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Risk Factors for Ectopic Eruption of First Permanent Molars in Children Undergoing Dental Treatment Under General Anesthesia: A Retrospective Study

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Abstract

Background Ectopic eruption (EE) of the first permanent molar (FPM) can lead to root resorption of the second primary molar (SPM), premature tooth loss, and malocclusion. Children undergoing dental treatment under general anesthesia (GA) often receive extensive restorations such as stainless steel crowns (SSCs), which may iatrogenically influence eruption. This retrospective study aimed to investigate the incidence of EE in children treated under GA and to identify associated risk factors.

Methods We reviewed records of children who underwent comprehensive dental treatment under GA between January 2020 and December 2022. A total of 114 children aged 3–7 years with available baseline and follow-up panoramic radiographs were included, representing 337 FPMs. Potential risk factors included age at surgery, sex, tooth position, jaw position, restoration type, distal step on the SSC, mesial angulation (MA), and horizontal distance (HD). EE was diagnosed using established radiographic criteria. Chi-square tests assessed associations between EE and categorical variables at the tooth level. Patient-level mean MA and mean HD were calculated separately for the maxilla and mandible, and ROC curve analysis was used to determine optimal cutoff values

Results The prevalence of EE was 10.7% (36/337) at the tooth level and 21.1% (24/114) at the patient level; 45.8% (11/24) of affected patients had EE in multiple FPMs (≥ 2). Crown-restored SPMs showed a significantly higher EE rate than non-crown restorations (13.0% vs. 2.6%, $P = 0.018$). However, the presence of a distal step on the SSC was not significantly associated with EE ($P = 0.172$; OR = 1.83, 95% CI: 0.76–4.39). The optimal cutoff values for the mandible were mean MA > 10.94° (AUC = 0.777) and mean HD < − 1.01 mm (AUC = 0.711). No significant associations were found with age, sex, tooth position, or jaw position.

Conclusions EE is common in children treated under GA. Crown restoration of the adjacent SPM, reduced horizontal distance, and increased mesial angulation significantly increase EE risk, whereas the distal step on the SSC is not significantly associated with EE. Regular clinical and radiographic monitoring of at-risk children is recommended, as early detection enables simple interventions and prevents irreversible sequelae.

Introduction

Ectopic eruption (EE) of the first permanent molar (FPM) is defined as a deviation from the normal eruption pathway, in which the mesial cusp of the FPM becomes impacted against the distal surface of the adjacent second primary molar (SPM)[1]. This condition can lead to premature root resorption or loss of the SPM, arch length deficiency, and malocclusion[1]. The reported prevalence of EE ranges from 2.2% to 13.92% at the patient level[2–4],with the maxilla affected far more frequently than the mandible [5, 6]. The etiology is multifactorial, including genetic predisposition, increased mesial angulation of the FPM, insufficient arch length, and maxillary tuberosity deficiency[7, 8].

Iatrogenic factors have also been implicated. SSCs are commonly used to restore severely decayed SPMs, particularly in children treated under general anesthesia (GA) [9]. Some authors have suggested that an improperly adapted SSC—especially one with a distal step or overhang—may mechanically obstruct the erupting FPM, potentially increasing the risk of EE[10]. However, evidence supporting this specific association remains limited and inconsistent. Conversely, when correctly contoured with a distal guide plane, an SSC can serve as an effective intervention to redirect an ectopically erupting FPM[11]. Thus, SSCs play a dual role in EE: as a potential risk factor when poorly placed, and as a therapeutic tool when properly designed.

Despite existing evidence, the relative contributions of demographic, radiographic, and restoration-related risk factors remain inconclusive, and few studies have specifically focused on children undergoing dental treatment under GA. In this patient population, the rate of SSC placement is high due to the severity of early childhood caries, and the risk of iatrogenic EE may be underestimated. Therefore, this retrospective study aimed to investigate the incidence of EE in this population and to identify associated risk factors, including age, sex, restoration type of the SPM, mesial angulation (MA) of the FPM, and horizontal distance (HD) between the FPM and SPM.The findings may provide preliminary evidence for restorative planning, postoperative monitoring, and preventive strategies to reduce iatrogenic EE risk during dental rehabilitation under general anesthesia.

