Original Article

The premature loss of primary first molars:

Space loss to molar occlusal relationships and facial patterns

Stanley A. Alexander[a]; Marjan Askari[b]; Patricia Lewis[c]

ABSTRACT

Objective: To investigate space changes with the premature loss of primary first molars and their relationship to permanent molar occlusion and facial forms.

Materials and Methods: Two hundred twenty-six participants (ranging in age from 7 years 8 months to 8 years 2 months; 135 female, 91 male) met all inclusion criteria designed to study space loss as a result of the premature loss of the primary first molar. After 9 months, space loss was evaluated in relationship to molar occlusion and facial form. Statistical evaluation was performed with the paired *t*-test and with a two-way analysis of variance for independent groups.

Results: Patients with leptoprosopic facial form and end-on molar occlusions all exhibited a statistically significant difference when compared to controls in terms of space loss ($P < .001$). The mandibular extraction site for individuals with a mesoprosopic/euryprosopic facial form and end-on molar occlusion displayed space loss as well ($P < .05$). All patients with a leptoprosopic facial form and Class I molar occlusion displayed space loss in the maxilla ($P < .05$) and the mandible ($P < .001$) respectively, that was statistically significant when compared to that of the control. Individuals within the mesoprosopic/euryprosopic group and with Class I molar occlusions showed no significant difference in space loss.

Conclusions: The relationship between the first permanent molar occlusion and facial form of the child has an influence on the loss of space at the primary first molar site. (*Angle Orthod.* 2015;85:218–223.)

KEY WORDS: Premature tooth loss; First primary molar; Occlusal relationship; Facial pattern

INTRODUCTION

It is generally accepted that a disruption in arch integrity of the primary or mixed dentition without space maintenance will lead to a malocclusion that is dependent upon the type and time of tooth loss. Miyamoto and co-workers[1] demonstrated that in a study of 225 school children the premature loss of primary canines and molars resulted in the need for orthodontic treatment when no space maintenance was utilized. In a review of the literature, Owen[2] and Bell et al.[3] have indicated that in almost all cases of early tooth loss, some decrease of arch length is to be expected, and this loss occurs within the first 6 months after the tooth is lost, at the time of active tooth eruption.

The insertion of space maintainers does not automatically follow the premature loss of deciduous teeth. The decision as to the type and placement of a space maintainer rests with the following criteria: when the tooth was lost, what tooth was lost, from which arch the tooth was lost, whether the permanent successor is present, the occurrence of space loss, the existing arch length requirements for the permanent dentition, and the cooperation and oral health status of the patient.

The premature loss of primary first molars requires space maintenance only under specific circumstances.[3] During the active eruption of the permanent first

[a] Chief Dental Officer, Holyoke Health Center, Holyoke, Mass; and Distinguished Teaching Professor Emeritus, Department of Orthodontics & Pediatric Dentistry, Stony Brook University, Stony Brook, NY.

[b] Director of Orthodontics, Holyoke Health Center, Holyoke, Mass.

[c] Assistant Professor (deceased), Stony Brook University, Department of Orthodontics & Pediatric Dentistry, Stony Brook, NY.

Corresponding author: Dr Stanley A. Alexander, Chief Dental Officer, Holyoke Health Center, 230 Maple Street, PO Box 6260, Holyoke, MA 01041
(e-mail: stanalexander427@gmail.com)

Accepted: May 2014. Submitted: March 2014.
Published Online: July 10, 2014

molar from ages 5–7 years, mesially directed forces may result in the loss of first primary molar space. Additionally, when the first permanent molar is in an end-to-end relationship before an early or late mesial shift has occurred, space loss may occur as a result of potential molar occlusal adjustments.

Additional factors often ignored in potential space loss are the morphologic differences of the child's face. Patterns of vertical or horizontal growth that are apparent clinically are usually overlooked in the young child as a result of established criteria for radiation exposure and the lack of necessity for cephalograms at a young age. Therefore, whether the patient exhibits a hypodivergent or hyperdivergent facial appearance, the diagnosis must be made during the clinical examination. The purpose of this investigation was to determine how much, if any, space loss occurred when the maxillary or mandibular first primary molar was lost prematurely in patients with end-on, Class I, and Class II molar occlusions and horizontal or vertical facial growth patterns.

