Original Article

Eruption rates of lower second premolars at different development stages evaluated with cone-beam computed tomography

Mariana Roennau Lemos Rinaldi[a]; Eduardo Martinelli de Lima[b]; Luciane Macedo de Menezes[b]; Susana Maria Deon Rizzatto[b]; Paulo Ricardo Baccarin Matje[a]; Roberto Vanin Pinto Ribeiro[c]

ABSTRACT

Objective: To evaluate and compare the eruption rates of lower second premolars (LPm2) at different developmental stages using cone-beam computed tomography (CBCT).

Materials and Methods: Retrospectively, 31 individuals (9.77 ± 1.25 years) had their LPm2 scored according to the Demirjian method, and afterwards they were split into three groups according to developmental stage, as follows: D = complete-formed crowns; E = root length less than crown height; and F = root length greater than or equal to crown height. Linear distances from the LPm2 crown tip to the anatomical reference line (ARL) and to the occlusal plane line (OPL) were measured in paired CBCT scans (T1, T2), taken with an average interval of 8.6 months between them. Eruption rates (mm/y) were calculated and then compared between groups.

Results: Eruption rates were greater for LPm2 at stage F than at stages D or E ($P < .01$) regardless of whether they were measured from the ARL (D = 2.84 mm/y; E = 2.55 mm/y; F = 5.38 mm/y) or from the OPL (D = 1.82 mm/y; E = 2.02 mm/y; F = 5.26 mm/y). Eruption rates evaluated from the ARL and the OPL had no statistically significant differences ($P = .052$), and a positive correlation ($r = .79$, $P < .001$) between them was observed.

Conclusions: LPm2 at Demirjian stage F showed greater eruption rates than at stages D or E, regardless of whether rates were measured from the ARL or the OPL. Faster eruption is expected for LPm2 at stage F. Evaluation of the LPm2's developmental stage using CBCT can aid in clinical decision making regarding the correct timing for intervention. (*Angle Orthod.* 2017;87:570–575)

KEY WORDS: Premolars; Tooth eruption; Tooth development; Cone-beam computed tomography

INTRODUCTION

Lower second premolar (LPm2) eruption time is of special interest to orthodontists because these are usually the last successor teeth to emerge, signaling the best timing to begin full orthodontic treatment.[1] Moreover, most of the leeway space in the lower arch is released at exfoliation of the predecessors, the second deciduous molars.[2,3] Comprehensive diagnosis often indicates preservation of the leeway space[3] and/or extraction of lower deciduous molars to favor development of the dentition.[4,5] The best timing for this approach could be at the terminal phase of the mixed dentition period, near the emergence of the LPm2.[2–5]

There is a clear relationship between root formation and tooth eruption.[4–6] Under normal dentition development, LPm2 begin their eruption with half-formed roots,[2] surpass the alveolar bone of the mandible with 65%-formed roots,[6] and emerge with 75%-formed roots.[5] More advanced developmental stages of the LPm2 are significantly correlated with shorter periods until emergence occurs.[1,7] However, beyond the static relationship between stages of tooth development and milestones of the eruption process, estimated eruption rates could determine the ideal time for treatment in each case. Currently, panoramic radiographs and oblique 45° cephalograms are the gold-standard methods of assessment used in most studies[1,4–8] of tooth development and eruption, regardless of image

[a] PhD Student, Department of Orthodontics, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil.

[b] Professor, Department of Orthodontics, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil.

[c] MD, Master's Student, Institute of Medical Science, University of Toronto, Toronto, Ontario, Canada.