Materials and methods

Sample selection

This study was approved by the Ethics Committee of Stomatological Hospital, Southern Medical University (KQIIT2021003). A total of 114 patients (aged 3–7 years) with 337 FPMs were included. The sample was selected from patients who underwent comprehensive dental treatment under GA between January 2020 and December 2022. Patients with at least one unerupted FPM at initial examination were included and followed for a minimum of 3 months until either complete eruption or diagnosed ectopic eruption occurred. Exclusion criteria were: 1) radiographs with inadequate clarity for accurate assessment, or absence of baseline or follow-up panoramic images; 2) cases where the SPM had been extracted prior to or during the observation period; 3) presence of cysts, tumors, or traumatic injuries in the observation area; 4) presence of any craniofacial anomalies, congenital deformities, or syndromes involving dental eruption; 5) SPMs with extensive carious lesions, which made it difficult to measure horizontal distance (HD) or mesial angulation (MA).

Radiographic assessment

All radiographic assessments were performed using digital panoramic radiographs on YlzRtBrowser software. The following parameters were evaluated.

Eruption status:Ectopic eruption was diagnosed when the mesial cusp of the FPM was positioned at or below the maximum convexity of the distal contour of the SPM, with evidence of root resorption or

impaction[12, 13](Fig. 1). For all confirmed EE cases, the severity of EE was further classified according to a three-degree system based on the degree of root resorption of the adjacent SPM, as described by Moca et al.[2]: moderate degree (resorption of dentine without pulp exposure); severe degree (resorption of the distal root or mesial root leading to pulp exposure); very severe degree (resorption affecting the mesial root of the primary second molar).

Fig. 1 Ectopic eruption of the maxillary first permanent molar (tooth 16)

The mesial cusp is locked beneath the distal contour of the adjacent second primary molar (tooth 55), with distal root resorption (arrow).

Mesial angulation: The MA of the FPM was measured as the intersection of the occlusal planes of the SPM and the FPM. The occlusal plane was drawn along the tips of the cusps of the SPM or the FPM[14] (Fig. 2). Negative values indicate distal tilt and positive values indicate mesial tilt for both jaws. Notably, maxillary FPMs normally show negative values (distal tilt), while mandibular FPMs normally show positive values (mesial tilt).

Fig. 2 Measurement of mesial angulation (MA) of the first permanent molar

The MA was measured as the intersection angle between the occlusal plane of the second primary molar and that of the first permanent molar, traced along the cusp tips.

(A) Maxillary FPM normally shows negative values (distal tilt); (B) Mandibular FPM normally shows positive values (mesial tilt).

Horizontal distance: The HD between the FPM and SPM is defined as the vertical distance from the most convex point on the mesial aspect of the crown of the FPM to the distal tangent line of the crown of the SPM [15](Fig. 3).

Fig. 3 Measurement of horizontal distance (HD) between the first permanent molar and adjacent second primary molar

The measurement was performed on tooth 46 and the adjacent second primary molar (tooth 85) in this example. HD was defined as the vertical distance from the most convex point on the mesial aspect of the first permanent molar crown to the distal tangent line of the adjacent second primary molar crown.

Distal step on the SSCs:For teeth restored with SSCs, the presence of a distal step was recorded.A distal step was defined as any detectable extension of the crown margin beyond the distal surface of the SPM (distance > 0 mm); its absence was recorded when the margin was flush with the distal surface (distance = 0 mm) [10](Fig. 4).

Fig. 4 Distal step on the stainless steel crown (SSC).

(A) Absence of a distal step on tooth 65: the crown margin termination was flush with the distal surface of tooth 65 (distance = 0 mm); (B) Presence of a distal step on tooth 65: the distal termination point of the crown margin extended beyond the distal surface of tooth 65. The blue line indicates the distance between these two points (> 0 mm).

All assessments were performed independently by two calibrated examiners. Disagreements were resolved through discussion or by consultation with a third examiner when necessary. Intra-observer reliability was assessed by re-evaluating 10% of the sample after one month.

Statistical analysis

Data were analyzed using SPSS 27 (SPSS Inc., Chicago, IL, USA). Categorical variables were expressed as frequencies and percentages. For continuous variables (MA and HD), the Shapiro-Wilk test was initially used to assess the normality of the data distribution. As the data for these variables were found to deviate significantly from a normal distribution ($P < 0.001$), they were subsequently summarized using medians with interquartile ranges (IQR). Chi-square tests were used to assess associations between EE and demographic/radiographic variables at the tooth level (n = 337). For this analysis, and with reference to previous literature[15], mesial angulation was dichotomized as ≥10° vs. <10° for mandibular FPMs and as ≥−10° vs. <−10° for maxillary FPMs. For the ROC analysis, patient-level mean values were used: for each patient, the mean MA and mean HD were calculated separately for the maxilla and mandible, and a patient was considered EE-positive if at least one FPM exhibited ectopic eruption. ROC curve analysis was performed at the patient level to assess the predictive value of these mean values for EE and to identify their optimal clinical cutoff values, determined by maximizing the Youden index. This approach avoided the clustering effect of multiple teeth within the same patient. Intra- and inter-observer agreement was evaluated using Cohen's kappa statistic (poor agreement, <0.40; moderate, 0.40–0.59; good, 0.60–0.74; excellent, 0.75–1.00). A P value of <0.05 was considered statistically significant.

