Original Article

Eruption of the permanent maxillary canines in relation to mandibular second molar maturity

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ABSTRACT

Objective: To evaluate the timing of spontaneous maxillary canine eruption in relation to stages of mandibular second molar maturation. Potential confounding effects from such factors as age, growth phase, and facial features were also explored.

Subjects and Methods: A sample of 106 healthy subjects (48 females and 58 males; age range, 9.4–14.3 years) with both permanent maxillary canines during the final phase of intraoral eruption were included. Mandibular second molar maturation (stages E to H) was assessed according to the method of Demirjian. Skeletal maturity was determined using the cervical vertebral maturational (CVM) method. Facial vertical and sagittal relationships were evaluated by recording the Sella-Nasion/mandibular plane (SN/MP) angle and the ANB angle. An ordered multiple logistic regression was run to evaluate adjusted correlation of each parameter with the mandibular second molar maturational stage.

Results: Overall, the prevalence of the different second molar maturational stages was 36.8%, 37.8%, and 27.4% for stages E, F and G, respectively. According to the regression model, this relation was not influenced by sex, CVM stage, SN/MP angle, and ANB angle.

Conclusions: Irrespective of sex, growth phase, and facial features, the maturational stage of the mandibular second molar may be a reliable indicator for the timing of spontaneous eruption of the maxillary canine. (*Angle Orthod.* 2013;83:578–583.)

KEY WORDS: Dental maturation; Canine eruption; Diagnosis; Timing; Orthodontics

INTRODUCTION

Permanent canines have primary roles in determining functional occlusion and a pleasant smile, and disturbances of normal development and eruption can have major consequences (for review, see Bedoya and Park[1]). Regarding the maxillary canine, an important and effective treatment modality to prevent impaction is based on intercepting and eliminating any factor that may interfere with eruption.[2] However, although a precise diagnosis of delayed eruption, that is, displacement or impaction, is needed, this cannot be done on the basis of chronological age or phase of dentition.[3,4] On the contrary, early studies,[3,4] confirmed by recent evidence,[5] have shown that permanent maxillary canines undergo spontaneous eruption until late puberty, that is, during prepubertal and pubertal growth phases. These results were determined using the statural height peak[3,4] or the maturation of the hand and wrist or cervical vertebrae[5] methods to identify the pubertal growth-spurt period in individual subjects. Therefore, the use of indicators of the timing of spontaneous maxillary canine eruption has been advocated as an adjunct to the diagnosis and management of canine displacement/impaction.[5]

Of interest, a recent primary study[6] on white subjects and a meta-analysis[7] on different ethnicities have consistently shown a significant association of the complete maturation, that is, complete root formation, of the mandibular second molar with attainment of a

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postpubertal growth phase. Therefore, considering how the maxillary canine eruption and mandibular second molar maturation are both parts of the same whole dentition development, a relation between the two processes may be hypothesized.

Thus, considering the relevant clinical implications reported earlier, the present study focused on the relation between the spontaneous eruption of the permanent maxillary canine and the maturation of the mandibular second molar to propose the monitoring of the latter as a means of predicting the timing for the spontaneous eruption of the former in individual subjects. Moreover, the potential confounding effects from such factors as age, growth phase, and facial features were also explored.

MATERIALS AND METHODS

A sample of 106 subjects (48 females and 58 males; age range, 9.4–14.3 years) at the Unit of Orthodontics of the University of Trieste with both permanent maxillary canines during the final phase of intraoral eruption were retrospectively included. Signed informed consent was obtained from the parents of the subjects before entry into the study, and the protocol was reviewed and approved by the local ethical committee. Thirty-three subjects of the present sample were included in a previous study[6] with a different purpose.

At their first clinical examination, intraoral photographs, a dental panoramic radiograph, and a lateral cephalogram were obtained from each subject as part of the pretreatment clinical recording. The following inclusion criteria were observed: (1) white ethnicity, (2) good general health with absence of any nutritional or developmental problems, (3) never orthodontically treated, (4) negative for any dental or facial anomaly (including massive caries, tooth loss, multiple agenesis), (5) no history of previous trauma in the orofacial region, and (6) absence of any pathologic obstacles to the eruption pathway of the maxillary canines, such as odontomas, cysts, or supernumeraries.[5] Moreover, only patients with minimal crowding or differential eruption degree between the two contralateral canines were considered. In case of a slight delay in the eruption of one canine over the other, the less erupted tooth was considered.

The final phase of canine eruption was defined as previously reported.[8] Briefly, it was the emergence of the canine from the initial appearance of the tip of the cusp in the dental arch to a 1-mm distance of the tip of the cusp from the maxillary occlusal plane (traced on the panoramic radiograph).