MATERIALS AND METHODS

The patients examined in this study were obtained from the University Clinics at Stony Brook University and gave consent as private patients to participate. Approval was also granted by the Internal Review Board of Stony Brook University on the Use of Human Subjects. The total patient sample of consecutively treated patients of the age group specified consisted of 226 children, 135 females and 91 males ranging in age from 7 years 8 months to 8 years 2 months.

Inclusion criteria consisted of the following:

- Signed consent form;
- Age group of patients between 7 years and 8.5 years;
- A mixed dentition with the permanent molar relationship in an end-on molar occlusion, Class I or Class II molar occlusion; the presence of four erupting or erupted maxillary incisors and four erupting or erupted mandibular incisors;
- A unilateral missing maxillary or mandibular first primary molar that had been extracted within 1 week of the examination or one that was planned for extraction; the contralateral and opposing arch having an intact occlusion;
- One-half or less root formation of the first premolar in the jaw below the missing first primary molar;
- No other missing teeth resulting from extraction or trauma;
- The absence of interproximal caries;
- The absence of any appliances in the oral cavity; and
- Parents or caretakers who did not want the child to receive a space maintainer.

Direct intraoral measurements were made twice by the first author and twice by the third author with a digital caliper set to the accuracy of 0.1 mm after the extraction of the first primary molar or of the space previously created as a result of the extraction. A second measurement was repeated 1 minute after the initial measurement, and the four measurements from both examiners were averaged to obtain a final number. All extraction sites were measured at the initial examination and at 9 months after the extraction procedure. The intact side served as a control. Space change was defined as the distance between the mesial midpoint of the first permanent molar and the distal midpoint of the primary canine. Of the 226 patients examined, only 12 displayed a full Class II molar occlusion (5%) and were therefore placed into the end-on category.

Facial Analysis

Two facial parameters served to describe the components of the facial form, according to the methods of Hall et al.[4] and Farkas et al.[5]: (1) Frontal: the ratio of the width of the bizygomatic diameter (BZD), which measured the horizontal distance in millimeters between the lateral borders of the cheekbones, and the maximum facial length (MFL), which measured the vertical length in millimeters from the root of the nose (nasion) to the lowest point on the border of the mandible in the mid-sagittal plane (gnathion). Ink dots were placed on the points of the patients' faces, as indicated, and measurements were made with a millimeter ruler. The BZD:MFL ratio determined if the patient had a leptoprosopic facial form (0.75 or less), a mesoprosopic facial form (0.76–0.79), or a euryprosopic facial form (0.8 or greater). As a result of the young age of the patients and their impending vertical facial development, the facial form was placed into two categories for evaluation: the leptoprosopic facial form and the mesoprosopic/euryprosopic facial form. (2) The lateral form, indicating hyperdivergency or hypodivergency: a mirror handle was gently placed along the border of the right mandible; if it intersected through the occipital bone the patient was classified as hyperdivergent; if it was tangent or below the occipital bone, the patient was classified as normodivergent or hypodivergent.

Statistical Analysis

To determine intra- and interobserver reliability, the intraclass correlation coefficient for absolute agreement was calculated. The intact primary molars served as controls and were measured as previously described. Data were entered utilizing the Statistical

Table 1. The Total Number of Missing Maxillary and Mandibular First Primary Molars Displaying Either an End-On Molar Occlusion, Class II Occlusion, or Class I Occlusion and their Associated Facial Forms

	Leptoprosopic	Mesoprosopic/Euryprosopic
Total No. of patients missing Maxillary first primary molars	End-on and Class II (67)	
	29	38
	Class I (44) 18	26
Total No. of patients missing Mandibular first primary molars	End-on and Class II (68)	
	25	43
	Class I (47) 17	30
Combined total of patients with missing primary first molars, No. (%)	89 (39)	137 (61)

Package for Social Sciences (SPSS, version 19, SPSS Inc, Chicago, Ill). Paired *t*-tests were used to compare the differences between the sets of initial intraoral measurements of the combined end-on and Class II occlusions and Class I molar occlusions and at the 9-month interval, respectively, for both facial form groups. A two-way analysis of variance for independent groups was used to evaluate the mean space change differences between the leptoprosopic group and the combined mesoprosopic/euryprosopic group with regard to the end-on and Class I molar occlusions. This analysis was chosen because two classifications can be structured: a comparison of change within the end-on and Class I relationships within the leptoprosopic form and the combined mesoprosopic/euryprosopic, and a comparison of change between the molar occlusions of the two facial form groups.