Results

A total of 337 first permanent molars from 114 patients (64 males and 50 females) were included in the analysis. The majority of patients were aged 4–5 years at the time of surgery (76.3%, 87/114). The overall prevalence of ectopic eruption was 10.7% (36/337) at the tooth level and 21.1% (24/114) at the patient level, with 45.8% (11/24) of affected patients exhibiting EE in multiple FPMs (≥ 2). Most cases were of moderate degree, accounting for 34 of the 36 affected teeth. At the tooth level, the median mesial angulation (MA) of the first permanent molars was 0.00° (IQR: −12.87° to 7.32°), and the median horizontal distance (HD) between the FPM and the adjacent SPM was 0.00 mm (IQR: −0.72 mm to 0.58 mm). Both inter-observer and intra-observer agreements were excellent, with kappa values ranging from 0.87 to 0.94 ($P < 0.001$).

The results of the chi-square analysis are summarized in Table 1. Ectopic eruption of FPMs was significantly associated with restoration type, MA of FPMs, and HD between SPMs and FPMs ($P < 0.05$). No significant associations were found with sex, age, tooth position, or jaw position ($P > 0.05$).

Most SPMs were restored with SSCs (77.4%). Crown-restored SPMs were associated with a significantly higher prevalence of EE in adjacent FPMs compared to non-crown restorations (13.0% vs. 2.6%, P = 0.018). EE in maxillary FPMs was more frequently observed when FPM MA was ≥ − 10° (P = 0.033). Mandibular FPMs with MA ≥ 10° showed a higher rate of EE (P = 0.003). EE in FPMs was also more frequently observed in cases where the HD between the SPM and the FPM was < 0 mm, i.e., closer to the adjacent tooth (P = 0.012).

The rate of EE of the adjacent FPM did not differ significantly between the distal-step-present and distal-step-absent groups (Table 2, 79.4% vs. 67.8%; χ^2 = 1.86, df = 1, P = 0.172; OR = 1.83, 95% CI: 0.76–4.39).

ROC analysis was performed at the patient level to evaluate the predictive value of mean MA and mean HD for EE, stratified by jaw position (maxilla vs. mandible). A patient was considered EE-positive if at least one FPM exhibited ectopic eruption. The results are summarized in Table 3. For the maxilla, neither mean MA (AUC = 0.666, P = 0.055) nor mean HD (AUC = 0.553, P = 0.541) showed statistically significant predictive value; therefore, no optimal cutoff was determined. In the mandible, mean MA exhibited good predictive performance (AUC = 0.777, 95% CI: 0.659–0.895, P = 0.001), with an optimal cutoff of 10.94°, a sensitivity of 64.3%, and a specificity of 84.2%. Mean HD in the mandible also showed significant discriminative ability (AUC = 0.711, 95% CI: 0.523–0.898, P = 0.013), and the optimal cutoff was − 1.01 mm, providing a sensitivity of 64.3% and a specificity of 86.8%.

Table 1
Prevalence of ectopic eruption and associated factors

Variables	Total	Presence of ectopic eruption of FPM		*P* Value
		Yes (%)	No (%)	
Age (years)				0.098
3	29	7 (24.1)	22 (75.9)	
4	139	14 (10.1)	125 (89.9)	
5	121	10 (8.3)	111 (91.7)	
6–7	48	5 (10.4)	43 (89.6)	
Sex				0.392
Male	191	18 (9.4)	173 (90.6)	
Female	146	18 (12.3)	128 (87.7)	
Tooth position				0.789
16	89	7 (7.9)	82 (92.1)	
26	92	11 (12.0)	81 (88.0)	
36	81	9 (11.1)	72 (88.9)	
46	75	9 (12.0)	66 (88.0)	
Jaw position				0.637
Maxilla	181	18 (9.9)	163 (90.1)	
Mandible	156	18 (11.5)	138 (88.5)	
Restoration type				**0.018***
Non-crown restoration	76	2 (2.6)	74 (97.4)	
Crown restoration	261	34 (13.0)	227 (87.0)	
MA of the maxillary FPM (°)				**0.033***
≥ −10	78	12 (15.4)	66 (84.6)	
< 10	103	6 (5.8)	97 (94.2)	
MA of the mandibular FPM (°)				**0.003***
≥ 10	48	11 (22.9)	37 (77.1)	
< 10	108	7 (6.5)	101 (93.5)	
HD between FPM and SPM (mm)				**0.012***

≥ 0	214	16 (7.5)	198 (92.5)
< 0	123	20 (16.3)	103 (83.7)

* Statistically significant ($P < 0.05$)by Pearson's chi-square test.

