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Risk factors for root resorption of second molars associated with impacted mandibular third molars

V. G. A. Suter[1], M. Rivola[1], M. Schriber[1], Y. Y. Leung[2], M. M. Bornstein[3]

[1]Department of Oral Surgery and Stomatology, School of Dental Medicine, University of Bern, Bern, Switzerland; [2]Oral and Maxillofacial Surgery, Faculty of Dentistry, The University of Hong Kong, Hong Kong SAR, China; [3]Applied Oral Sciences, Faculty of Dentistry, The University of Hong Kong, Hong Kong SAR, China

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Abstract. External root resorption (ERR) affecting mandibular second molars (M2) may occur when the adjacent third molar (M3) is impacted in close proximity. This retrospective cohort study aimed to assess the presence, severity, and location of ERR on M2 due to M3 using cone beam computed tomography (CBCT) scans and to identify associated factors. The angle between the axis of M2 and M3 was measured. ERR on M2 was classified as absent, slight, moderate, or severe. The location of contact between M3 and M2, the size of the dental follicle, and patient demographic characteristics were recorded. A total of 433 patients with 640 M3 were included. A male predilection was found with regard to ERR ($P = 0.0004$). ERR was identified on 31.9% of M2 and was slight in 30.2%, moderate in 1.4%, and severe in 0.3% of cases. The presence of ERR was associated with direct contact between M2 and M3 ($P < 0.0001$), the angle between M2 and M3 ($P < 0.0001$), the inclination of M3 ($P = 0.001$), and the location of contact ($P = 0.0005$). This study showed ERR to be a frequent finding. ERR is associated with a mesioangular position of M3 in more than one third of cases, and a proximity ≤ 0.5 mm between M2 and M3 favours ERR.

Key words: root resorption; cone beam computed tomography; wisdom tooth; third molar; second molar.

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External root resorption (ERR) is observed in association with mechanical or inflammatory factors such as dental trauma[1], chronic periodontitis[2], pressure resulting from orthodontic appliances[3–5], cysts[6], benign or malignant tumours[7–9], and through close proximity to an unerupted tooth[10–13]. ERR affecting mandibular second molars (M2) has been associated with the presence of mandibular third molars (M3)[10,13,14–20]. Severe ERR may cause significant attachment loss or a pulpal pathology that results in tooth extraction; even mild to moderate ERR may result in reduced periodontal attachment regeneration after removal of the adjacent M3[16]. Mild or moderate ERR not reaching the pulp is usually asymptomatic and is often not detected by clinical examination. Therefore, reliable radiographic information on ERR would be helpful for clinical decision-making.

Most previous studies analysing ERR of M2 due to M3 have used panoramic imaging or apical radiographs and have reported prevalence varying from 0.3% to 24.2%[10,14–17]. However, two-dimensional (2D) plain radiography may include overlaps that negatively affect the diagnosis of the extent of ERR on M2. Recently, studies have investigated ERR by means of cone beam computed tomography (CBCT), which allows evaluation in three different planes and the detection of even slight defects. Prevalence rates as high as 49.43% have been observed using CBCT[19]. The presence of slight ERR (75%) was found to predominate over moderate or severe ERR[19,20].

There is still only limited evidence regarding the characteristics of ERR on M2 caused by impacted M3 using CBCT[18–21]. The use of CBCT may help to demonstrate the presence and severity of ERR on M2. This may further help to identify the possible risk factors for ERR on M2 due to M3, and thus help with the development of guidelines on the timing of M3 removal to prevent ERR on M2.

The aim of this study was to assess the presence and severity of ERR affecting lower M2 due to M3 using CBCT scans. The specific aims of the study were to identify any relationship of ERR to the position of M3 and the angle between M2 and M3. Furthermore, potential associations between ERR and age, sex, full bony impaction, size of the dental follicle, and presence/absence and location of direct contact between the two teeth were analysed.

Materials and methods

Study design

This retrospective cohort study included patients who had an M2 adjacent to an impacted mandibular M3 as seen on CBCT. All written radiographic reports of patients referred between January 2012 and July 2015 for CBCT examination to the section of Dental Radiology and Stomatology, Department of Oral Surgery and Stomatology, University of Bern, were screened. Reports with a description of lower M3 were retained. All CBCT images were obtained with a 3D Accuitomo 170 unit (Morita Corp., Kyoto, Japan) with full scan rotation (360°) for 17.5 seconds (standard mode) or 10.5 seconds (high speed mode), and exposure settings of 5.0 mA and 90 kV. The field of view (FOV) and respective voxel size was 4 × 4 cm/80 μm, 6 × 6 cm/125 μm, 8 × 8 cm/160 μm, or 10 × 10 cm/160 μm. To be included in the study, the lower M2 and M3 had to be present and sufficiently visible in the FOV. Cases were excluded if the presence of artefacts did not allow evaluation, if the M3 had completely erupted, or if the root development was less than 2/3. Cases with the presence of extended caries affecting M2 or M3 and/or a pathology of the distal mandible (i.e., a cyst or odontogenic tumour) were also excluded.