Corresponding author: Dr Eduardo Martinelli de Lima, Department of Orthodontics, Faculty of Dentistry, Pontifical Catholic University of Rio Grande do Sul, Av. Ipiranga 6681, Prédio 6, CEP 90619-900, Porto Alegre, RS, Brazil (e-mail: elima@pucrs.br)

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Figure 1. The anatomical reference line (ARL); superimposition of paired cone-beam computed tomography (CBCT) scans on the mandible's natural reference structures, described by Björk[10]; and the occlusal plane line (OPL).

enlargement, distortion, and superimposition of anatomic structures. Despite the clear limitation for the use of cone-beam computed tomography (CBCT) in children, a retrospective study using CBCT to evaluate eruption rates and correlate them with the tooth's development stage could improve clinician's interpretation of the radiographic assessments, aiding on the decision-making process with regard to time of treatment.[2]

The present study aimed to evaluate and compare the eruption rates of LPm2 at different developmental stages using CBCT scans. For that purpose, LPm2 were scored according to the Demirjian method[9] and had their eruption measured from the mandible's natural reference structures[10] and from the occlusal plane.

MATERIALS AND METHODS

This study was approved by the Research and Ethics Committee of the Pontifical Catholic University of Rio Grande do Sul (PUCRS). Sample size calculation determined seven individuals in each group, considering a clinically significant difference of 1.5 mm/y in the eruption rate of LPm2, with a standard deviation of 1.33 mm/y (observed in a previous study[8]), a power of 80%, and a bilateral alpha level of 5% (Statistical Solutions, LLC Systems, Cottage Grove, Wis).

We retrospectively reviewed all patients with paired CBCT scans available from previous treatments and studies[11] at the Faculty of Dentistry, PUCRS. Inclusion criteria were healthy individuals between 7 and 13 years of age with LPm2 at Demirjian[9] developmental stages D, E, or F. Exclusion criteria were individuals with congenital malformations; lower premolars agenesis; ankylosed, extracted, or early-lost lower deciduous molars; severe space discrepancy in the lower arch; history of orthodontic treatment or any other treatment interfering with the natural eruption of lower premolars; and LPm2 at Demirjian[9] stages earlier than D or later than F, where D = complete-formed crowns; E = root length less than crown height; and F = root length greater than or equal to crown height.

Thirty-one individuals (18 girls, 13 boys) met the inclusion criteria. The mean age of participants was 9.77 ± 1.25 years. The average interval between paired CBCT scans (T1, T2) was 8.6 ± 3.74 months. Scans were taken at 120 kV, 8 mA, and 0.3-mm voxel dimension. Data were reconstructed with 0.3-mm slice thickness and stored in Digital Imaging and Communications in Medicine format (DICOM). Images generated by the InVivoDental software (version 5.0, Anatomage, San Jose, Calif) underwent standardization on axial, sagittal, and coronal planes, with references on the oval, spiny, and round foramina as well as on the hypoglossal canal.[12]

Right and left sides of the mandible underwent multiplanar reconstructions, similar to lateral cephalograms. Thereafter, images were resized, with respect to the reference scale, with Adobe Photoshop software (version CS3, Adobe Systems, San Jose, Calif) so that different resolutions were standardized.

The mandible's natural reference structures, as described by Björk,[10] were highlighted on all images with the Adobe Illustrator software (version CS3, Adobe Systems, San Jose, Calif). The anatomical reference line (ARL) was traced on the image of the initial CBCT scan (T1) by joining the mental protuberance[13] and the lowest point of the crypt of the third molar germ (Figure 1). If third molars had initially formed roots, the reference used was the upper wall of the mandibular canal, at the midpoint between the distal edge of the permanent second molar and the medial border of the third molar. Then, initial (T1) and follow-up (T2) scans were superimposed[14] on the mandible's natural reference structures (tip of the chin, inner cortical structure at the inferior border of the symphysis, trabecular structures related to the mandibular canal, and the lower contour of a molar germ before the beginning of root formation), and the ARL was transferred from the initial (T1) to the follow-up scan (T2) (Figure 1). Thus, a stable baseline in relation to growth was employed, adapted from the method proposed by Dibbets.[15] In addition, the occlusal plane line (OPL) was traced, joining the incisal edges of the lower central incisors and the mesiobuccal cusps of the permanent first molars, and plotted on images for analysis (Figure 1).

