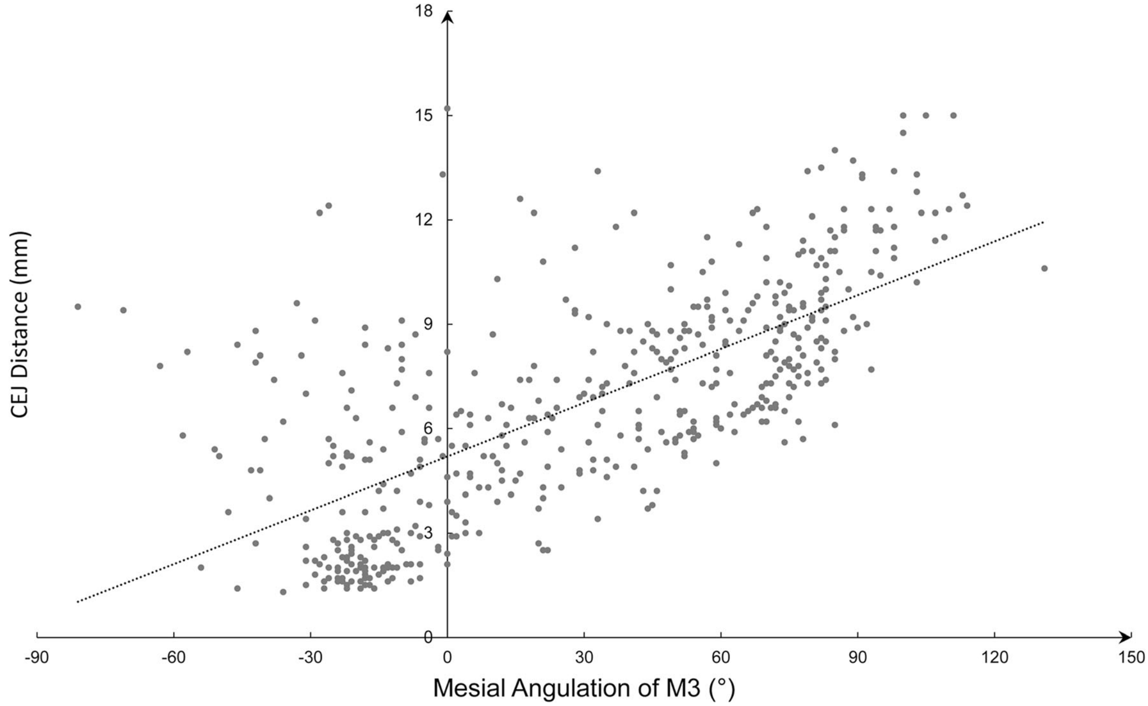

Fig. 3 Correlation between mesial angulation of the third molar (M3) and "CEJ distance" ($R^2 = 0.480$, $P < 0.001$). CEJ distance, the distance between the mesial cementoenamel junction (CEJ) of the M3 and the distal CEJ of the second molar (M2)

Potential factors associated with ERR in M2s were explored separately for upper and lower jaws in our study. Some risk factors were related to ERR both in maxillary and in mandibular M2s, including mesio-angular and class C impaction of M3s. The results have strengthened clinical observations that the mesially and horizontally impacted M3s were

Table 2 Multivariate logistic regression analysis of demographic/radiographic parameters as risk factors for prevalence of ERR in maxillary M2s

Variables	OR (95% CI)	*P* value
Age (years)		
16–25	1	
26–35	4.29 (1.64–11.20)	*0.003**
≥ 36	3.06 (1.23–7.63)	*0.016**
Mesial angulation of M3[a]		
< − 14°	1	
− 14–15°	1.63 (0.70–3.77)	0.254
16–75°	9.66 (3.21–29.09)	*< 0.001**
Impaction depth of M3		
Class A	1	
Class B	6.80 (1.30–35.50)	*0.023**
Class C	11.24 (2.30–54.93)	*0.003**