The images were examined on a Dell 380 Precision workstation (Dell SA, Geneva, Switzerland) and a 19-inch Eizo FlexScan monitor with a resolution of 1280 × 1024 pixels (Eizo Nanao AG, Wädenswil, Switzerland) using specialized computer software (i-Dixel version 2.2.1.2; Morita Corp., Kyoto, Japan). To optimize additional image evaluation, the specific 'zoom box' tool of the software was used. The images were evaluated by one observer (M.R.), and all three planes were considered. M.R. was trained and calibrated by a dentist (V.S.) experienced in dentomaxillofacial radiology.

Outcome measures and data collection

The primary outcome was to identify the presence of ERR on M2 adjacent to M3. The severity of ERR was classified according to the criteria of Ericson and

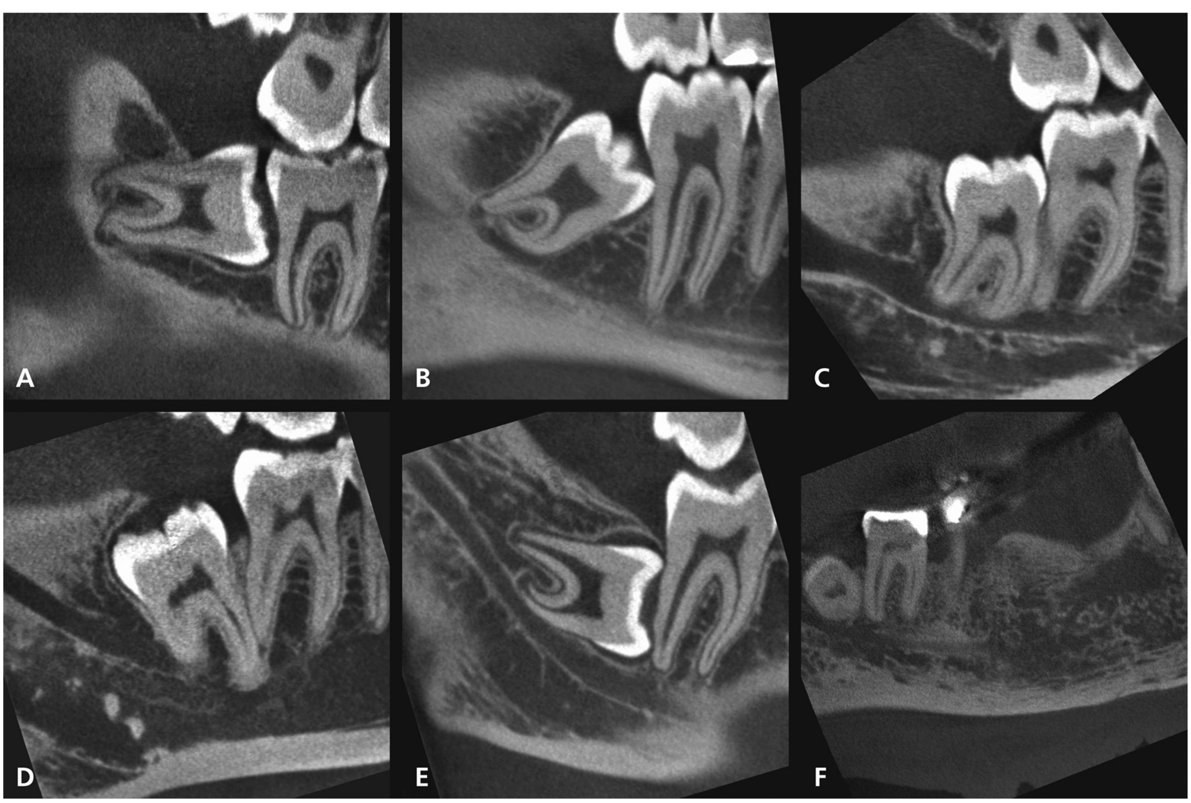

Fig. 1. Inclination of the third molar according to Winter's classification (1926), in sagittal sections of CBCT scans: horizontal (A), mesioangular (B), vertical (C), distoangular (D), inverted (E). A further group 'transverse' was added for lingually and buccally inclined teeth (F).