Table 2
Association between distal step on the SSC and EE of the adjacent FPM

FPM eruption status	Distal step present n (%)	Distal step absent n (%)	Total
Ectopic eruption	27 (79.4)	7 (20.6)	34
Normal eruption	154 (67.8)	73 (32.2)	227
Total	181	80	261

Data are presented as n (row %). Pearson's chi-square test: $\chi^2 = 1.86$, df = 1, $P = 0.172$.

Odds ratio (OR) = 1.83, 95% CI:0.76–4.39.

Table 3
ROC parameters for mean MA and mean HD by jaw position

Predictor	AUC	95% CI	*P* value	Optimal cutoff	Sensitivity(%)	Specificity(%)
Maxillary mean MA	0.666	0.518–0.814	0.055	——	——	——
Maxillary mean HD	0.553	0.372–0.734	0.541	——	——	——
Mandibular mean MA	0.777	0.659–0.895	**0.001***	10.94	64.3	84.2
Mandibular mean HD	0.711	0.523–0.898	**0.013***	−1.01	64.3	86.8

The ROC analysis included 114 patients (maxilla: n = 95; mandible: n = 90).

*Statistically significant (P < 0.05) using ROC curve analysis.

Discussion

This study systematically evaluated the incidence of EE of the FPM in children who underwent comprehensive dental treatment under general anesthesia and identified significant risk factors, including restoration type, mesial angulation, and horizontal distance between the FPM and SPM.

Ectopic eruption is a multifactorial phenomenon involving complex interactions between dental and skeletal growth.At the tooth level, increased MA of the FPM and reduced HD between the FPM and SPM

were significantly associated with increased risk of EE. This aligns with Chen et al. [16], who showed that greater eruptive angulation and a higher impaction index on panoramic radiographs predict irreversible EE outcomes. The negative HD (i.e., the FPM erupting closer to or overlapping the distal aspect of the SPM) indicates a physical obstruction that directs the FPM mesially. Our findings support the concept that spatial inadequacy, often caused by a large SPM crown or a distally positioned SPM, is a key mechanical factor in EE.

Specifically, our chi-square analysis showed that the EE rate was higher in maxillary FPMs with angulation ≥ − 10° and in mandibular FPMs with angulation ≥ 10° (Table 1). This difference reflects anatomical orientation: maxillary FPMs normally erupt with a slight distal angulation; a less negative (more upright or even positive) angle indicates abnormal eruption, whereas in the mandible a pronounced mesial tilt is pathological.

At the patient level, we further evaluated whether mean MA and mean HD could predict EE. The identified cutoff values for mean mandibular MA and mean mandibular HD (Table 3) were easily recognizable on panoramic radiographs and warrant closer monitoring. Clinicians can use these cutoff values to identify high-risk children and develop individualized radiographic follow-up plans. However, the moderate AUC values indicate only moderate predictive ability. In contrast, neither mean MA nor mean HD in the maxilla showed significant predictive value (Table 3), suggesting that other factors may govern EE in the upper arch. These cutoff values were derived from retrospective data and require external validation in prospective cohorts.

Crown-restored SPMs were significantly associated with an increased risk of EE (Table 1), whereas the distal step was not (Table 2). This suggests that the effect of crown restoration on EE is not primarily driven by the distal step. The wide confidence interval for the distal step likely reflects limited statistical power due to the small number of EE events in the SSC-restored subgroup (n = 34), and other aspects of crown adaptation—such as crown contour, proximal contact, or loss of distal guiding anatomy—may be more relevant. Although one previous study reported a significant association [10], its estimate was based on a similarly small sample and yielded a very wide confidence interval (1.06–79.26). Clinically, while careful crown contouring remains important, clinicians should not rely on the distal step as a sole predictor of EE; rather, a comprehensive assessment of multiple factors is recommended when evaluating children at risk.

