Original Article

Ectopic eruption of the maxillary second molar: *Predictive factors*

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ABSTRACT

Objective: The purpose of this study was to investigate the diagnostic aspects, contributing conditions, and predictive key factors associated with ectopic eruption of maxillary second molars.

Material and Methods: This retrospective study evaluated the study models, lateral cephalographs, and panoramic radiographs of 40 adult subjects (20 men, 20 women) with bilateral ectopic eruption and 40 subjects (20 men, 20 women) with normal eruption of the maxillary second molars. Studied variables were analyzed statistically by independent *t*-tests, univariate and multivariate logistic regression analysis, followed by receiver-operating characteristic analysis.

Results: Tooth widths of bilateral lateral incisors, canines, and premolars were wider in the ectopic group, which resulted in greater arch lengths. The ANB angle and maxillary tuberosity distance (PTV-M1, PTV-M2) were smaller in the ectopic group. The long axes of the maxillary molars showed significant distal inclination in the ectopic group. The multivariate logistic regression analysis showed that three key factors—arch length, ANB angle, and PTV-M1 distance—were significantly associated with ectopic eruption of the second molars. The area under the curve (AUC) was the largest for the combination of the three key factors with an AUC greater than 0.75. PTV-M1 alone was the single factor that showed the strongest association with ectopic eruption (AUC = 0.7363).

Conclusions: An increase in arch length, decrease in ANB angle, and decrease in maxillary tuberosity distance to the distal aspect of the maxillary first molar (PTV-M1) were the most predictive factors associated with ectopic eruption of maxillary second molars. (*Angle Orthod.* 2017;87:583–589)

KEY WORDS: Ectopic eruption, Molar, Prediction, Etiology, Orthodontics

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INTRODUCTION

Tooth eruption is associated with various biological factors. Disturbances during the eruption process may be from genetic, systemic, or local factors. Genetic or systemic factors affect the tissues and cells involved in the eruption of multiple teeth and are found in patients with certain developmental syndromes.[1] Local factors are primarily from physical barriers that obstruct normal tooth eruption and affect only a few permanent teeth. Eruption disturbances due to local factors are predominantly found in the canine or molar area and can be caused by fibromatous scar tissue after surgery, inflammation, premature loss of primary teeth, space shortage within the dental arch, etc.[1,2]

Previous studies on eruption abnormalities of molars have focused on the maxillary first molars with reports of low incidence ranging from 2% to 6%.[2–6] Eruption disturbance of permanent second molars occurs even less frequently and varies from 0% to 2.3%.[7,8] Since eruption of second molars takes place later sequen-

Table 1. Age (Years) of Subjects at the Preliminary Visit

Sex	Normal Eruption Group	Ectopic Eruption Group
Men	27.1 ± 8.7	22.3 ± 4.4
Women	29.3 ± 11.1	23.5 ± 8.5
Total	28.2 ± 9.9	22.9 ± 6.7

tially, it may occur with poor angulation or contact, which is evident in cases of arch-length discrepancy. In addition, eruption disturbances of the second molars could be aggravated by orthodontic treatment, such as headgear usage or full arch distalization.[9] However, achieving proper second molar alignment has clinical significance because these molars contribute to normal development of the dentition by forming the distal ends of the dental arch, which provide occlusal support for proper mastication and aid in the coordination of facial growth.[9–12] Accordingly, eruption aspects of the second molars should be considered at the initial examination for proper alignment and prevention of additional iatrogenic complications.

Ectopic eruption of the maxillary second molars has not been fully reviewed, except for in a few case reports.[13,14] Therefore, the purpose of this study was to investigate diagnostic factors and predictive clinical characteristics associated with ectopic eruption of maxillary second molars in adults.