OR, odds ratio; *CI*, confidence interval

* Statistically significant ($P < 0.05$ by multivariate logistic regression analysis)

[a] The primary groups 16–45° and 46–75° were merged into a new group 16–75°, due to insufficiency of sample size

Table 3 Multivariate logistic regression analysis of demographic/radiographic parameters as risk factors for prevalence of ERR in mandibular M2s

Variables	OR (95% CI)	*P* value
Age (years)		
16–25	1	
26–35	0.87 (0.46–1.67)	0.684
≥ 36	0.62 (0.30–1.26)	0.185
Mesial angulation of M3[a]		
≤ 15°	1	
16–45°	16.17 (5.43–48.20)	*< 0.001**
46–75°	49.41 (16.74–145.82)	*< 0.001**
>75°	11.21 (3.76–33.40)	*< 0.001**
Impaction depth of M3		
Class A	1	
Class B	0.65 (0.35–1.21)	0.177
Class C	3.09 (1.15–8.31)	*0.025**
Buccal/lingual inclination of M3		
No	1	
Buccal	1.09 (0.40–2.96)	0.867
Lingual	0.72 (0.41–1.28)	0.269

OR, odds ratio; *CI*, confidence interval

* Statistically significant ($P < 0.05$ by multivariate logistic regression analysis)

[a] The primary groups < − 14° and − 14–15° were merged into a new group ≤ 15°, due to insufficiency of sample size

Table 4 Association between ERR severity and patient age

Position	Age (year)	ERR severity			*G*	*P* value
		Slight	Moderate	Severe		
Maxillary	16–25	15	0	0	0.707	*< 0.001*[*]
	26–35	11	2	9		
	≥ 36	7	3	13		
Mandibular	16–25	53	4	0	0.560	*< 0.001*[*]
	26–35	47	10	3		
	≥ 36	33	18	3		

[*] Statistically significant ($P < 0.05$ by Goodman and Kruskal's gamma rank correlation analyses between ordinal variables)

more likely to cause ERR in M2s [8, 13–15, 17], probably because of a relatively large contact area between the M3 and the M2. Our data found that class C impaction were associated with the highest prevalence of ERR in maxillary and mandibular M2s (45.3% and 65.3%, respectively), which was in line with previous reports that the apical region was the most susceptible region for ERR in subjects with completely impacted M3s [8]. Nevertheless, Oenning et al stated that class A and B impaction was related to a higher ERR prevalence in mandibular M2s compared with class C [16]. More recently, Wang et al demonstrated that class A and C impaction had a higher risk to cause ERR in mandibular M2s when compared with Class B [12]. These discrepancies may be due to the difference of patient selection and inclusion criteria. A large-sample study with a consistent inclusion/exclusion criteria from multiple clinical centers would be invaluable to further our understanding of M3 impaction and its effects on the adjacent M2, including the prevalence of ERR in M2s.

Moreover, the present study revealed that horizontally impacted M3s in the lower jaw and class B impacted M3s in the upper jaw were also risk factors of ERR in M2s. Of note, the mesial inclination of M3s was quantified in this study, reducing observation bias and enriching information about mesially impacted M3s in detail. Although horizontally impacted M3s have a larger contact area with their adjacent M2s, mesially impacted M3s with an inclination of 46–75° were identified to have the highest risk to cause ERR in mandibular M2s, according to our results. This implied that ERR of M2s was most likely to occur when the stress from the mandibular impacted M3 was directed to a certain area of the distal surface of the M2. Maxillary M3s with mesial angulation 46–75° could not be isolated for the regression analysis due to the limited samples, though we

Table 5 Comparisons of the severity of ERR in maxillary M2s among groups classified according to the radiographic characteristics