Although the EE rate in our GA-treated population was higher than that reported in the general population [2–4], most cases were of moderate severity. Early detection allows simple interventions, such as separator placement or distal trimming of the SSC, which are highly successful in preventing permanent root resorption or space loss [16].

Notably, 45.8% of patients with EE had multiple FPMs affected, suggesting a constitutional predisposition (e.g., arch length deficiency, atypical eruption pattern)[10, 17]. For these high-risk individuals, additional iatrogenic factors such as SSC placement may further increase the risk of EE in other quadrants. Therefore, when EE is detected in one quadrant, the other quadrants should be carefully

evaluated. If an SSC is necessary, parents should be informed of the increased risk of EE and regular follow-ups every 6–12 months should be scheduled.

No significant difference in EE prevalence was found between the maxilla and mandible (Table 1). This finding diverges from most previous reports, which have consistently shown maxillary predominance in EE [5, 6]. This discrepancy may be attributed to our unique population of GA-treated children with extensive SSC restorations. The strong association between crown restoration and EE suggests that this iatrogenic risk factor may be distributed across both jaws, potentially attenuating the natural maxillary predominance. Additionally, the chi-square test, as a univariable analysis, cannot adjust for confounders, and the limited number of EE events further reduced statistical power.

No significant associations were found between EE and sex or tooth position. The literature on sex predilection remains mixed[17–19], and these discrepancies may arise from differences in sample size, diagnostic criteria, and population genetics.

This is the first study to examine whether age at GA influences the subsequent risk of EE of the FPM, contrasting with previous literature that primarily reports the prevalence of EE across different physiological age groups in the general population[5, 8]. Using a rigorous retrospective cohort design that included only children aged 3–7 years with unerupted FPMs at the time of GA and followed them until definitive eruption outcome, we found no significant difference in EE incidence among different GA age groups. This negative finding suggests that, for the purpose of EE prevention, necessary GA treatment should not be withheld merely because of the patient's young age.Therefore, clinicians should focus more on monitoring eruption dynamics during the critical window of 7–8 years of age [16, 20]rather than on the specific age at which GA was performed.

This study has several limitations. First, the retrospective design and limited number of EE events (n = 36) restricted the analysis to univariable methods, precluding robust multivariable regression to control for potential confounders. Second, we did not evaluate other potential confounders such as arch perimeter or supernumerary teeth [16, 20], and the assessment of distal step status was based on panoramic radiographs, which cannot fully capture three-dimensional crown adaptation. Third, the sample was derived from a single institution's GA database, which may limit generalizability to non-GA populations. Future prospective studies with larger sample sizes are needed to confirm the independent contributions of each risk factor, preferably incorporating standardized three-dimensional imaging, longer follow-up periods, and a control group of children treated without GA.

Conclusions

Ectopic eruption of FPMs is common in children treated under GA, with a patient-level prevalence substantially higher than that reported in the general population. Crown restoration of the adjacent SPM, reduced horizontal distance, and increased mesial angulation are significant risk factors, whereas the distal step on the SSC does not appear to be significant. Given the predisposition for multiple-quadrant

involvement, children with EE in one quadrant warrant regular follow-up and comprehensive assessment —rather than reliance on a single indicator—to facilitate early intervention.

Abbreviations

EE
Ectopic eruption
FPM
First permanent molar
SPM
Second primary molar
GA
General anesthesia
SSC
Stainless steel crown
MA
Mesial angulation
HD
Horizontal distance
IQR
interquartile ranges
ROC
Receiver operating characteristic
OR
Odds ratio
CI
Confidence interval

Declarations

Ethics approval and consent to participate

This study was approved by the Stomatological Hospital Ethics Committee, School of Stomatology, Southern Medical University (KQIIT2021003). All procedures complied with the principles of the Helsinki Declaration. Informed consent was obtained from the legal guardians of the children involved in the study.

Consent for publication

Not applicable. This manuscript does not contain any individual person’s data in any form.

Competing interests

The authors declare no competing interests.