MATERIALS AND METHODS

This retrospective study included 40 patients (20 men, 20 women) with bilateral ectopic eruption of maxillary second molars who had visited the Gangnam Severance Dental Hospital from 2010 to 2013 for orthodontic treatment. Forty patients with normal eruption of maxillary second molars (20 men, 20 women) were assigned as the normal eruption group. All subjects were of Korean descent, and the average age was 28.20 years for the normal eruption group and 22.88 years for the ectopic eruption group (Table 1). This study was approved by the Institutional Review Board of Gangnam Severance Dental Hospital, Yonsei University (No. 3-2014-0088).

Criteria for inclusion in the normal eruption group were as follows: (1) maxillary second molars well aligned buccolingually within 0.5 mm of misalignment, (2) marginal ridge discrepancy between the maxillary first and second molars within 0.5 mm, and (3) buccal cusps of the maxillary second molars within 1 mm of buccal displacement measured from the line connecting the contralateral palatal cusps (Figure 1). Criteria for inclusion in the ectopic eruption group were based on the Index of Orthodontic Treatment Need[15] and included cases with greater than 2 mm of misalignment. The criteria were as follows: (1) amount of buccolingual misaligment of maxillary second molars more than 2 mm, (2) marginal ridge discrepancy between the maxillary first and second molars more than 2 mm, and (3) buccal cusps of the maxillary second molars displaced buccally by more than 2 mm from the line connecting the contralateral palatal cusps (Figure 2). Patients were excluded from the study if they had incomplete eruption of the second molars, one or more missing teeth in the upper arch, abnormal shape or prosthetic treatment of the second molars, severe irregularity of the anterior teeth according to Little's irregularity index,[16] or systemic disease, including cleft lip and palate.

Linear measurements were made on study models as shown in Figure 3. Mesiodistal tooth widths from the second molars to the central incisors were obtained by measuring the greatest distance between the contact points of all maxillary teeth. Maxillary intermolar and intercanine widths were measured. Maxillary arch length was recorded by measuring the distance from the buccal surface of the central incisor to the mesial

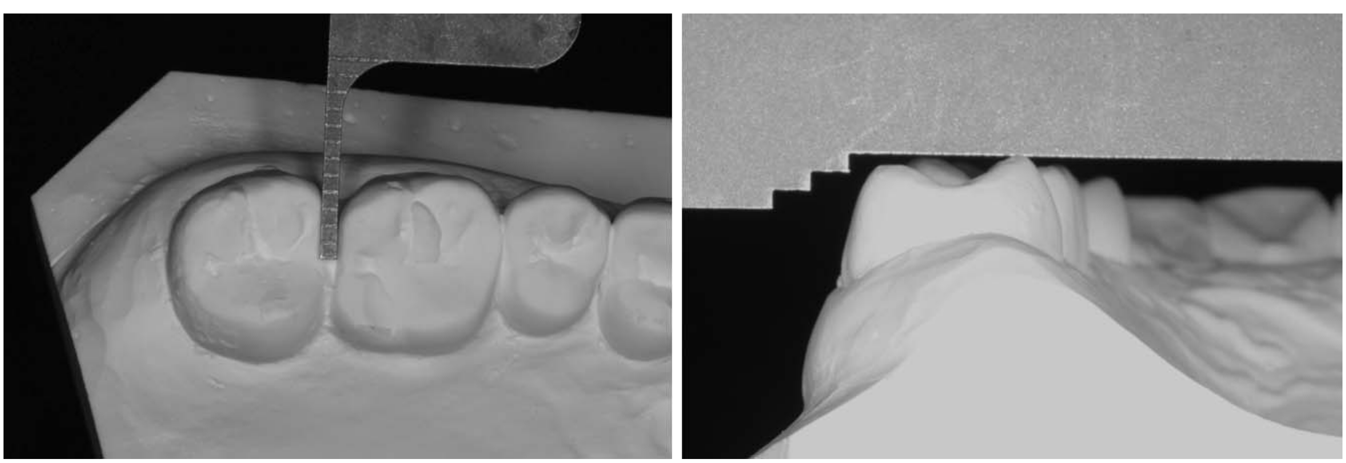

Figure 1. Representative dental study model for the normal eruption group.