Table 1. Comparison of the LPm2 Eruption Rates Between the Right and Left Sides[a]

		Eruption Rate			
		Occlusal Plane Line (OPL)		Anatomical Reference Line (ARL)	
LPm2	n	Mean ± SD, mm/y	P	Mean ± SD, mm/y	P
Right	31	3.38 ± 2.82	.382[ns]	3.88 ± 2.55	.648[ns]
Left	31	3.70 ± 3.05		4.09 ± 2.57	

[a] Paired *t*-test. LPm2 indicates lower second premolars; SD, standard deviation; and ns, nonsignificant.

The observer assessed 124 images (31 individuals, two CBCT, right and left sides) in a random order, blinded to subjects and to T1 or T2 scan type. Perpendicular linear distances were measured from the crown tip of the LPm2 to the ARL and to the OPL, on right and left sides, with Radiocef software (version 2.0, Radio Memory, Belo Horizonte, Brazil). Differences between measurements (T2-T1) were divided by the number of months elapsed between scans and multiplied by 12 to generate the eruption rates (mm/y). LPm2 were scored according to the Demirjian[9] method and divided into three groups according to the developmental stage: stage D, E, or F.

For testing reproducibility of tooth development scores and linear measurements from the ARL and the OPL, both of the evaluations were repeated by the same observer on 20 scans that were randomly selected, after a 30-day interval.

Statistical Analysis

Intraobserver agreement between repeated assessments was analyzed with Kappa coefficient (k) for the Demirjian[9] scores and with intraclass correlation coefficients (ICCs) for the linear measurements taken from the ARL and the OPL. Nonparametric Kolmogorov-Smirnov test assured that the data were normally distributed. A paired *t*-test was used to perform comparisons between the eruption rates from the ARL and from the OPL, as well as from the right and left sides. In addition, correlation analysis between ARL and OPL rates was performed using the Pearson's correlation coefficient (*r*). Analysis of variance was chosen to compare eruption rates between LPm2 at stages D, E, or F; Tukey's post hoc test was used to identify the statistically significant differences, if applicable. SPSS statistical software (version 18.0, SPSS, Chicago, Ill) was used for management and analysis of the data. Results were significant at the 95% confidence level.

Table 2. Comparison and Correlation of the LPm2 Eruption Rates Between the Anatomical Reference Line (ARL) and the Occlusal Plane Line (OPL)[a]

		LPm2 Eruption Rate		
	n	Mean ± SD, mm/y	P	r
ARL	31	3.99 ± 2.54	.052[ns]	.797
OPL	31	3.54 ± 2.92		

[a] Paired *t*-test, Pearson's correlation coefficient. LPm2 indicates lower second premolars; SD, standard deviation; andns, nonsignificant.

Table 3. Descriptive Statistics: Comparison of the Eruption Rates Between LPm2 at Different Demirjian Stages[a]

		LPm2 Eruption Rate			
		Occlusal Plane Line		Anatomical Reference Line	
Demirjian Stage	n	Mean ± SD, mm/y	P	Mean ± SD, mm/y	P
D	7	1.82 ± 0.96 A	<.001	2.84 ± 1.35 A	<.01
E	9	2.02 ± 1.65 A		2.55 ± 1.95 A	
F	15	5.26 ± 3.15 B		5.38 ± 2.58 B	

[a] Analysis of variance, Tukey's test. LPm2 indicates lower second premolars; SD, standard deviation, Means followed by different letters are significantly different from each other.

RESULTS

Intraobserver agreement between two evaluations with a 30-day interval was excellent for the Demirjian[9] scores (k = .939) and for the linear distances from the ARL (ICC = .99) and the OPL (ICC = .98).

Demirjian[9] scores for each subject showed 100% agreement between right and left sides. In addition, there were no significant differences between the eruption rates of right and left LPm2 ($P > .05$) (Table 1). From there on, the mean eruption rate (mean value between right and left sides) was used for the following comparisons.