Variables	*n*	Mean rank	*Z* or H_C	*P* value
Mesial angulation of M3[a]			6.979	*0.031*[*]
< − 14°	21	37.38 (II)		
−14–15°	17	24.65 (I)		
16–75°	22	28.45 (I, II)		
Impaction depth of M3[b]			− 3.159	*0.002*[*]
Class A and B	21	21.90		
Class C	39	35.13		
Buccal/lingual inclination of M3			3.734	0.155
No	17	24.97		
Buccal	32	33.84		
Lingual	11	29.32		
ERR location of M2			29.057	*< 0.001*[*]
Cervical	17	18.12 (I)		
Middle	12	21.29 (I)		
Apical	31	40.85 (II)		

[*] Statistically significant difference ($P < 0.05$ by Mann-Whitney U test or Kruskal-Wallis test)

[a] The primary groups 16–45° and 46–75° were merged into a new group 16–75°, due to insufficiency of sample size

[b] The primary groups Class A and Class B were merged into a new group Class A and B, due to insufficiency of sample size

I, II Different letters indicate statistically significant difference between groups, while the same letter indicates no statistically significant difference between groups ($P < 0.017$ by Post-hoc comparisons using the Bonferroni method to correct the significance level)

Table 6 Comparison of the severity of ERR in mandibular M2s among groups classified according to the radiographic characteristics

Variables	*n*	Mean rank	*Z* or H_C	*P* value
Mesial Angulation of M3[a]			2.687	0.261
≤ 45°	34	81.56		
46–75°	89	83.90		
> 75°	48	93.04		
Impaction depth of M3			4.233	0.120
Class A	60	83.50		
Class B	79	83.15		
Class C	32	97.73		
Buccal/lingual inclination of M3			4.754	0.093
No	104	82.25		
Buccal	13	79.69		
Lingual	54	94.73		
ERR location of M2			11.100	*0.004*[*]
Cervical	83	81.91 (I)		
Middle	66	83.25 (I)		
Apical	22	109.68 (II)		

[*] Statistically significant difference ($P < 0.05$ by Mann-Whitney U test or Kruskal-Wallis test)

[a] The primary groups < −14°, − 14–15° and 16–45° were merged into a new group ≤ 45°, due to insufficiency of sample size

I, II Different letters indicate statistically significant difference between groups, while the same letter indicates no statistically significant difference between groups ($P < 0.017$ by Post-hoc comparisons using the Bonferroni method to correct the significance level) found they resulted in a very high prevalence of ERR in their adjacent M2s. A further study with sufficient sample size in the upper jaw was needed to provide a better insight.

Age over 25 years was identified as another risk factor for ERR in maxillary M2s, which accorded with previous findings that younger patients had relatively lower incidence of ERR [8, 12, 16, 17]. However, we found no significant association between ERR prevalence and age for mandibular M2s. This could be explained by the fact that, when compared to upper impacted M3s, lower impacted M3s are either more readily symptomatic or more visually accessible, thus leading to earlier extraction.

Although ERR was more frequently found in mandibular M2s than in maxillary ones, it was overall more severe in maxillary M2s than in mandibular ones. Our results supported the notion that once ERR occurs, its severity increases with age because root resorption induced by mechanical pressure from impacted teeth may be progressive over time [12]. From this viewpoint, early removal of the impacted M3s was highly suggested to prevent further damage to M2s once ERR was detected. Notably, ERR at apical third of the root was found to be the most severe, which was in line with the findings by Nemcovsky et al [8]. According to their statement, the pressure on the periodontal ligament and distal surface of the roots of M2s would decrease when M3s were partially erupted. Another possible explanation is that apical cementum is considerably softer than cervical cementum [23]. When the upper and lower jaws were separately considered, ERR in maxillary M2s mostly occurred at the apical third of the root, while ERR in mandibular M2s least occurred at the apical third (Tables 5 and 6). Based on the above, it is indeed reasonable that the severity of ERR in maxillary M2s was higher than that in mandibular M2s.