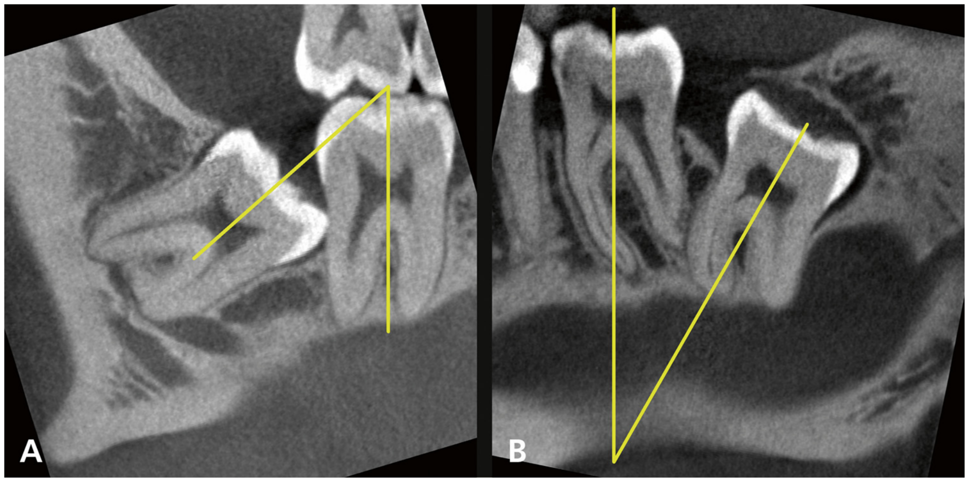

Fig. 2. Sagittal sections of CBCT images illustrating the measurement of the angle between the second and third molars. The axis was defined to be perpendicular to the occlusal plane of each tooth. Teeth were assigned to groups of horizontal/mesioangular/inverted position (A) and distoangular position (B). No angle measurements were performed for vertical or transverse teeth.

Kurol[22] as (1) no resorption with intact root surface, the cementum layer may have been lost; (2) slight resorption with resorption of up to half of the dentine thickness; (3) moderate resorption with resorption of the dentine midway to the pulp or more, with the pulp lining unbroken; (4) severe resorption with resorption reaching the pulp. The position of M3 was classified according to Winter's classification (1926): horizontal, mesioangular, vertical, distoangular, or inverted[23]. A further group 'transverse' was added for lingually and buccally inclined M3 (Fig. 1). Furthermore, the angle between the axis (defined to be perpendicular to the occlusal plane) of M2 and M3 was measured. Depending on the rotation of M3, with the crown pointed either towards the root of M2 or to the posterior jaw (away from the root), the teeth were grouped as (a) horizontal/mesioangular/inverted, or (b) distoangular (Fig. 2). No angle measurements were performed for vertical or transverse teeth. The type of impaction in relation to the bone was defined as full bony impaction or as retention with soft tissue coverage. Proximity between M2/M3 (yes/no) was defined as a distance of $\leq$0.5 mm[24], and its location in relation to the long axis was classified as cervical, middle, or apical. For the developmental state of the root of M3, the three options were (1) complete with closed apical foramen; (2) almost complete, but with open apical foramen; (3) more than 2/3 of root developed. The size of the dental follicle was regarded as absent ($<$1 mm), regular (1–3 mm), enlarged (3–5 mm), or cystic ($>$5 mm; excluded from the present study). Demographic data collected included sex and age of the patients, and the inclusion of one or two lower M3 per patient.

Examinations and data collection were performed according to the guidelines of the World Medical Association Declaration of Helsinki[25]. The study protocol was approved by the standing ethics committee of the State of Bern and by Swiss Ethics.

Data analysis

Descriptive statistics, including the distribution among the sample of the first and all additional parameters, were first calculated. For angle measurements, the mean, median, maximum, and minimum values were calculated separately for the group of horizontal/mesioangular/inverted M3 and for the group of distoangular M3. For age, the mean, median, maximum, and minimum values were calculated. Furthermore, age was divided into three groups ($<$25 years, 25–35 years, $>$35 years) to determine the age distribution. A risk percentage (%) of the presence of ERR was computed for every level for the categorical variables of the respective factor. Then, the effects of the different factors (patient age, patient sex, inclination of M3, angle between M2/M3, direct contact and location of contact between M2/M3, type of impaction, dental follicle) on the presence/absence of ERR were analysed using a logistic regression model. Significant factors were further analysed using either Fisher's exact test for categorical variables or the Student *t*-test for numerical variables, in order to detect differences in the presence of ERR. In the case of a significant result for Fisher's exact test, each pair of levels of the respective factor was then analysed again. For all tests, sex and age were analysed at the patient level, whereas the other variables were analysed at the tooth level. The level of significance was set at 0.05. All results were calculated using the statistical software package R, version 3.3.0 (The R Project for Statistical Computing, Vienna, Austria).