Eruption rates evaluated from the ARL and the OPL had no statistically significant differences ($P = .052$), and a positive correlation ($r = .79$, $P < .001$) was observed between them (Table 2).

Regardless of whether we consider the ARL or the OPL, the eruption rates were greater for LPm2 at stage F (ARL = 5.38 ± 2.58 mm/y; OPL = 5.26 ± 3.15 mm/y) than at stage D (ARL = 2.84 ± 1.35 mm/y; OPL = 1.82 ± 0.96 mm/y) or E (ARL = 2.55 ± 1.95 mm/y; OPL = 2.02 ± 1.65 mm/y) ($P < .01$) (Table 3).

A box plot (Figure 2) revealed that the ARL eruption rate of 3.6 mm/y was surpassed by 95% of the LPm2 at stage F, while 75% of the LPm2 at stages D or E showed eruption rates below 3.6 mm/y. Likewise, in terms of the OPL, eruption rates were greater than 3.6 mm/y for 75% of the LPm2 at stage F and were below 3.6 mm/y for 75% of the LPm2 at stage E and 100% of the LPm2 at stage D.

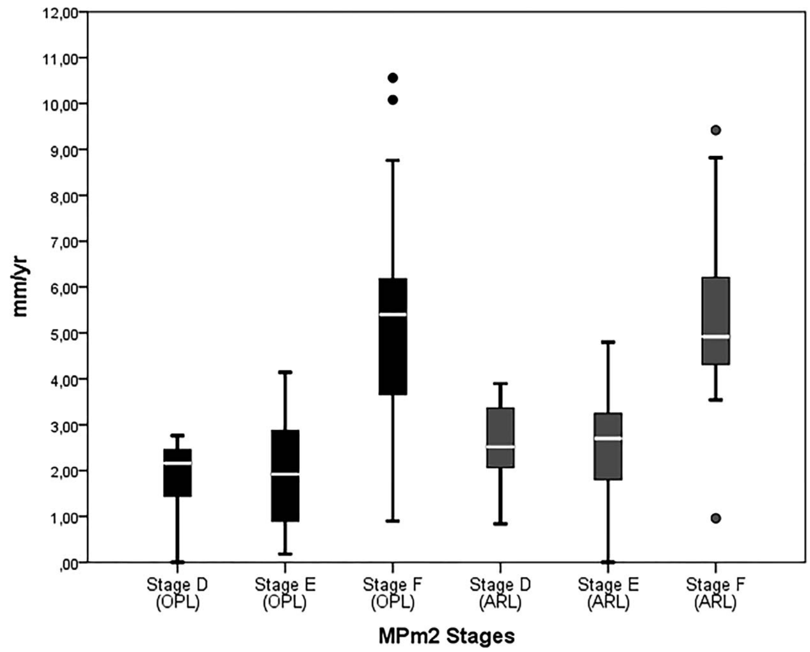

Figure 2. Eruption rates of the lower second premolars (LPm2) in a box plot. Horizontal line in the middle of box shows mean value; horizontal lines in box give 25% and 75% quartiles; horizontal lines outside box give 5% and 95% percentiles; dots represent outliers.

DISCUSSION

In this retrospective study, 31 paired CBCT scans from 31 patients were analyzed to compare the eruption rates between LPm2 at different developmental stages, represented by Demirjian[9] stages D, E, and F. There was no change of developmental stage of the LPm2 during the study.

Using CBCT scans in this study helped to improve the precision of tooth development scores and of tooth eruption measurements. A painstaking analysis carried out by the observer led to excellent intraobserver agreements between the 30-day interval evaluations, both for the Demirjian[9] scores and for linear measurements from the ARL and the OPL.

The sample gathered individuals with transverse maxillary deficiency, associated with displaced maxillary canines and/or supranumerary teeth. CBCT scans supported accurate diagnostics and treatment plans for each particular case.[16] The PUCRS orthodontic department database enabled us to complete this study, extending possible benefits to other populations.