RESULTS

The intraclass correlation coefficient revealed good repeatability for all intraoral and extraoral measurements. The mean value for all intraoral measurements was .966 (range, .875–.995) for intraobserver repeatability and .944 (range, .845–.990) for interobserver repeatability, respectively. The mean value for all extraoral (facial) measurements was .975 (range, .915–.995) for intraobserver repeatability and .950 (range, .880–.980) for interobserver repeatability, respectively.

Table 1 represents the overall composition of the patients in the study. All patients who displayed a leptoprosopic facial form appeared clinically to be hyperdivergent, while the combined mesoprosopic/euryprosopic group was normodivergent. The majority of patients had end-on molar occlusions in the early mixed dentition. These individuals comprised 60% of the patients, while Class I molar occlusions occurred in 40% of the patients examined. Of the total population examined, 39% were leptoprosopic, while the majority (61%) displayed mesoprosopic/euryprosopic facial forms.

The Leptoprosopic Facial Form and End-On Molar Occlusion (Table 2)

Patients displaying a leptoprosopic facial form and end-on molar occlusion showed no change in either the maxillary or mandibular control sides. However, both maxillary and mandibular space loss occurred in the first primary molar site that was statistically

Table 2. Comparison of Space Changes (mm) Between the Initial Examination and 9-Month-Follow-Up Examination in Both the Control and Extraction Sides for Patients with End-On Molar Occlusions and Leptoprosopic or Mesoprosopic/Euryprosopic Facial Forms

Facial Form	Initial	9 Mo	Significance (*P*)
Leptoprosopic (N = 54)			
Maxillary control	16.80 ± 1.28	16.71 ± 1.36	=.25
Mandibular control	17.79 ± 1.41	17.65 ± 1.30	=.22
Maxillary extraction	16.98 ± 1.41	15.23 ± 1.33[a]	≤.001*
Mandibular extraction	17.99 ± 1.63	16.61 ± 1.74[b]	≤.001*
Mesoprosopic/Euryprosopic (N = 81)			
Maxillary control	17.11 ± 1.30	17.05 ± 1.26	=.25
Mandibular control	17.60 ± 1.38	17.71 ± 1.42	=.30
Maxillary extraction	17.15 ± 1.40	17.22 ± 1.51	=.41
Mandibular extraction	17.61 ± 1.55	16.02 ± 0.29[c]	≤.05*

[a] Space loss occurred in all 29 subjects by mesial migration.

[b] Space loss occurred by mesial migration of distal segments and distal canine tipping in 21 subjects and by mesial migration only in four subjects.

[c] Space loss occurred by mesial migration of distal segments and distal tipping of the canine in 38 subjects and by mesial migration only in five subjects.

* Indicates a statistically significant difference.

Table 3. Comparison of Space Changes (mm) between the Initial Examination and the Follow-Up Examination at 9 Months in Both the Control and Extraction Sides in Patients with Class I Molar Occlusions and Leptoprosopic or Mesoprosopic/Euryprosopic Facial Forms

Facial Form	Initial	9 Mo	Significance (*P*)
Leptoprosopic (N = 35)			
Maxillary control	16.91 ± 1.41	16.81 ± 1.41	=.26
Mandibular control	17.65 ± 1.39	17.59 ± 1.39	=.30
Maxillary extraction	16.80 ± 1.66	15.91 ± 0.43[a]	≤.05*
Mandibular extraction	17.96 ± 1.71	16.25 ± 0.93[b]	≤.001*
Mesoprosopic/Euryprosopic (N = 56)			
Maxillary control	17.11 ± 1.35	17.20 ± 1.43	=.30
Mandibular control	17.71 ± 1.43	17.66 ± 1.39	=.25
Maxillary extraction	17.05 ± 1.22	16.94 ± 1.20	=.10
Mandibular extraction	17.88 ± 1.71	17.80 ± 1.69	=.30

[a] Space loss occurred in all 18 subjects by mesial migration.

[b] Space loss occurred by mesial migration of distal segments and distal tipping of the canine in 15 subjects and by mesial migration only in two subjects.