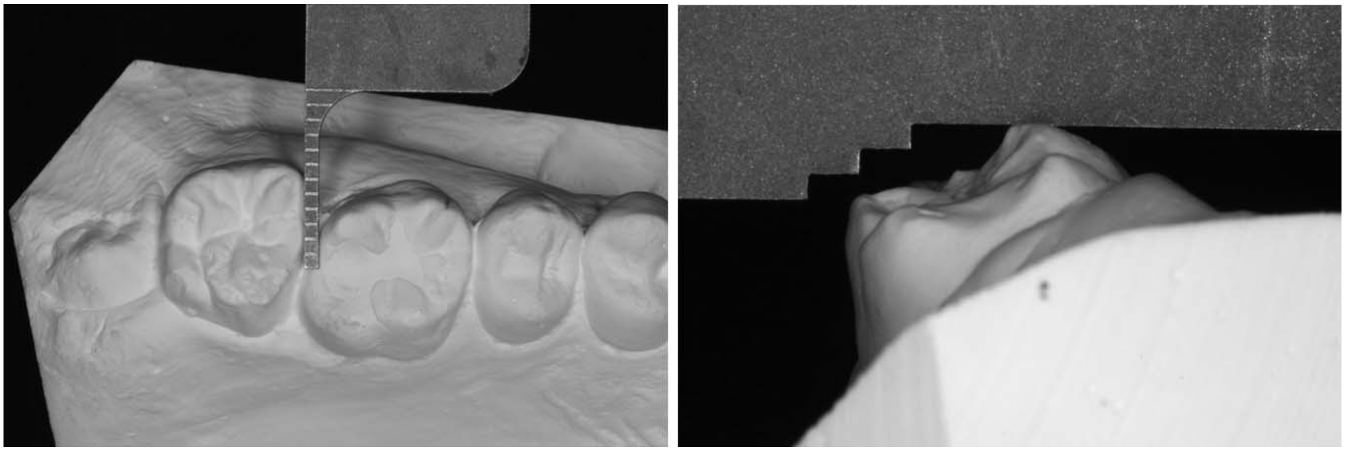

Figure 2. Representative dental study model for the ectopic eruption group.

surface of the first molar in the right and left side of the arch and calculating the average value. Palatal height in the midpalatal plane was determined by measuring the perpendicular distance from the occlusal plane (OP) constructed from the first permanent molars, as described by Thilander.[17] Displacement of the anterior contact points of the maxillary arch from the canines to the central incisors was quantified from each study model using Little's irregularity index.[16]

Lateral cephalographs were evaluated using 11 angular and four linear measurements (Figure 4). The horizontal reference line (HRL) was defined as the line rotated clockwise by 7° from the Sella-Nasion (SN) line at Nasion. The vertical reference line (VRL) was perpendicular to the HRL at Nasion. Angles formed by Sella-Nasion-A point (SNA), Sella-Nasion-B point (SNB), and A point-Nasion-B point (ANB) were used to evaluate sagittal skeletal discrepancies. Angles formed by SN-Palatal Plane (SN-PP), SN-Occlusal Plane (SN-OP), and SN-Mandibular Plane (SN-MP) were measured for vertical skeletal discrepancies. Angles between HRL and the line connecting the most distal convex points of the maxillary first molar (M1) and second molar (M2) were evaluated for molar inclination (HRL to M1d-M2d). Angles between OP and the long axis of the first and second molar, which were the lines connecting the midpoint of the crown and furcation for each molar (OP-M1 and OP-M2), angular difference between long axes of the molars (angle M1-M2), and maxillary incisor angulation (SN-U1) were measured as well. The four linear measurements used in this study were the shortest distance from the line perpendicular to the HRL at pterygoid point to M1d and M2d (HRL-M1d, HRL-M2d) and the distance of VRL to A point and VRL to U1 point.