There is still insufficient evidence to support or refute routine prophylactic removal of asymptomatic impacted M3s in adults [1]. Our study has found a relatively high prevalence of ERR in M2s adjacent to impacted M3s and a higher risk of ERR in maxillary M2s for patients older than 25 years, which may support prophylactic extraction of impacted M3s. Besides, we identified mesial angulation and impaction depth of M3s as important factors associated with ERR prevalence in M2s, which should be taken into consideration for making clinical decisions. Surgeons should also take into account other pathological changes related to M3s and the potential complications associated with the surgery before removing M3s. In addition, since the prognosis and the treatment of ERR in M2s adjacent to impacted M3s are dependent on location and severity of the lesion [24], the analyses of location and severity of ERR in this study could provide in-depth reference for the treatment planning of involved M3s and M2s.

The radiographic distinction between ERR and root caries are generally reliable when assessed by CBCT images, which have better sensitivity and specificity compared with 2D radiographs [4, 7]. However, ERR was diagnosed only by radiographs in this research, lacking validations by clinical or histological information. Further longitudinal studies should be designed to provide more supporting evidence. CBCT may not provide adequate contrast resolution for proper assessment of soft tissues, hence, impacted M3s were not classified according to the coverage by soft tissue or bone in the present study, missing a potential influencing factor for ERR of M2s. Another limitation is that M3s with less than two third of the root developed were excluded in the study, despite the possibility that M3s with developing roots may lead to some cases with ERR of the adjacent M2s. In addition, the statistical unit in this study was the M3, even when 2–4 M3 s per patient were included in some cases. Ideally, at most, one M3 per jaw for each patient should be selected; otherwise, it could give rise to bias.

In conclusion, ERR in M2s adjacent to impacted M3s is not a rare clinical condition and can be accurately identified by CBCT scans, especially in the mandibular M2s. On the other hand, the severity of ERR is generally higher in maxillary M2s. When a maxillary impacted M3 is mesially inclined or in class B/C impaction, clinicians should evaluate carefully whether there is ERR in its adjacent M2 and take into account further assessment by CBCT, followed by watchful monitoring and careful consideration of extracting the M3, especially for patients over 25 years old. For the mandibular M3s, mesially or horizontally impacted ones or those in class C should be kept under surveillance. While we have identified that M2s can be resorbed by the presence of M3s, whether M3s should be surgically removed depends on presence of clinical needs represented by the presence of symptoms and the extent to which the resorption has occurred to necessitate removal of M3s to preserve M2s as functional units in the dentition. Clinicians should also pay close attention to the clinical presentation to reduce the impact of any intervention on anatomical structures which are closely related.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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 For this type of study (retrospective study), formal consent is not required.