Skeletal maturity was assessed through the cervical vertebral maturational (CVM) method.[9] This method comprises six stages (CS1 to CS6). An experienced orthodontist, blinded to the age and sex of the subjects, assessed the skeletal maturity of the subjects. Finally, the subjects were clustered, according to their growth phases, as prepubertal (CS1 and CS2), pubertal (CS3 and CS4), and postpubertal (CS5 and CS6).

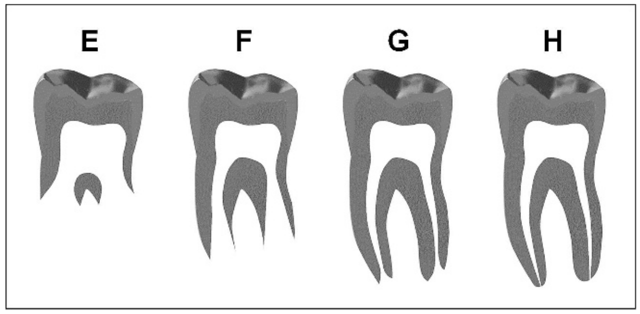

Figure 1. Maturational stages of the mandibular second molar according to Demirjian et al.[10] (stages E to H).

Assessment of Mandibular Second Molar Maturity

Mandibular second molar maturity (Figure 1) was assessed through the calcification stages, according to the method of Demirjian et al.[10] (stages E to H), from the panoramic radiographs of the left-side mandibular teeth. Alternatively, when the left side was not clearly visible, the right side was assessed. Briefly, these stages are defined as follows:

> Stage E: (1) The walls of the pulp chamber form straight lines, the continuity of which is broken by the presence of the pulp horn, which is larger than in the previous stage; and (2) the root length is less than the crown height.
> Stage F: (1) The walls of the pulp chamber form a more or less isosceles triangle, with the apex ending in a funnel shape; and (2) the root length is equal to or greater than the crown height.
> Stage G: The walls of the root canal are parallel, and its apical end is still partially open.
> Stage H: (1) The apical end of the root canal is completely closed; and (2) the periodontal membrane has a uniform width around the root and the apex.

An experienced orthodontist, blinded to the skeletal maturation stages and the age and sex of the subjects, assessed the dental maturity of the mandibular second molars using the distal root as the reference structure.

Cephalometric Recordings

Facial vertical and sagittal relationships were evaluated by recording the Sella-Nasion/mandibular plane

Table 1. Chronological Age, SN/MP Angle, and ANB Angle for Females (n = 48) and Males (n = 58)[a]

	Females		Males		
Parameter	Mean ± SD	Range	Mean ± SD	Range	Diff.
Age (years)	11.4 ± 1.1	9.4–13.6	11.6 ± 1.2	9.4–14.3	NS
SN/MP angle (°)	33.1 ± 5.7	21.4–47.6	34.4 ± 5.4	22.7–48.3	NS
ANB angle (°)	3.8 ± 2.1	−1.3–9.1	3.7 ± 1.8	0.5–8.0	NS

[a] SN/MP indicates Sella-Nasion/mandibular plane; SD, standard deviation of the mean; Diff., significance of the difference between the sexes; NS, not statistically significantly different.

(SN/MP) angle and the ANB angle, respectively. The mandibular plane was defined as the Gonion-Gnathion line. The cephalograms were hand traced by a single investigator. Cephalometric software (Viewbox, version 3.0, dHAL Software, Kifissia, Greece) was used for measurements on digitized cephalograms. Subjects were not clustered as hyper-/normo-/hypodivergent or as skeletal Class I/II/III as previously done.[5,11] Instead, multiple regression models were used to evaluate the effects of these variables on the correlations between the maxillary canine eruption and mandibular second molar maturation.

Repeatability and Method Error Calculation

The following analyses were performed on 20 pairs of recordings randomly selected. Repeatability for the assessed maturational stages of both the cervical vertebrae and mandibular second molar was evaluated through a weighted kappa coefficient. This kappa coefficient was weighted linearly as this makes the coefficient less sensitive to the number of categories[12] or stages, thus avoiding biases in the interpretation of the results. A weighted kappa coefficient above 0.80 stands for an almost perfect repeatability.[13] Method error of the recordings for both SN/MP angle and ANB angle was quantified though the method of moments variance estimator,[14] which has the advantages of not being affected by any unknown bias, that is, systematic errors, between pairs of measurements.[14]

Statistical Analysis

Normality of the data sets and the equality of variance among them were evaluated by the Shapiro-Wilk test and Levene test, respectively. Between the sexes, the statistical significance of the differences in mean ages, SN/MP angle, and ANB angle was evaluated by an independent sample *t*-test, whereas those for the distributions of the growth phases (as prepubertal and pubertal) and the second molar maturational stages (as E, F, and G) were evaluated by a χ^2 test.