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Author Contribution

Ke Chen designed the study, finalized the manuscript, and acted as guarantor. Yuan-wen Xie and Ya-nan Chen collected and analyzed the data and drafted the manuscript, who contributed equally to this work and should be considered co-first authors. Yan Chen, Xi-yan Chen Cheng-jun Sun and Yan Zhang collected the data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

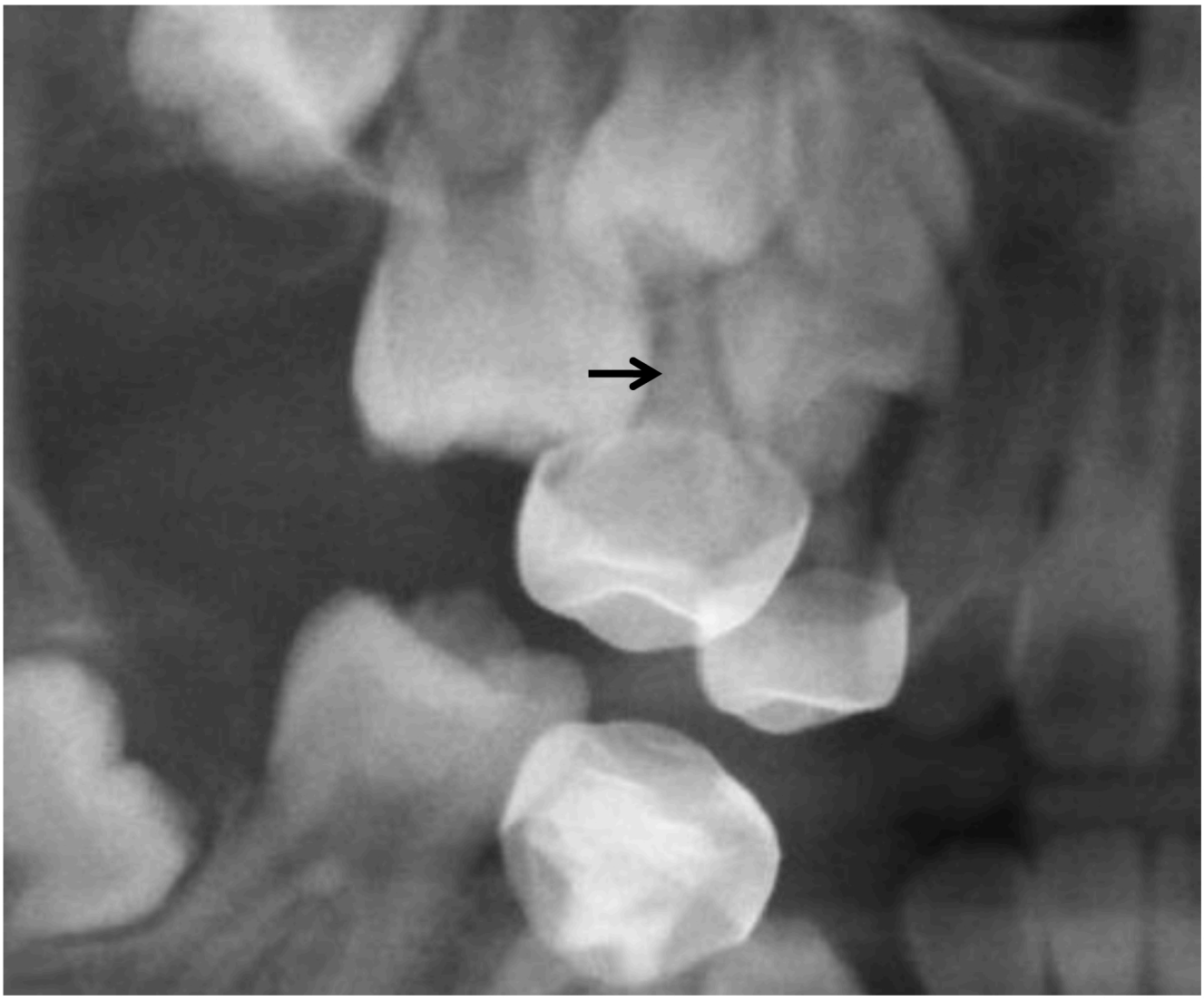


Figure 1

Ectopic eruption of the maxillary first permanent molar (tooth 16)

The mesial cusp is locked beneath the distal contour of the adjacent second primary molar (tooth 55), with distal root resorption (arrow).