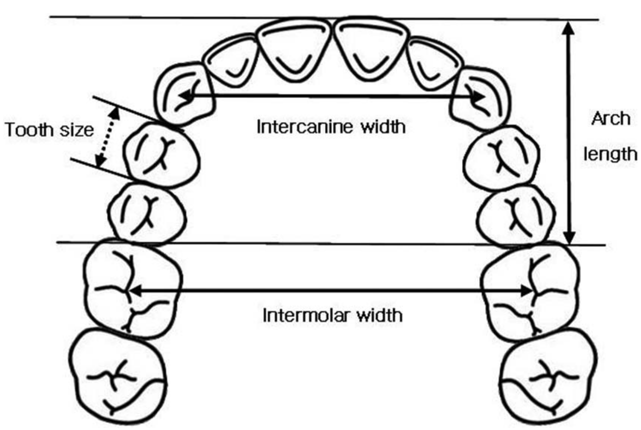

Figure 3. Analysis of study models.

Panoramic radiographs were used to verify the angulations of the first and second permanent molars (Figure 5). The OP was drawn from the first molar to the incisal edge of the central incisor on right and left sides. Angulation formed by the long axis of the first and second molars to OP was measured, and differences between the long axes of the two molars were evaluated.

All evaluations and measurements were performed by a single examiner. Reproducibility of measurement was assessed by statistically analyzing the difference between two measurements taken at an interval of 2 weeks in 20 randomly selected patients. The intraclass correlation coefficients showed high reliability ($r =$ 0.94–0.96). All statistical analyses were performed using SPSS software program, version 20.0 (IBM Co, Armonk, NY). Continuous variables were examined for normality by the Kolmogorov-Smirnov test, Q-Q plot, and histogram. No variables except intermolar width violated the normality condition and were presented as mean and standard deviation (SD) or median (min, max). Differences between the normal and ectopic eruption groups were compared by independent *t*-tests and Mann-Whitney U tests. Variables associated with ectopic eruption from the univariate analyses were

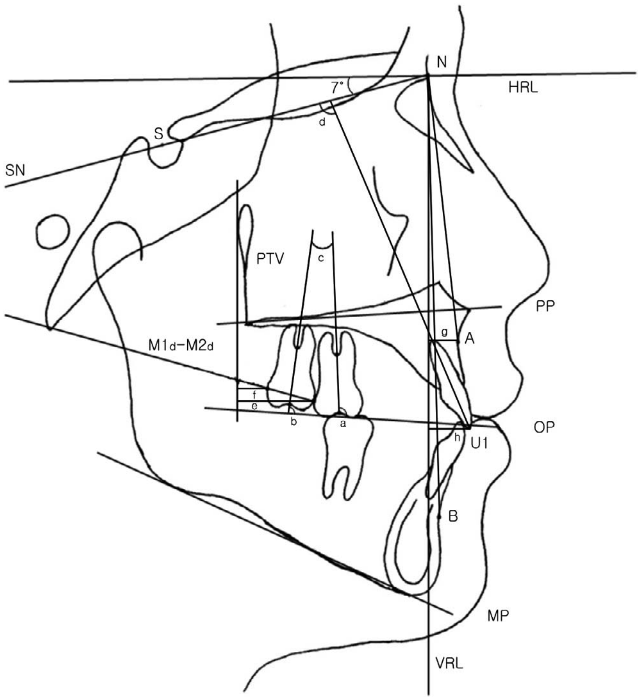

Figure 4. Reference lines and measurements on lateral cephalographs. Reference lines used were horizontal reference line (HRL); vertical reference line (VRL); pterygoid vertical plane (PTV); line connecting distal convex points of first and second molars (M1d-M2d line); and palatal, occlusal, and mandibular planes (PP, OP, and MP, respectively). Angular measurements included sella-nasion-A point (SNA), sella-nasion-B point (SNB), and A point-nasion-B point (ANB); angles between SN to PP, SN to OP, SN to MP, HRL to M1d-M2d, and SN to U1; angulation between OP and the long axis of the first molar (a), second molar (b), and difference between a and b (c). Linear measurements included shortest distance between the line perpendicular to HRL at PTV and M1d (e) or M2d (f); shortest distances between VRL to A point (g) and VRL to U1 point (h).