Results

Population studied

A CBCT was performed to evaluate the lower M3 of 541 patients. The M3 of 108 patients ($n = 183$) were excluded for the following reasons: less than 2/3 of the root of the M3 was developed ($n = 43$), completely erupted M3 ($n = 41$), absence of M2 ($n = 13$) or M2 not fully visible in the FOV ($n = 30$), presence of a pathology in the posterior mandible and/or in the area of the M2/M3 ($n = 40$), impacted M2 ($n = 9$), extensive caries affecting M2 or M3 ($n = 5$), artefact ($n = 2$).

Ultimately, 433 patients with 640 M3 were included in the analysis. Of the 433 patients included, 207 had a CBCT scan for both M3 in the lower jaw and 226 for one M3 only. The mean age of the patients was 28.2 years (range 15–80 years; Table 1). The male-to-female ratio was 1:1.2. Most patients (54.0%) were younger than 25 years of age.

Characteristics of lower M2/M3

The 640 M3 studied were almost equally distributed between the left (50.3%) and the right (49.7%) mandible (Table 2).

Table 1. Demographic characteristics of the patients included in the study.

Total patients, *n*	433
Age, years	
Mean	28.2
Median	24.0
Maximum	80.0
Minimum	15.0
Patients in age group, *n* (%)	
<25 years	234 (54.0)
25–35 years	109 (25.2)
>35 years	90 (20.8)
Sex, *n* (%)	
Female	235 (54.3)
Male	198 (45.7)

Table 2. Characteristics of the third and second molars included in the study.

Teeth, *n* (%)	
Overall	640
Left mandibular M3	322 (50.3)
Right mandibular M3	318 (49.7)
Developmental state of M3 roots, teeth *n* (%)	
Almost complete, open apical foramen	303 (47.3)
Complete, closed apex	279 (43.6)
>2/3 root developed	58 (9.1)
Inclination of M3, *n* (%)	
Mesioangular	218 (34.1)
Vertical	186 (29.1)
Distoangular	135 (21.1)
Horizontal	83 (13.0)
Inverted	16 (2.5)
Transverse	2 (0.3)
Type of impaction of M3, *n* (%)	
Full bony impaction	5 (0.8)
Retention with soft tissue coverage	635 (99.2)
Size of dental follicle of M3	
Absent	295 (46.1)
Regular	329 (51.4)
Enlarged	16 (2.5)
Contact M2/M3, *n* (%)	
Yes	444 (69.4)
Location cervical	328 (51.2)
Location middle	98 (15.3)
Location apical	18 (2.8)
No	196 (30.6)
M2 resorption and severity, *n* (%)	
Yes	204 (31.9)
Slight resorption	193 (30.2)
Moderate resorption	9 (1.4)
Severe resorption	2 (0.3)
No	436 (68.1)

M2, second mandibular molar; M3, third mandibular molar.

Most of the M3 had a mesioangular inclination (34.1%), followed by a vertical (29.1%) and distoangular (21.1%) position. Most M2 (69.4%) were in close contact (≤0.5 mm) with the M3, most often in the cervical part of the M2 root. The follicular space was found to be <1 mm in 46.1% (absent) and between 1 mm and 3 mm in 51.4% (regular).

Root resorption on lower M2

No resorption was found on CBCT images of 436 M2 (68.1%). Slight resorption (Fig. 3A, Table 2) was observed for 193 teeth (30.2%). Nine M2 (1.4%) demonstrated moderate resorption (Fig. 3B) and two M2 (0.3%) demonstrated severe resorption (Fig. 3C). At the patient level, 174 (40.2%) patients (78 female and 96 male) had an M2 with ERR. Male patients exhibited a higher rate of ERR (96 out of 198; 48.5%) than female patients (78 of 235; 33.2%) ($P = 0.0004$).

With regard to measured angles, 317 M3 were included in the group horizontal/mesioangular/inverted and 135 in the group distoangular. In the mesioangular/horizontal/inverted group, 158 M2 had ERR, and the mean angle measurement associated with ERR was 57.10° (median 50.84°, min 30.08°, max 111.70°; Fig. 4). In the distoangular group, 11 M2 had ERR, and the mean angle was 20.10° (median 18.43°, min 4.19°, max 78.85°; Fig. 5).

Statistical analysis showed that patient sex, inclination of the M3, the angle between M2 and M3, and the presence and location of the contact between M2 and M3 were significantly associated with the presence of ERR (Table 3). In the mesioangular/horizontal/inverted group, the mean angle of teeth with ERR differed significantly from the mean angle of teeth without resorption ($P < 0.0001$). The risk percentage for having ERR was 62.5% for an inverted inclination, 54.2% for a horizontal inclination, and 47.2% for a mesioangular inclination. Direct contact between M2 and M3 was associated with a 45.0% risk percentage of having resorption; without contact, the risk was 2.0%. An apical location of the contact between M2 and M3 was associated with 83.3% risk of ERR (Table 3).