Subsequently, the adjusted correlations of these variables with the dental maturational stages were evaluated by multiple ordered logistic regression, which is a regression model for ordinal dependent variables. In particular, the following explanatory variables (categories) were entered in the model: age, sex (females, males), growth phase (prepubertal, pubertal), SN/MP angle, and ANB angle. Each of the three dental maturational stages (E, F, and G) was the category of the dependent variable, with stage G as the reference category. For sex and growth phase, reference categories were males and pubertal, respectively. Briefly, the beta coefficients retrieved by this ordinal regression model are the ordered log odds of being in a more mature stage of the mandibular second molar for a one-unit increase in SN/MP angle or ANB angle (continuous variable) or when belonging to a nonreference category (ie, females vs males and prepubertal vs pubertal), given all of the other variables in the model are held constant.

Moreover, data from a previous investigation[6] on dental maturation were retrieved, and means and standard errors of the chronological ages of the subjects at each maturational stage of the mandibular second molar were plotted for females and males. This was a cross-sectional study on a large sample of subjects; therefore, the difference in mean ages between the subjects, clustered according to two consecutive maturational stages, may be considered as the time required for the investigated tooth to mature from one stage to the next, especially from stage E to stage G. A *P* value less than .05 was used for rejection of the null hypothesis.

RESULTS

For appraisal of the stages of both cervical vertebrae and second molar maturational stages, the weighted kappa coefficients for repeatability were above 0.92. The method error for the cephalometric recordings was lower than 1°.

The mean ages of the subjects, along with the SN/MP angle and ANB angle, for females and males are summarized in Table 1. All of these parameters were similar between the sexes, and there were no significant differences.

The relative distributions of the different growth phases and second molar maturational stages for females and males are summarized in Table 2. A

Table 2. Relative Distributions of the Different Growth Phases and Second Molar Maturational Stages for Females and Males [a]

Parameter	Females, N (%)	Males, N (%)	Diff.
Growth phase			
Prepubertal	16 (33.3)	40 (69.0)	$P < .001$
Pubertal	32 (66.7)	18 (31.0)	
Second molar maturation			
Stage E	22 (45.8)	17 (29.3)	**NS**
Stage F	14 (29.2)	26 (44.8)	
Stage G	12 (25.0)	15 (25.9)	

[a] No subjects in the postpubertal growth phase or mandibular second molar at stage H were seen. Diff. indicates significance of the difference between the sexes; NS, not statistically significantly different.

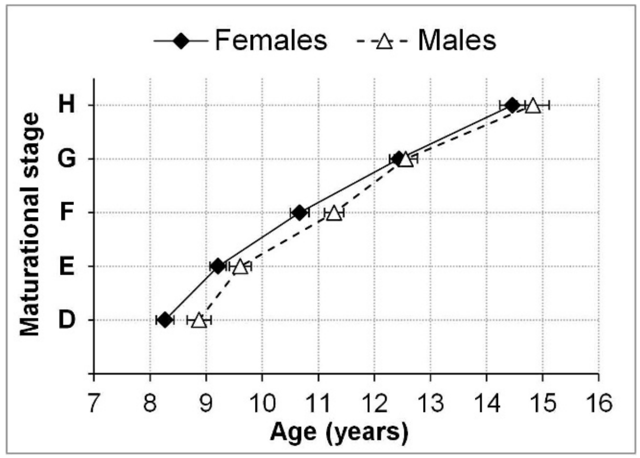

Figure 2. Chronological ages among the different mandibular second molar maturational stages for females (N = 208) and males (N = 146). Data are presented as mean ± standard error of the mean. Data were retrieved from cases included in a previous study.[6]

greater percentage of subjects in the pubertal growth phase was seen for females (66.7%) compared with males (31.0%; $P < .01$). Overall, the prevalences of the different second molar maturational stages were 36.8%, 37.8%, and 27.4% for stages E, F, and G, respectively. No stage H was seen, and the distributions of the other stages were similar between the sexes, with no significant difference.

The ordered multiple regression model for the association of each explanatory variable with the second molar maturational stage is summarized in Table 3. With the exception of age (β, 0.543; $P < .01$), none of the explanatory variable yielded a statistically significant interaction with the second molar maturity.