* Indicates a statistically significant difference.

significant. Average space loss in the maxilla was 1.75 mm, and in the mandible the average space loss was 1.38 mm. The clinical loss of space in the maxilla was due to mesial migration of both the second primary molar and permanent first molar. All space loss in the maxilla (29 extraction sites) displayed this form of lost space. Space loss in the mandible was due to both mesial migration of the teeth distal to the extraction space and distal movement of the primary canine in 21 of the individuals, while the remainder of space loss appeared attributable to mesial migration of the distal segments in four subjects.

The Mesoprosopic/Euryprosopic Facial Form and End-On Molar Occlusion (Table 2)

The maxillary and mandibular control sides showed no loss of space during the 9-month period. All patients represented by an end-on molar occlusion and a mesoprosopic/euryprosopic facial form showed no clinically significant or statistically significant loss of space in the maxillary first primary molar extraction site. On average, space loss in the mandible was 1.59 mm, and this loss was statistically significant when compared to the initial measurements. The pattern of space loss was the same as with the leptoprosopic facial form patients in that it occurred by a combination of mesial movement of the distal segment and distal tipping of the primary canine in 38 subjects and by mesial migration in five subjects.

The Leptoprosopic Facial Form and Class I Molar Occlusion (Table 3)

The maxillary and mandibular control sides showed no loss of space during the time period examined. After 9 months, space loss occurred in both the maxillary and mandibular extraction sites in the leptoprosopic facial form patients. On average, maxillary space loss was 0.89 mm, and in the mandible, space loss was 1.71 mm. Both values were statistically significant. The pattern of space loss was identical to that of the patients with end-on molar occlusions. All space loss in the maxilla of 18 individuals was due to mesial migration, while the pattern of space loss in the mandible occurred by mesial migration of the distal segments and distal tipping of the primary canine in 15 individuals and by mesial migration only in two subjects.

The Mesoprosopic/Euryprosopic Facial Form and Class I Molar Occlusion (Table 3)

In both the maxillary and mandibular arches, after 9 months in both the control and the extraction sides, no space loss occurred that was either clinically or statistically significant in patients who had Class I molar occlusions and mesoprosopic/euryprosopic facial forms.

Mean Space Changes

When an end-on occlusion was evaluated for mean space change that occurred over the 9-month period in patients with a leptoprosopic facial form and the combined facial forms, a statistically significant difference was observed for both the maxillary and mandibular sites, respectively. Average space change for the end-on occlusion patients with a leptoprosopic facial form was −1.75 mm in the maxilla and −1.38 mm in the mandible, while the combined forms showed a +0.07-mm change in the maxilla and a −1.59-mm change in the mandible. A statistically significant difference was also observed when the Class I patients were compared with their respective facial forms. Average space change for the Class I occlusion patients with a leptoprosopic facial form was −0.89 mm in the maxilla and −1.71 in the mandible,

Table 4. Mean Space Changes (mm) in the Primary First Molar Extraction Sites in Patients with Leptoprosopic vs Mesoprosopic/Euryprosopic Facial Forms and End-On and Class I Molar Occlusions

	Leptoprosopic		Mesoprosopic/Euryprosopic	
	End-On	Class I	End-On	Class I
Maxilla	−1.75 ± 0.31*,**	−0.89 ± 0.16*,**	0.07 ± 0.03*	−0.11 ± 0.05*
Mandible	−1.38 ± 0.26	−1.71 ± 0.43*	−1.59 ± 0.43**	−0.08 ± 0.04*,**

* Indicates a statistically significant difference between end-on and Class I occlusions, respectively, between the facial forms, $P \leq .001$.

** Indicates a statistically significant difference between the end-on and Class I occlusions within the facial forms. $P \leq .01$ for the leptoprosopic group; $P \leq .001$ for the mesoprosopic/euryprosopic group.

while the mesoprosopic/euryprosopic forms resulted in changes of −0.11 mm in the maxilla and −0.08 mm in the mandible, respectively (Table 4).

Comparison of space change with leptoprosopic facial forms vs mesoprosopic/euryprosopic facial forms with respect to the end-on and Class I occlusions yielded the following results: a statistically significant difference was noted in the maxilla of leptoprosopic individuals when the end-on and Class I occlusion were compared for mean space change; a statistically significant difference was also observed in the mandible of the mesoprosopic/euryprosopic individuals when an end-on and Class I occlusion were compared to each other (Table 4).