Discussion

This study demonstrated that the presence and severity of ERR on M2 due to M3 could be identified by CBCT. This study further showed that mesioangular and horizontal impaction of M3 were correlated with more ERR on the adjacent M2 and that inverted M3 were also highly associated with ERR on M2. These findings could help surgeons and patients in the clinical decision−making process when determining whether a M3 should be removed, especially in a prophylactic manner when taking the risk of the future development of ERR into account.

ERR on two−dimensional and three−dimensional radiographs

Earlier studies analysing ERR of M2 due to M3 used 2D radiographs. Generally, lower rates of mandibular M2 resorption were observed on panoramic radiographs (0.3%[10], 1.3%[15], 1.7%[17], 4.7%[26]), as well

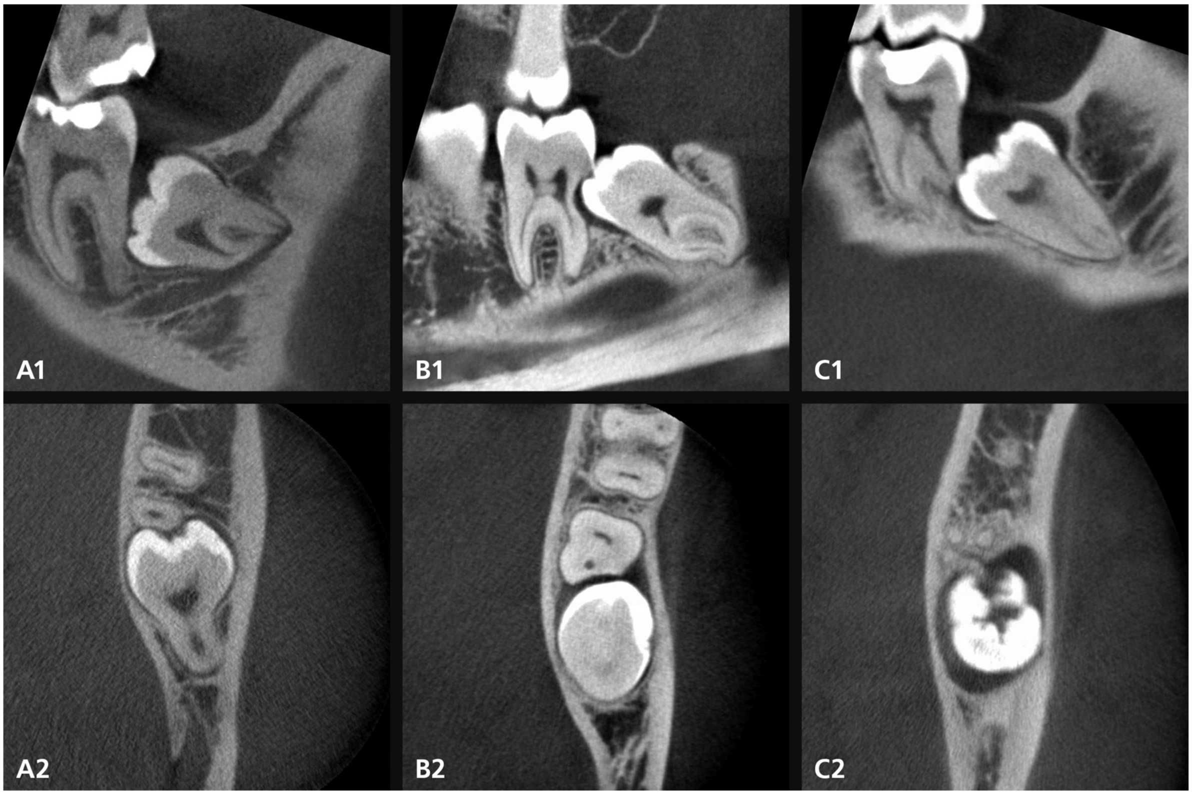

Fig. 3. Sagittal and horizontal sections of CBCT images illustrating different degrees of resorption. A: slight resorption (A1 sagittal, A2 horizontal section); B: moderate resorption (B1 sagittal, B2 horizontal section); C: severe resorption (C1 sagittal, C2 horizontal section).

as on apical radiographs (6%[14], 24.2%[16]). The over-projection of anatomical structures renders the evaluation of the presence of ERR difficult on panoramic radiographs. In a retrospective study of panoramic radiographs, superimposition of M2 and M3 was observed in almost half of the cases[27]. The advantage of CBCT is the ability to evaluate the root surface of M2 in all three planes, with the horizontal plane being the most relevant in interpreting the presence of resorption. Two recent studies compared the identification of ERR on panoramic radiographs and CBCT scans. Oenning et al.[18] detected 4.3 times more ERR using CBCT imaging: the prevalence was 22.88% on analysis of CBCTs and 5.31% on analysis of panoramic radiographs. Matzen et al.[21] reported agreement between the evaluations on panoramic radiographs and CBCT of 54–74% (range of the four observers).