Chronological ages among the different mandibular second molar maturational stages for females and males as retrieved from a previously investigated sample[6] are shown in Figure 2. The overall mean (standard error) values were 8.5 ± 0.1, 9.4 ± 0.1, 10.9 ± 0.1, 12.5 ± 0.1, and 14.6±0.2 years for stages D, E, F, G, and H, respectively. Mean time intervals between stages E to F and stages F to G were 1.5 and 1.6 years, respectively. The slight differences seen between females and males were not statistically significant.

DISCUSSION

This cross-sectional study was undertaken to evaluate the relation between the spontaneous eruption of maxillary canine and mandibular second molar maturation. All the subjects had canine eruption of the mandibular second molar within maturational stages E, F, and G (see Figure 3), irrespective of growth phase and other investigated factors.

Being that spontaneous eruption of maxillary canines and mandibular second molar maturation are parts of the same dental maturation process, a correlation between them was expected. However, whether the eruption of the former may be predicted by the maturation of the latter with satisfactory reliability, and whether other factors may influence this prediction, has still not been reported. Subjects included herein were seeking orthodontic treatment; therefore, a greater prevalence of malocclusion in the present sample was seen compared with a similar group in the general population.[15] In particular, a general tendency toward hyperdivergent skeletal class II was encountered (Table 1).

The overall prevalence of subjects at the prepubertal growth phase seen herein (52.8%) was similar, though lower, than that reported previously (56.6%).[5] According to previous results,[4,5] no subject herein showed spontaneous eruption of the maxillary canine at the postpubertal growth phase.

In the present study, the correlation between the spontaneous maxillary canine eruption and maturation

Table 3. Ordered Multiple Regression Model for the Association of Each Explanatory Variable With the Second Molar Maturational Stage[a]

Parameter	β (SE)	95% CI	Significance
Age	0.543 (0.192)	0.167–0.919	$P < .01$
Sex (females)	−0.484 (0.415)	−1.297–0.330	NS
Growth phase (prepubertal)	−0.308 (0.428)	−1.146–0.531	NS
SN/MP angle	−0.023 (0.034)	−0.090–0.044	NS
ANB angle	−0.096 (0.101)	−0.294–0.102	NS

[a] Stage H is the reference category for the second molar maturation; n =106. β (SE) indicates mean beta coefficient (standard error of the mean); 95% CI, 95% confidence interval; NS, not statistically significantly different.