DISCUSSION

Conflicting perspectives exist for the clinical management of prematurely lost first primary molars.[2–13] Kisling[9] have indicated that after the eruption of the first permanent molar, space maintainers need not be inserted, since negligible space is lost at this time, a recommendation also supported by the American Academy of Pediatric Dentistry.[12] However, the degree of interdigitation of the permanent molar occlusion may play a vital role in terms of whether space maintenance is or is not required,[14] as our results indicate.

We observed that the facial pattern of children after 7 years of age, as well as molar occlusion, may influence the necessity for space maintainers when early recommendations made them unnecessary.[11,12] Although the use of appliances is advocated to maintain space for the eruption of the permanent dentition when the primary teeth are lost prematurely, it is not entirely age- or stage-of–first permanent molar eruption–dependent[8,9] when facial appraisal is developed at the chairside.

Since the pattern of facial growth has been established at an early age,[14–16] very little if any change is anticipated to naturally occur. Leptoprosopic individuals represented 39% of patients examined, while it was more common to observe the combined mesoprosopic/euryprosopic individuals, as we originally suspected, since the lower face elongates as the child matures[17,18]; however, the growth pattern appeared to influence the degree of space loss when combined with the molar relationship. Leptoprosopic patients with end-on and Class I molar occlusions consistently lost space in the maxillary and mandibular first primary molar site, while space loss in the combined group of patients only occurred in the mandibular extraction site with end-on occlusions. The loss of mandibular space in the combined group is consistent with findings that report a greater loss of space in the mandible than in the maxilla,[2,6,7] possibly due to the combination of both mesial and distal movements into the extraction site. This finding is also consistent with studies[19–23] that have shown that weaker jaw muscles are associated with hyperdivergent individuals, who also display reduced muscle size, efficiency, and anchorage loss during orthodontic tooth movement. No space loss in the maxilla or mandible was observed in individuals with a Class I molar occlusion and mesoprosopic/euryprosopic facial forms, indicating that space maintenance may not be necessary in patients with these clinical findings.

Interestingly, when mean space changes were evaluated all end-on and Class I occlusions, respectively, were statistically significant, except for mandibular extraction space between the leptoprosopic and combined facial forms. Comparison of mean value differences within a fraction of a millimeter in the maxilla of Class I individuals is clinically insignificant; however, it is important to note the large variation in space loss between the leptoprosopic and combined forms. When the leptoprosopic individuals were compared to mesoprosopic/euryprosopic patients, a statistically significant difference was observed in the maxilla of the leptoprosopic form for end-on vs Class I patients and in the mandible of the mesoprosopic/euryprosopic form for end-on vs Class I individuals. The high mean space change in the extraction site appeared to be due to the end-on occlusions in which space loss was more apparent. Although statistically insignificant, no appreciable space change occurred in the maxilla of the combined facial form group, regardless of whether the occlusion was end-on or Class I. Statistically insignificant, but clinically significant, was the space loss change in the mandible for both the end-on and Class I occlusions with the leptoprosopic facial form. This amount of space loss has treatment implications. These clinical finding may indicate that facial forms as well as occlusal relationships of the permanent first molar indicate the use and need of space maintenance when primary first molars are prematurely lost.

No determination of permanent molar root length completion was evaluated in these patients; therefore, it is also possible that until root formation is completed, permanent first molar movement may result in loss of space in patients with weaker musculatures as well. Although space loss was reported in the study, no change in the overall molar classification (Angle) was observed. The lack of change in the molar occlusal relationship despite space loss was most likely the result of concurrent normal antero-posterior growth of the jaws.

Based upon these findings, it is advised that space maintenance for the premature loss of primary first molars be revisited. The placement of a space maintainer in the maxilla or mandible is recommended when a patient presents with one of the following conditions: (1) a leptoprosopic facial form and end-on molar relationship and missing maxillary or mandibular primary first molars or (2) a mesoprosopic/euryprosopic facial form, end-on molar occlusion, and missing mandibular first primary molars. The occlusal relationship of the permanent first molar or its eruptive status is no longer the sole factor in this treatment planning decision, but should be a component in space management.