ERR prevalence on CBCT

Oenning et al.[19] used a similar method to analyse ERR on CBCT images and found a higher prevalence (49.43%) than in the present investigation (31.9%). These differing results could be explained by the sample size (116 versus 640 teeth), the selection of M3 (only horizontal and mesioangular inclinations versus all inclinations), the CBCT device (i-CAT and Picasso-Trio versus Accuitomo), and the number of observers (two versus one). In particular, the smaller sample with the inclusion of only horizontal and mesioangular teeth could be the reason for the higher rate of ERR found in the previous study[19], as this group of teeth also showed a high rate of ERR in the present investigation. Interestingly, a Chinese investigation performed at a referral hospital reported a lower incidence of ERR (20.17%) using CBCT and including only M3 that were mesially and horizontally impacted[20].

Image acquisition parameters, including the voxel size, also have an influence on the detection of ERR, as demonstrated by in vitro studies showing that smaller voxel sizes (0.12–0.15 mm) were better for detection[28,29]. The present study used scans with voxel sizes between 0.08 and 0.16 mm.

Sex predilection

In the present study, male patients exhibited a significantly higher rate of ERR than female patients, with a risk percentage of 41.4%. In contrast, no significant sex predilection was found in other studies using CBCT scans[16,19,20]. A study performed on peri-apical radiographs and including 199 impacted M3 found 7.5% ERR on the adjacent M2 and ERR twice as often in men as in women[14]. It was postulated by Nitzan et al.[14] that sex hormones could be one of the additional factors involved in the process of ERR. There may be an analogy to bone metabolism, as the cells involved – osteoclasts in bone and odontoclasts in teeth – use the same receptor ligand system, known as RANK/RANKL[30]. However, the theory is controversial, since testosterone has been shown to decrease osteoclast formation in a dose-dependent manner in vitro. Furthermore, bone resorption is suppressed in healthy males[31,32]. On the other hand, women's oestrogen protects against bone resorption, which could explain the lower ERR in females[31].

Age predilection

A positive association between ERR and older age was found in earlier studies using peri-apical radiographs[13] and CBCT[19,20]. Wang et al.[20] found that age

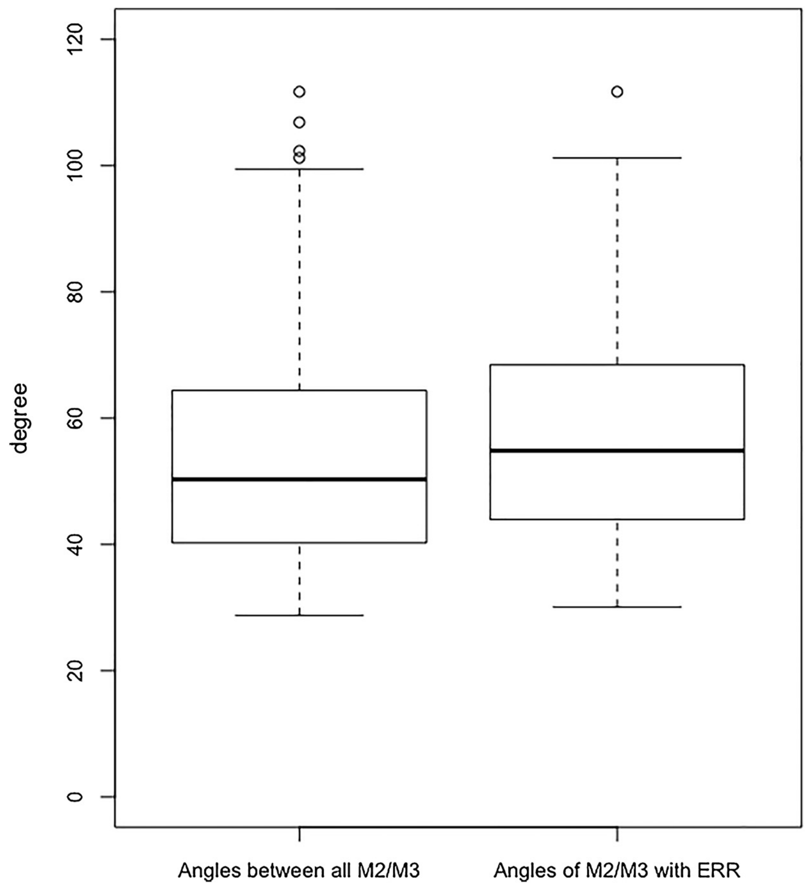

Fig. 4. Box plot showing the distribution of angle measurements between second molars (M2) and third molars (M3) in the group of mesioangular/horizontal/inverted M3, for all teeth and for those with concomitant external root resorption (ERR) of M2.