References

1. Ghaeminia H, Perry J, Nienhuijs ME, Toedtling V, Tummers M, Hoppenreijs TJ, Van der Sanden WJ, Mettes TG (2016) Surgical removal versus retention for the management of asymptomatic disease-free impacted wisdom teeth. Cochrane Database Syst Rev 8:CD003879. https://doi.org/10.1002/14651858.CD003879.pub4
2. Chou YH, Ho PS, Ho KY, Wang WC, Hu KF (2017) Association between the eruption of the third molar and caries and periodontitis distal to the second molars in elderly patients. Kaohsiung J Med Sci 33(5):246–251. https://doi.org/10.1016/j.kjms.2017.03.001
3. Nunn ME, Fish MD, Garcia RI, Kaye EK, Figueroa R, Gohel A, Ito M, Lee HJ, Williams DE, Miyamoto T (2013) Retained asymptomatic third molars and risk for second molar pathology. J Dent Res 92(12):1095–1099. https://doi.org/10.1177/0022034513509281
4. Patel S, Dawood A, Wilson R, Horner K, Mannocci F (2009) The detection and management of root resorption lesions using intraoral radiography and cone beam computed tomography - an in vivo investigation. Int Endod J 42(9):831–838. https://doi.org/10.1111/j.1365-2591.2009.01592.x
5. Fuss Z, Tsesis I, Lin S (2003) Root resorption–diagnosis, classification and treatment choices based on stimulation factors. Dent Traumatol 19(4):175–182. https://doi.org/10.1034/j.1600-9657.2003.00192.x
6. 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. https://doi.org/10.1016/0030-4220(81)90047-5
7. Yi J, Sun Y, Li Y, Li C, Li X, Zhao Z (2017) Cone-beam computed tomography versus periapical radiograph for diagnosing external root resorption: a systematic review and meta-analysis. Angle Orthod 87(2):328–337. https://doi.org/10.2319/061916-481.1
8. 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. https://doi.org/10.1111/j.1600-051X.1996.tb00616.x
9. 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. https://doi.org/10.1111/j.1834-7819.1999.tb00211.x
10. 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. https://doi.org/10.1016/j.joms.2005.11.102
11. Li ZB, Qu HL, Zhou LN, Tian BM, Chen FM (2017) Influence of non-impacted third molars on pathologies of adjacent second molars: a retrospective study. J Periodontol 88(5):450–456. https://doi.org/10.1902/jop.2016.160453
12. Wang D, He X, Wang Y, Li Z, Zhu Y, Sun C, Ye J, Jiang H, Cheng J (2017) External root resorption of the second molar associated with mesially and horizontally impacted mandibular third molar: evidence from cone beam computed tomography. Clin Oral Investig 21(4):1335–1342. https://doi.org/10.1007/s00784-016-1888-y
13. 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. https://doi.org/10.1016/j.joms.2014.03.023
14. Matzen LH, Schropp L, Spin-Neto R, Wenzel A (2017) Radiographic signs of pathology determining removal of an impacted mandibular third molar assessed in a panoramic image or CBCT. Dentomaxillofac Radiol 46(1):20160330. https://doi.org/10.1259/dmfr.20160330
15. Matzen LH, Schropp L, Spin-Neto R, Wenzel A (2017) Use of cone beam computed tomography to assess significant imaging findings related to mandibular third molar impaction. Oral Surg Oral Med Oral Pathol Oral Radiol 124(5):506–516. https://doi.org/10.1016/j.oooo.2017.07.007
16. 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. https://doi.org/10.1016/j.joms.2014.10.008
17. Tassoker M (2018) What are the risk factors for external root resorption of second molars associated with impacted third molars? A Cone-Beam Computed Tomography Study. J Oral Maxillofac Surg 77:11–17. https://doi.org/10.1016/j.joms.2018.08.023
18. Pell G, Gregory G (1933) Impacted mandibular third molars-classification and modified technique for removal. Dent Dig 39:330–338
19. Shiller WR (1979) Positional changes in mesio-angular impacted mandibular third molars during a year. J Am Dent Assoc 99(3):460–464. https://doi.org/10.14219/jada.archive.1979.0295
20. Leone SA, Edenfield MJ, Cohen ME (1986) Correlation of acute pericoronitis and the position of the mandibular third molar. Oral Surg Oral Med Oral Pathol 62(3):245–250. https://doi.org/10.1016/0030-4220(86)90001-0
21. 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. https://doi.org/10.1016/j.joms.2015.11.024
22. Ericson S, Bjerklin K, Falahat B (2002) Does the canine dental follicle cause resorption of permanent incisor roots? A computed tomographic study of erupting maxillary canines. Angle Orthod 72(2):95–104. https://doi.org/10.1043/0003-3219(2002)072<0095:DTCDFC>2.0.CO;2
23. Malek S, Darendeliler MA, Swain MV (2001) Physical properties of root cementum: part I. A new method for 3-dimensional evaluation. Am J Orthod Dentofac Orthop 120(2):198–208. https://doi.org/10.1067/mod.2001.114535
24. 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. https://doi.org/10.1016/S0099-2399(83)80149-6