Because at baseline there were no significant differences between right and left LPm2 values, either for the Demirjian[9] scores or for the eruption rates from ARL and OPL, the overall mean values were employed in the following evaluations. Unequal distribution within groups prevented comparisons of eruption rates by sex. However, another study[6] showed no significant differences between boys and girls regarding LPm2 root formation.

Two references were used to enable evaluation of the eruption rates. Because the lower border of the mandible remodels during growth,[8,10,13] the ARL was constructed based on the natural reference structures described by Björk.[10] If observed from the ARL, the tooth moves away from stable skeletal structures toward the line of occlusion. The OPL, however, moves away and tilts, according to differential growth of the alveolar bone at regions of the lower permanent first molars and incisors.[13,17] This may lead to an underestimation of the tooth's eruption rate measured from the OPL. The smaller values measured from OPL, however, were not significantly different from those measured from the ARL, and a positive correlation between both eruptions rates was identified in this study.

In this sample, the Demirjian[9] method proved useful in distinguishing eruption rates between tooth development stages. The results revealed significantly greater eruption rates for LPm2 at stage F, regardless of whether rates were evaluated from ARL or OPL. Few individuals did not follow the sample's general trend, as expected in this kind of study. Exploring the raw data, only one individual with LPm2 at stage F showed an eruption rate from ARL that was below 3.6 mm/y (Figure 2). Extrapolating this finding, one could estimate eruption rates of greater than 3.6 mm/y for LPm2 at stage F in every 14 out of 15 orthodontic patients. On the other hand, LPm2 at stages D and E showed eruption rates of less than 3.6 mm/y in every three out of four individuals. These findings clearly indicate greater eruption rates for LPm2 at stage F.

The present study enriches our current knowledge by quantifying actual LPm2 eruption rates at different tooth development stages. Emergence is likely to occur within 12 months for LPm2 at stage F, located less than 5 mm from the gingival boundaries. In a similar situation, LPm2 at stages D or E would take longer until emergence occurs.

From this standpoint, by counterbalancing the expected eruption rates and the tooth distances to the point of emergence, clinicians can determine the ideal time for treatment in each patient. For instance, in cases with mixed dentition and crowded lower incisors, lingual arch to leeway space preservation should be maintained until LPm2 eruption and crowding dissipation. If rationally postponed, the appliance stays a shorter period in the oral environment,[3] reducing possible side effects, such as lower incisor proclination,[18] plaque retention, and cytotoxicity related to the silver-soldered joints.[19]

In another example, a suitable waiting strategy prior to bonding full fixed appliances avoids longer treatment periods.[1] In addition, extractions of second deciduous molars, often required in interceptive guidance of occlusion, produce better results if performed during periods of greater eruption rates of the LPm2.[2,4,20]

Eruption rates depend on bone formation as the root grows, space in the dental arch, tooth eruption path, and resorption of the deciduous teeth.[21] In this study, the exclusion criteria did not take into consideration intrinsic and extrinsic factors that could interfere with LPm2 eruption. For instance, disturbances in the LPm2 eruption axis may alter the estimation of the eruption rates. In addition, individual variation should be taken into account, as few individuals did not follow the trend of the greater study population. Further studies could elucidate etiologic factors related to slower or faster eruption within the same developmental stage. Since CBCT should only be ordered when fully justified (to avoid unnecessary radiation), it is reasonable to use the results obtained here to aid in interpretation of panoramic radiographs and oblique 45° cephalograms. However, a multicenter study gathering a larger number of CBCT scans might improve our understanding of the relationship between root formation and tooth eruption.

CONCLUSION

Evaluation of the eruption rates of LPm2 using CBCT showed the following:

- LPm2 at Demirjian[9] stage F have greater eruption rates than at stages D or E, regardless of whether the rates were measured from the ARL or the OPL.
- Evaluation of the LPm2 developmental stage using CBCT can aid in clinical decision making regarding the correct timing for intervention.

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