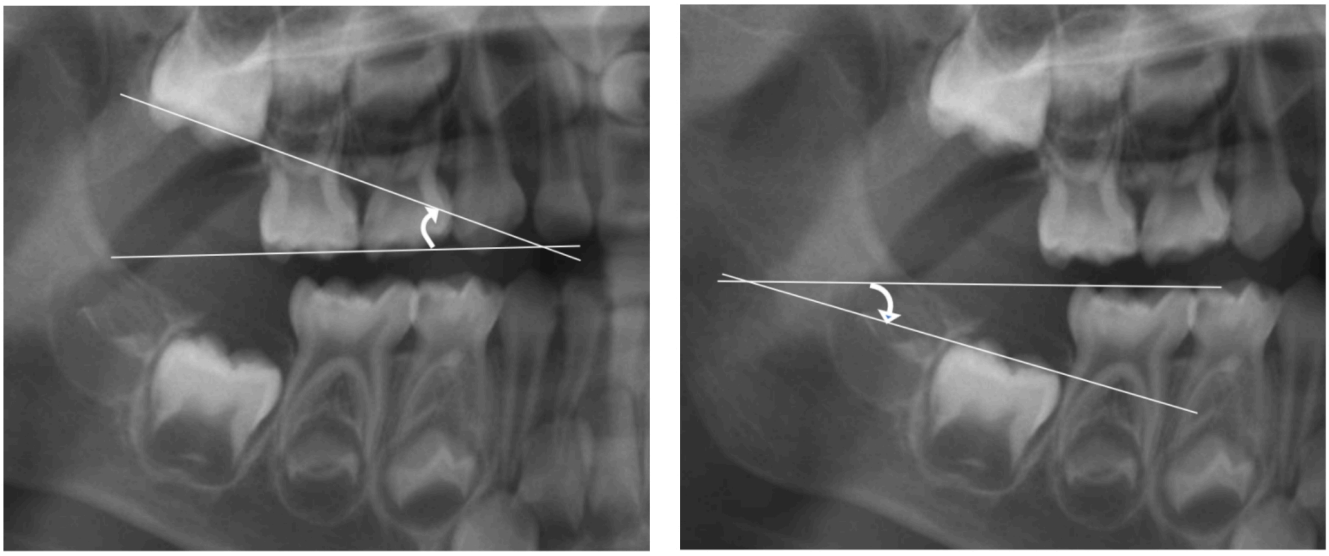


Figure 2

Measurement of mesial angulation (MA) of the first permanent molar

The MA was measured as the intersection angle between the occlusal plane of the second primary molar and that of the first permanent molar, traced along the cusp tips.

(A) Maxillary FPM normally shows negative values (distal tilt); (B) Mandibular FPM normally shows positive values (mesial tilt).