CONCLUSIONS

- During a 9-month observation period after the premature loss of the primary first molar, space loss occurs in the maxilla and mandible of patients with a leptoprosopic facial form and Class I or end-on molar occlusion.
- During a 9-month observation period after the loss of the primary first molar in patients with a mesoprosopic/euryprosopic facial form, loss of space occurred only at the mandibular site.
- The reevaluation of the usage of space maintenance for prematurely lost primary first molars should also be based upon facial forms and not exclusively on the eruptive status of the first permanent molar or on molar occlusion alone.

REFERENCES

1. Miyamoto W, Chung CS, Yee PK. Effect of premature loss of deciduous canines and molars on malocclusion of the permanent dentition. *J Dent Res*. 1976;55:584–590.
2. Owen DG. The incidence and nature of space closure following the premature extraction of deciduous teeth—a literature survey. *Am J Orthod*. 1971;59:37–49.
3. Bell RA, Dean JA, McDonald RE, Avery DR. Managing the developing occlusion. In: Dean JA, Avery DR, McDonald RE, eds. *Dentistry for the Child and Adolescent*. Maryland Heights, Mo: Mosby Elsevier; 2011:550–613.
4. Hall JG, Froster-Iskenius UG, Allenson JE. *Handbook of Normal Physical Measurements*. Oxford, UK: Oxford University Press; 2003.
5. Farkas LG, Katic MJ, Forrest CR. International anthropometric study of facial morphology in various ethnic groups and races. *J Craniofac Surg*. 2005;16:615–646.
6. Kumari BP, Kumari NR. Loss of space and changes in the dental arch after premature loss of the lower primary molar: a longitudinal study. *J Indian Soc Pedod Prev Dent*. 2006; 24:90–96.
7. Lin YT, Chang LC. Space changes after premature loss of the mandibular primary first molar: a longitudinal study. *J Clin Pediatr Dent*. 1998;22:311–316.
8. Kisling E, Hoffding J. Premature loss of primary teeth: part III, drifting patterns for different types of teeth after loss of adjoining teeth. *J Dent Child*. 1979;46:34–38.
9. Kisling E, Hoffding J. Premature loss of primary teeth: part V, treatment planning with due respect to the significance of drifting patterns. *J Dent Child*. 1979;46:300–306.
10. Lin YT, Lin WH, Lin YTJ. Immediate and six month space changes after premature loss of a primary maxillary molar. *J Am Dent Assoc*. 2007;22:117–120.
11. Bell RA, Dean JA. Growth and development/management of the developing occlusion. In: Nowak AJ, Casamassimo PS, eds. *The Handbook of Pediatric Dentistry,* 4th ed. Chicago, IL: American Academy of Pediatric Dentistry; 2011:124–125.
12. American Academy of Pediatric Dentistry Clinical Affairs Committee, Guideline on Management of the Developing Dentition and Occlusion in Pediatric Dentistry. In: Pediatric Dentistry Reference Manual 35: Chicago, IL; 2013/2014: 243–255 Special Issue.
13. Taylor LB, Full CA. Space maintenance: is it necessary with cuspal interlock? *J Dent Child*. 1994;61:327–329.
14. Valadian I, Porter D. *Physical Growth and Development: From Conception to Maturity*. Boston, Mass: John Wright–PSG; 1977.
15. Brodie AG. Facial patterns: a theme on variation. *Angle Orthod*. 1946;16:75–87.
16. Enlow DH, Hans MG. *Essentials of Facial Growth*. Philadelphia, Pa: WB Saunders; 1996.
17. Nanda SK. Patterns of vertical growth in the face. *Am J Orthod Dentofacial Orthop*. 1988;93:103–116.
18. Bishara SE, Jakobsen JR. Longitudinal changes in three normal facial types. *Am J Orthod*. 1985;88:496–502.
19. Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal and long face adults. *J Dent Res*. 1983;62:566–570.
20. Proffit WR, Fields HW. Occlusal forces in normal and long face children. *J Dent Res*. 1983;62:571–574.
21. Ingervall B, Minder C. Correlation between maximum bite force and facial morphology in children. *Angle Orthod*. 1997; 67:415–422.
22. Garcia-Morales P, Buschang PH, Throckmorton GS, English JD. Maximum bite force, muscle efficiency and mechanical advantage in children with vertical growth patterns. *Eur J Orthod*. 2003;25:265–272.
23. Buschang PH, Jacob H, Carrillo R. The morphological characteristics, growth and etiology of the hyperdivergent phenotype. *Sem Orthod*. 2013;19:212–226.