included in the multivariate logistic regression analysis using backward stepwise elimination. Variables that showed statistical significance in the multivariable logistic regression analysis were further assessed using receiver-operating characteristic (ROC) analysis to obtain the area under the ROC curve (AUC). Comparisons were made using the Delong method for statistical significance of AUC.[18] A P value $<.05$ was considered significant.

RESULTS

Measurements made on study models showed significantly greater values in tooth widths of the bilateral lateral incisors, canines, first premolars, and second premolars in the ectopic eruption group. Consequently, the ectopic eruption group had significantly greater arch length compared with the normal eruption group (Table 2).

In the lateral cephalometric analysis, the angles ANB, Op-M1, and Op-M2 were significantly smaller in the ectopic eruption group. The angular value of HRL to M1d-M2d was significantly greater in the ectopic eruption group. The distances of PTV-M1d and PTV-M2d were significantly shorter in the ectopic eruption group (Table 3).

In the panoramic radiograph evaluation, bilateral angles OP-M2 were significantly smaller in the ectopic eruption compared with the normal eruption group. As a result, bilateral angular differences between the long axes of M1 and M2 were significantly greater in the ectopic eruption group (Table 4).

The multivariate logistic regression analysis showed that arch length, ANB angle, and distance of PTV-M1d were significantly associated with ectopic eruption of the second molars (Table 5). The ROC curves were

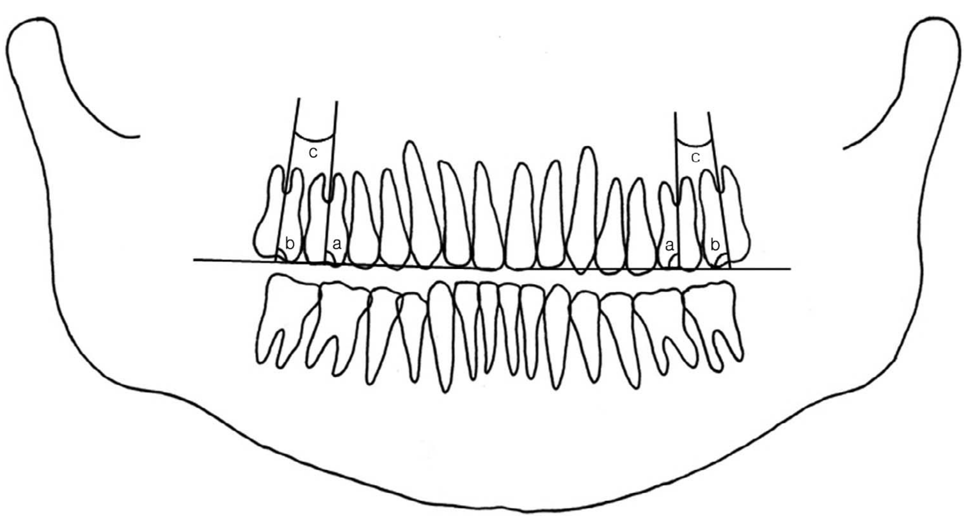

Figure 5. Angular measurements on panoramic radiographs. Angulation between occlusal plane and long axis of the maxillary first (a) and second molar (b), angulation difference between the molars (c).