over 35 years was an independent risk factor for ERR, with an adjusted odds ratio of 2.47. This could not be confirmed by the present study data. Similarly, other studies did not find any association between the incidence of ERR and age[14,27].

Inclination as a risk for root resorption

In the present study, the group of inverted M3 was small ($n = 16$, 2.5%), but the inverted inclination was highly associated with ERR ($n = 10$, risk percentage of 62.5%). This finding is of particular interest, since earlier studies excluded these cases[19,20]. This group of teeth seems to be at increased risk for ERR, and should ideally be included in future studies to confirm the present findings.

Using CBCT scans, proper angle measurements offer the opportunity to more precisely analyse the range in which ERR is most present. As the type of contact (crown M3 to root M2, or root M3 to root M2) and the respective angles were considered relevant to the frequency of ERR, the M3 were grouped into two groups for angle measurements. Measurement of the angle between the long axes of M2 and M3 was also chosen in an earlier study evaluating ERR of M2 in relation to impacted upper ($n = 70$) and lower ($n = 132$) M3 on 202 peri-apical radiographs[16]. A significant predilection for ERR was found in association with mesioangulated M3 with an angle $>60°$. Limitations of this earlier study include the lower accuracy of measurements of angles performed on 2D radiographs than on CBCTs and that the precise evaluation of the presence or absence of ERR was limited due to the single projection view available for interpretation. Furthermore, upper and lower third molars were pooled for analysis in that study.

Direct contact and vertical position of M3 as a risk for root resorption

Pressure applied directly on the root surface of an adjacent tooth has often been mentioned in the literature as a main factor for ERR[14,33,34]. This is in line with the present study findings, as significantly more ERR ($P < 0.0001$) was found for teeth in direct contact. The study sample also showed an association between the presence of a contact between M2/M3 and the inclination of the teeth, independent of the presence of ERR. Thus, as horizontally and mesioangularly inclined M3 are prone to be in direct contact with M2, this could be an explanation for the fact that teeth from these groups are more often associated with ERR. Both factors – the direct contact and the angulation of teeth – are associated to each other.

Oenning et al.[19] suggested that the cemento-enamel junction of teeth was more susceptible to ERR, as more ERR was found in the cervical area of their sample. In the present study sample, the cervical location of contact between the teeth was the most often observed (51.2%). However, the apical location was associated with the highest risk of ERR (risk percentage 83.3%), followed by the middle location (58.2%) and the cervical location (39.0%). The inclination of the teeth was also significantly associated with the location of contact. Inverted