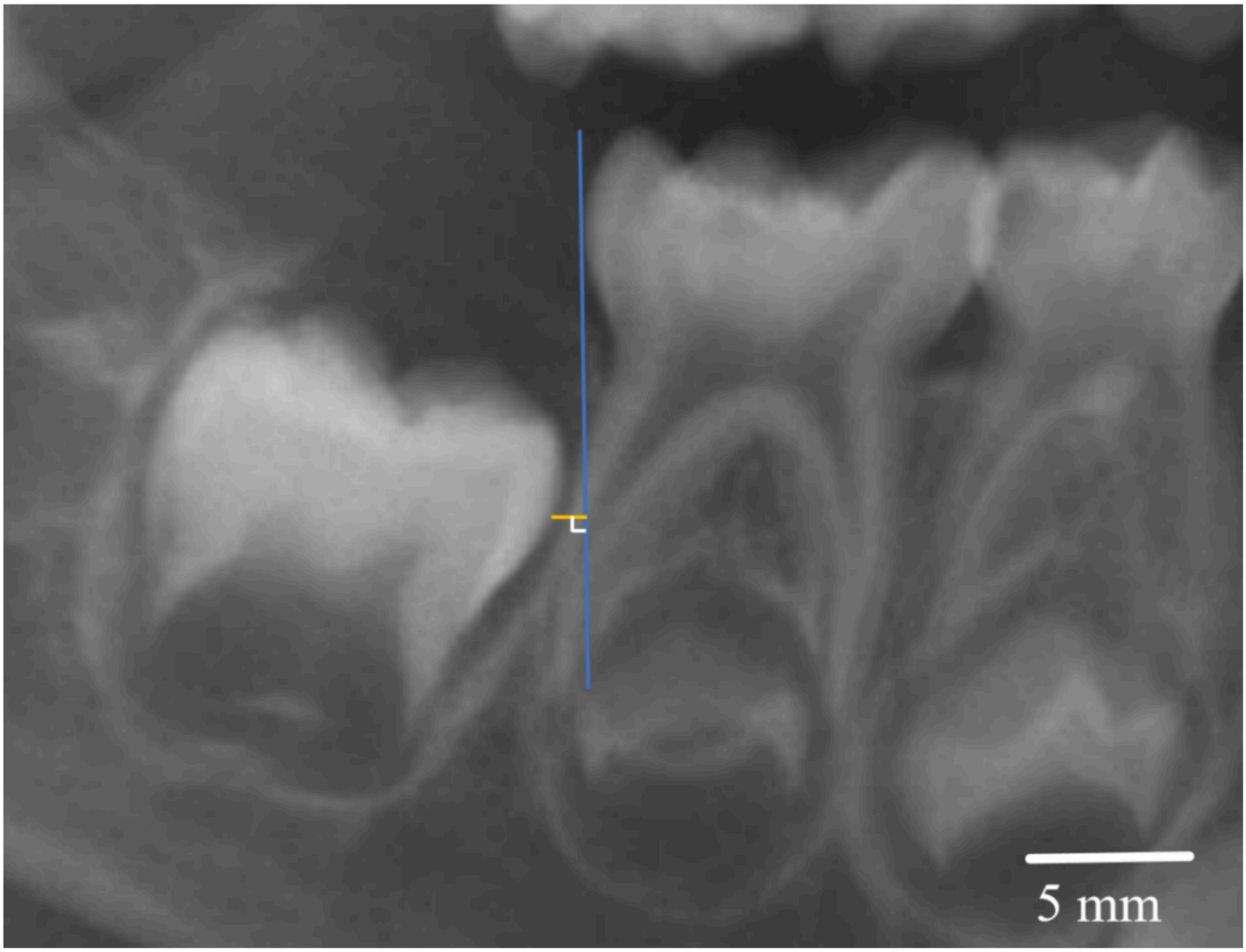


Figure 3

Measurement of horizontal distance (HD) between the first permanent molar and adjacent second primary molar

The measurement was performed on tooth 46 and the adjacent second primary molar (tooth 85) in this example. HD was defined as the vertical distance from the most convex point on the mesial aspect of the first permanent molar crown to the distal tangent line of the adjacent second primary molar crown.

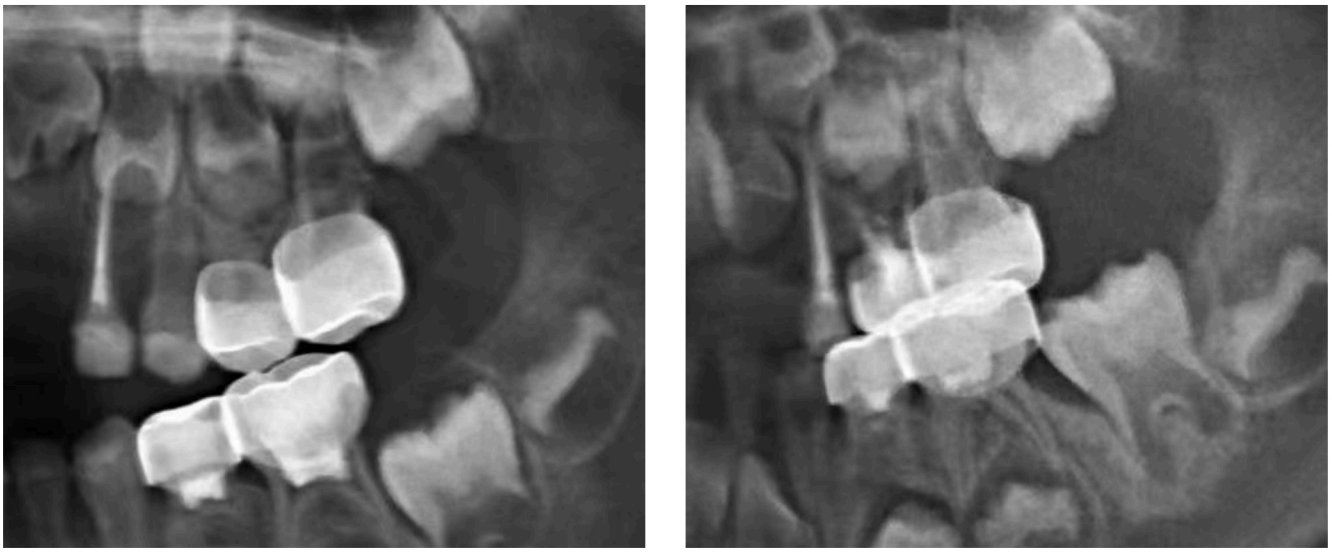


Figure 4

Distal step on the stainless steel crown (SSC).

(A) Absence of a distal step on tooth 65: the crown margin termination was flush with the distal surface of tooth 65 (distance = 0 mm); (B) Presence of a distal step on tooth 65: the distal termination point of the crown margin extended beyond the distal surface of tooth 65. The blue line indicates the distance between these two points (> 0 mm).