Table 2. Study Model Analysis of the Normal and Ectopic Eruption Group (Mean ± Standard Deviation) (mm)[a]

Measurement	Normal Eruption	Ectopic Eruption	*P*
I1 (R)	8.6 ± 0.5	8.7 ± 0.5	.364
I2 (R)	7.1 ± 0.6	7.3 ± 0.6	.006**
C (R)	7.9 ± 0.4	8.2 ± 0.4	.008**
P1 (R)	7.3 ± 0.4	7.7 ± 0.6	.003**
P2 (R)	6.9 ± 0.5	7.2 ± 0.5	.014*
M1 (R)	10.5 ± 0.7	10.7 ± 0.7	.328
M2 (R)	10.0 ± 0.6	10.0 ± 0.6	.965
I1 (L)	8.5 ± 0.5	8.7 ± 0.5	.208
I2 (L)	6.9 ± 0.6	7.3 ± 0.7	.006**
C (L)	7.9 ± 0.4	8.1 ± 0.5	.007**
P1(L)	7.4 ± 0.4	7.7 ± 0.5	.027*
P2 (L)	6.9 ± 0.4	7.1 ± 0.6	.028*
M1 (L)	10.4 ± 0.6	10.6 ± 0.7	.102
M2 (L)	9.9 ± 0.5	9.9 ± 0.7	.744
Intermolar width	48.7 (38.6,58.1)	49.1 (39.8,48.3)	.989
Intercanine width	35.3 ± 2.3	35.9 ± 2.4	.267
Arch length	27.2 ± 2.6	28.9 ± 2.6	.005**
Palatal height	20.9 ± 2.0	20.5 ± 2.4	.447
LII	3.7 ± 3.1	4.8 ± 2.8	.103

[a] I1 indicates central incisor width; I2, lateral incisor width; C, canine width; P1, first premolar width; P2, second premolar width; M1, first molar width; M2, second molar width; LII, Little's irregularity index; R, right side; L, left side.

* $P < .05$; ** $P < .01$; *** $P < .001$.

generated for the three variables (arch length, ANB angle, PTV-M1d). The AUC for the combination of all three variables was larger than 0.75. The AUC for PTV-M1d was significantly greater (AUC = 0.7363) than those of the other two variables (Figure 6).

DISCUSSION

Ectopic eruption of maxillary second molars is often unnoticed by the patient because of its posterior location in the dental arch. However, the second molars have a significant role of grinding in mastication and are the common cause for working, balancing, and protrusive occlusal disturbances.[19] In addition, ectopic eruption of the maxillary second molars usually occurs in a distobuccal direction, which may make it difficult for the patient to maintain proper oral hygiene. Therefore, factors associated with ectopic eruption of maxillary second molars should be considered at the diagnostic phase.

Upon evaluation of study models, the arch length was significantly greater in the ectopic eruption group, which was a result of wider lateral incisors, canines, and premolars compared with the normal eruption group. Although statistically insignificant, the central incisors and first molars also showed greater average widths in the ectopic eruption group. This was in agreement with previous studies that reported that dental crowding occurs more commonly in people with larger mesiodistal dimensions of teeth.[3,20,21]

The ectopic eruption group showed a significantly smaller ANB angle. The average value of SNA was smaller and A point was more posteriorly located relative to the VRL in the ectopic eruption group. This implies that the maxilla was in a relatively posterior position in the ectopic eruption group, which is in accordance with a previous study that observed a smaller and retropositioned maxilla relative to the cranial base with ectopic eruption.[3]

The PTV to maxillary first molar distance increases with growth by an average of 1 mm/year from 10 to 18 years of age as a result of bone apposition at the

Table 3. Lateral Cephalographic Analysis of Normal and Ectopic Eruption Group (Mean ± Standard Deviation)