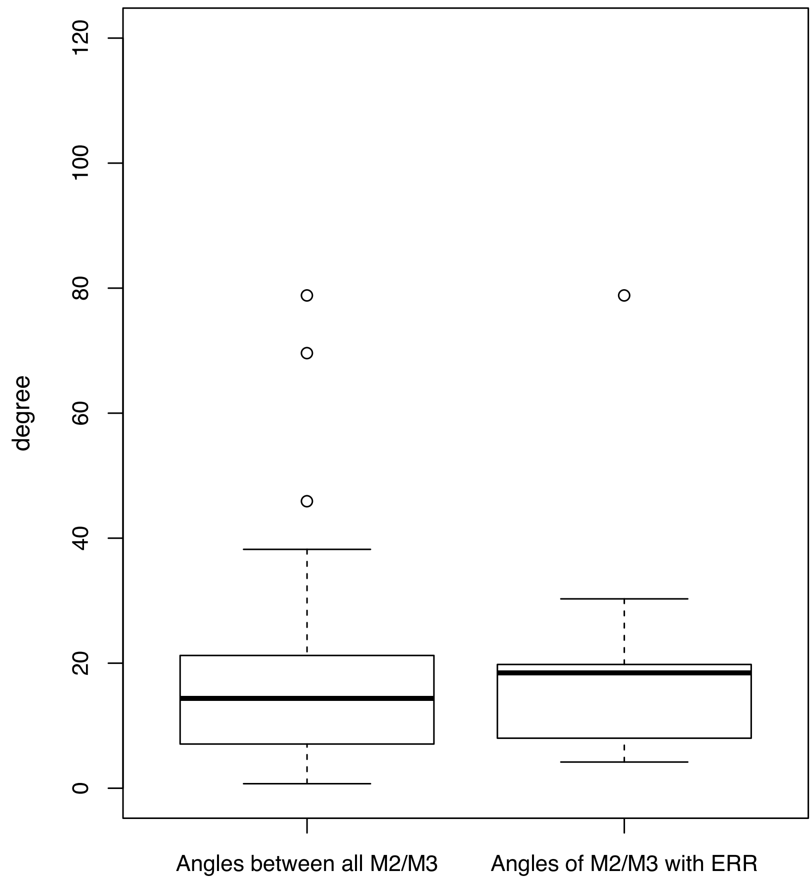

Fig. 5. Box plot showing the distribution of angle measurements between second molars (M2) and third molars (M3) in the group of distoangular M3, for all teeth and for those with concomitant external root resorption (ERR) of M2.

teeth more often had an apical contact location than teeth with other inclinations. This may be a confounding factor, meaning that the apical contact location and inverted tooth inclination are presenting one combined risk.

Clinical presence of ERR seen on CBCT

The presence of ERR as observed on CBCT scans has not yet been confirmed by clinical correlation. Such a study would be quite difficult to perform, as M2 are usually not removed even if resorption is found on the respective CBCT scan. An intraoperative clinical evaluation of the root of M2 after removal of M3 is challenging to perform and standardize, especially for mild resorption. Nemcovsky et al.[16] analysed ERR first on peri-apical radiographs and then after extraction of the M2 by visual inspection and histological analysis. Among the 11 M2 included, eight were identified with ERR based on the peri-apical radiograph, nine with ERR by clinical examination, and all M2 exhibited signs of resorption on histological analysis.

Clinical relevance

Guidelines and recommendations for whether M3 should be removed as a prophylactic measure or only as a therapeutic procedure in the presence of a clear pathology vary considerably between countries and are subject to controversy in the literature[35,36]. Like earlier studies, the present study found that mesioangular and horizontal M3 were most often correlated with the presence of ERR on M2[16,18,21]. The present study adds the information that an angle measured between the vertical axes of M2 and M3 of between 44.07° (p25) and 68.01° (p75) is associated with an increased risk of ERR. Patients with teeth in this angle range may be informed by their dentist that they are at risk of ERR even if resorption is not visible and/or present at the time of examination.

In conclusion, mandibular M3 in a horizontal or mesioangular position and with a mean angle measurement of 57.10° were most often associated with ERR on M2. Direct contact between M2 and M3 represents a further risk for ERR and this factor is not independent from M3 inclination. The prophylactic removal of these teeth to avoid the development of ERR on M2 might be a justifiable clinical option.

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Table 3. Statistical analysis regarding the presence of root resorption in relation to patient-related and tooth-related variables.

Variables	*p*-Value
Patient variables	
Sex (risk percentage)	0.0004[a]
Female (25.1%)	
Male (41.4%)	
Age (years)	0.3790[b]
Tooth variables	
Inclination of M3 (risk percentage)	0.001[a]
Horizontal (54.2%)	
Mesioangular (47.2%)	
Vertical (18.8%)	
Distoangular (8.15%)	
Inverted (62.5%)	
Transverse (no resorption, only two cases included)	
Angle between M2 and M3	
Measurements—group horizontal/mesioangular/inverted	$<$0.0001[b]
Measurements—group distoangular	0.4189[c]
Contact M2/M3 (risk percentage)	
Contact (45.0%) vs. no contact (2.0%)	$<$0.0001[c]
Location	0.0005[a]
Cervical (39.0%)	
Middle (58.2%)	
Apical (83.3%)	
Type of impaction	
Full bony impaction vs. soft tissue coverage	1.0[a]
Dental follicle	
Absent/regular/enlarged	0.995[c]

M2, second mandibular molar; M3, third mandibular molar.
[a] Fisher's exact test.
[b] Student *t*-test.
[c] Logistic regression model.

Competing interests. All authors confirm that they do not have any conflict of interest.

Ethical approval. Ethical approval for the study was given by the standing ethics committee of the State of Bern (Ref Nr. KEK-BE: 392/2015) and by Swiss Ethics (Basec: 2015-00224).

Patient consent. Not required.

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Address:
Valerie G. A. Suter
Department of Oral Surgery and Stomatology
School of Dental Medicine
University of Bern
Freiburgstrasse 7
3010 Bern
Switzerland
Tel: +41 31 632 25 45/66. Fax: +41 31 632 09 14
E-mail: valerie.suter@zmk.unibe.ch