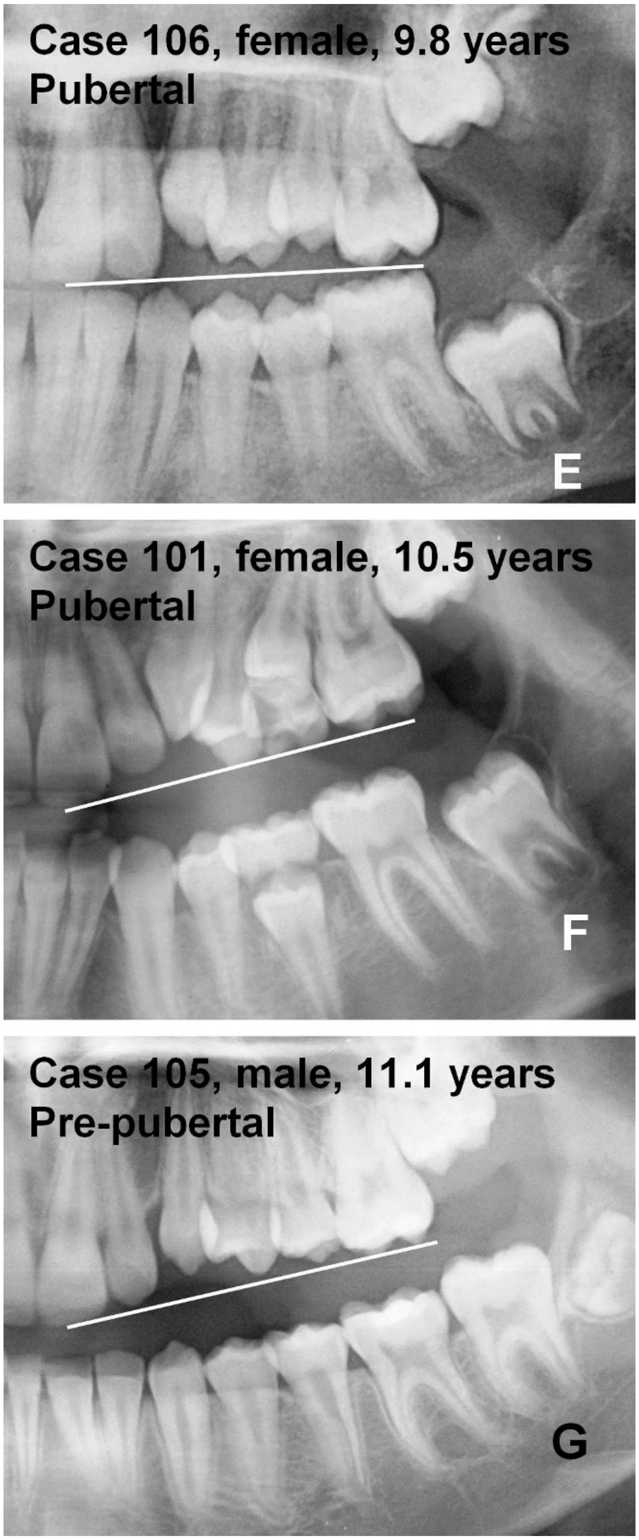

Figure 3. The permanent maxillary canine during the final phase of eruption in three subjects, along with the maturational stages of the mandibular second molar. In these subjects, the final phase of eruption of the maxillary canine is associated with maturational stages E (patient 106), F (patient 101), and G (patient 105).

of the mandibular second molar was not influenced by sex, growth phase, or dentofacial growth features. On the contrary, a previous study[5] reported an earlier eruption for hyperdivergent subjects but only when the maxillary canine eruption is attained at a prepubertal growth phase. This finding is consistent with the evidence that dental maturation would occur earlier in subjects with an extreme vertical face type.[11] However, previous studies[5,11] did not adjust correlations by the use of multiple regression models. Regarding the sagittal skeletal facial features, the present evidence is in agreement with previous findings.[5] Nevertheless, potential effects by other factors, such as genetic or hormonal features, may be responsible for the intersubject variation seen in the timing of the spontaneous eruption of the maxillary canines.

In comparison with the growth phase, maturation of the mandibular second molar may thus be considered more strictly related to the spontaneous eruption of the maxillary canine. This may be expected as these are two events of the same overall maturation of the dental arches. Therefore, as reported for the attainment of the postpubertal growth phase,[5] canine impaction can be suspected when not erupted after the complete root formation of the mandibular second molar. In this case, an implementation of the diagnosis would be deemed.

Consistently for both females and males, intervals of 18 months were seen as the time required for a mandibular second molar to mature from stage E to F and from stage F to G (Figure 2). This information on the timing of maturation of the mandibular second molar may be helpful when managing interceptive treatments for maxillary displaced canines. Indeed, knowledge of the timing at which the maxillary canines can still undergo spontaneous eruption is useful for determining the expected appearance in the oral cavity. On the contrary, if a canine has not erupted by the attainment of mandibular second molar stage H, even after an interceptive treatment, a surgical approach may be considered, especially if other diagnostic features of canine impaction are noted.[1] Considering that all subjects undergo spontaneous eruption of the maxillary canine when the mandibular second molar maturation is between stages E and G, information regarding timing of eruption may be available in all the subjects, irrespective of sex, growth phase, and vertical and sagittal skeletal facial features.

Even though the CVM method has been shown to be a reliable indicator of the timing of canine eruption, this analysis requires a lateral head film, which is available as a pretreatment record. However, in several instances, optimal treatment timing is delayed until after the diagnosis, making a later reevaluation of the growth phase necessary. Moreover, the cervical vertebrae might be partially covered by the protection collar, which would be necessary to reduce radiation exposure.[16] On the other hand, radiographic recording of the hand and wrist requires additional x-ray exposure and a dedicated x-ray machine. Importantly, for both methods, re-execution of recordings to reevaluate growth phases only is not indicated according to some recent guidelines.[17] In this view, the use of the mandibular second molar maturation to predict the timing for eruption of the maxillary canines offers the advantage of easy interpretation, and it does not require additional x-ray exposure to the patient when a dental panoramic record is available. The radiographic recording of the region of the mandibular second molar also avoids doubling or superimposition of the recorded structures with anatomic features of the distal root that are clearly visible. Moreover, the same panoramic radiograph may be used to retrieve other relevant information regarding the identification of a potential displaced/impacted canine.[18] Finally, if needed, an intraoral periapical radiographic record of the mandibular second molar may be taken during follow-up visits with minimal irradiation to the patients.

CONCLUSIONS

- Spontaneous eruption of the maxillary canine occurs between stages E and G of the mandibular second molar, irrespective of sex, growth phase, and facial features.
- The maturational stage of the mandibular second molar may be a reliable indicator for the timing of spontaneous eruption of the maxillary canine.

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