Measurement	Normal Eruption	Ectopic Eruption	*P*
SNA (°)	82.0 ± 3.3	81.3 ± 3.9	.359
SNB (°)	78.4 ± 4.8	80.0 ± 5.2	.166
ANB (°)	3.6 ± 3.5	1.3 ± 3.9	.006*
SN-PP (°)	10.3 ± 3.2	10.5 ± 3.5	.791
SN-OP (°)	19.8 ± 6.6	18.4 ± 5.0	.283
SN-MP (°)	40.1 ± 7.4	38.4 ± 6.1	.276
HRL to M1d-M2d (°)	19.2 ± 5.7	23.3 ± 9.0	.017*
OP-M1 (°)	93.6 ± 5.7	90.2 ± 7.7	.025*
OP-M2 (°)	87.6 ± 6.8	81.8 ± 10.4	.004**
Angle M1-M2 (°)	6.0 ± 4.1	8.4 ± 7.2	.072
SN-U1 (°)	106.2 ± 9.5	107.6 ± 9.0	.501
PTV-M1d (mm)	18.2 ± 4.4	14.5 ± 4.1	.000***
PTV-M2d (mm)	8.5 ± 3.9	6.1 ± 3.4	.006**
VRL-A (mm)	−1.3 ± 3.5	−2.2 ± 4.5	.326
VRL-U1 (mm)	4.1 ± 6.1	3.3 ± 7.5	.605

* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 4. Panoramic Radiographic Analysis of Normal and Ectopic Eruption Group (Mean ± Standard Deviation) (°)[a]

Measurement	Normal Eruption	Ectopic Eruption	*P*
OP-M1(R)	93.3 ± 4.6	91.5 ± 6.8	.174
OP-M2(R)	85.1 ± 5.6	76.6 ± 9.6	.000***
OP-M1(L)	89.0 ± 4.0	89.6 ± 5.9	.254
OP-M2(L)	83.8 ± 6.2	73.8 ± 8.5	.000***
Angle M1-M2(R)	8.2 ± 4.6	14.9 ± 8.0	.000***
Angle M1-M2 (L)	7.1 ± 4.7	15.8 ± 7.9	.000***

[a] OP-M1 indicates angle between occlusal plane and maxillary first molar; Op-M2, angle between occlusal plane and maxillary second molar; Angle M1-M2, angle between long axes of M1 and M2; R, right side; L, left side.

* $P < .05$; ** $P < .01$; *** $P < .001$.

Table 5. Multivariate Analysis Factors Associated With Ectopic Eruption of Maxillary Second Molars

Variable	Multivariate Analysis: Odds Ratio (95% Confidence Interval)	*P*
Arch length	1.312 (1.055–1.630)	.015*
ANB	0.802 (0.689–0.933)	.004**
PTV-M1d	0.765 (0.657–0.890)	.001**

* $P < .05$; ** $P < .01$; *** $P < .001$.

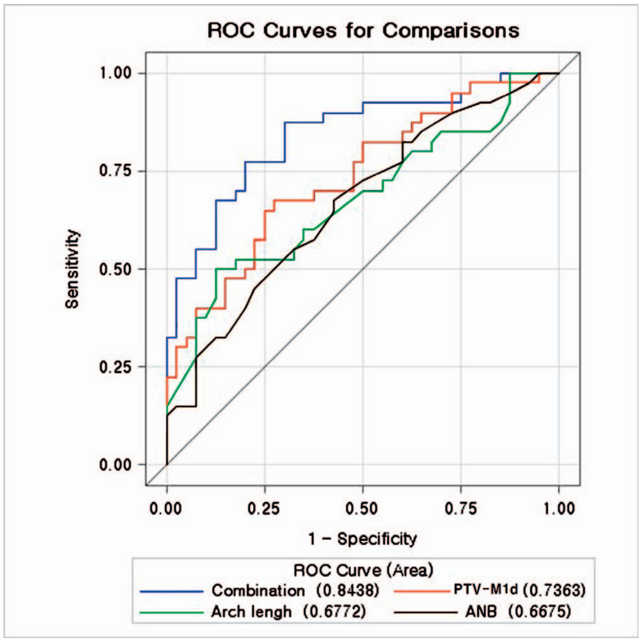

Figure 6. ROC curves for prediction of ectopic eruption of maxillary second molars. ROC indicates receiver-operating characteristic; combination, combination of PTV- M1d, arch length and ANB.

maxillary tuberosity and anterior movement of the first molar by alveolar bone growth.[22] In addition, subjects with pronounced forward growth of the maxillary complex have been reported to have enhanced periosteal apposition at the posterior outline of the maxillary tuberosity.[23,24] However, a lack of bony growth or an alteration in the chronology of bone growth at the tuberosity region has been observed to be related to ectopic eruption of maxillary first molars.[6,25] In this study, the PTV-M1d and PTV-M2d distances were significantly shorter in the ectopic eruption group. Considering the results of the ANB, PTV-M1d, and PTV-M2d measurements; it may be inferred that proper eruption of the second maxillary molars is facilitated by forward growth of the maxilla and sufficient bone apposition at the maxillary tuberosity region, which is found to be deficient in the ectopic eruption group.

The eruption path of maxillary second molars should be considered as it differs from that of other permanent teeth by the absence of preceding primary teeth. Before eruption, maxillary posterior teeth are not positioned perpendicular to the OP. The roots of the maxillary second molars are markedly palatal, near the roots of the first molars, and their occlusal surfaces are directed distobuccally. Upon eruption, the cone-funnel mechanism brings the maxillary second molars into their definitive occlusal position.[26] In other words, the maxillary molars are distally inclined at emergence but are uprighted as they come in contact with the opposing teeth. Therefore, the degree of distal inclination of the upper molars relative to the OP has been suggested as an important etiologic factor to consider in evaluating ectopic eruption.[3,6] Similar to previous reports, the ectopic eruption of the second molars in this study showed a steeper compensatory curve, which was confirmed by the increase in inclination of the first and second molars by about 4.1° relative to the HRL compared with the normal eruption group. This was also shown in panoramic radiographs as the tooth axis of the second molar was distally inclined relative to the OP in the ectopic eruption group. The difference in angle between the first and second molars was also larger in the ectopic eruption group. It appears that the distobucally inclined second molar at emergence was not redirected mesiolingually during the later stages of eruption due to the lack of available tuberosity space, which resulted in ectopic eruption.

A previous study evaluated vertical dimensions of subjects with posterior occlusal discrepancies and found a relationship between dolichocephalic patterns or posterior rotation of the chin and the ectopic eruption of maxillary first molars.[27] However, in the current study, there were no significant differences in the vertical skeletal patterns measured by the palatal, occlusal, and mandibular planes between the normal and ectopic eruption groups. This was probably because the ectopically erupted second molars were infraoccluded distobuccally and did not have a wedging or opening effect on the posterior occlusion.

Upon multivariate logistic regression analysis, an increase in arch length, decrease in ANB angle, and decrease in the distance of PTV-M1d were identified as the key factors associated with ectopic eruption of the second molars (Table 5). A combination of these three key variables showed the highest association with ectopic eruption by an AUC of 0.8438 followed by PTV-M1d as the single most influential factor (Figure 6). Thus, subjects with decreased maxillary tuberosity distance measured from the distal aspect of the first molars would have a high possibility of ectopic eruption of maxillary second molars and treatment plans should be directed accordingly.

This study evaluated adult patients with erupted second molars, and key factors of ectopic eruption were identified. However, changes related to growth and their influence on ectopic eruption were not included, which is a limitation of this retrospective study. Future prospective studies of adolescents would be useful for clinicians in predicting the eruption patterns of second molars.

CONCLUSIONS

- Wider tooth widths of the lateral incisors, canines, and premolars were observed in the ectopic eruption group, which resulted in significantly greater arch lengths.
- The ectopic eruption group had a relatively retrusive maxillary position, and the maxillary tuberosity region was shorter compared with the normal eruption group.
- The long axes of the maxillary second molars showed significant distal inclination in the ectopic eruption group.
- The factors that had a significant impact on ectopic eruption were increase in arch length, decrease in ANB angle, and decrease in the distance of PTV-M1d. A combination of these factors showed high predictability for ectopic eruption of the maxillary second molars (AUC $=$ 0.8438).
- Among the three factors, PTV-M1d was the single factor that showed the strongest association with ectopic eruption (AUC $=$ 0.7363).

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