

# Scientific Article



## Dental Arch Space Changes Following Premature Loss Of Primary First Molars: A Systematic Review

William Tunison, BSc<sup>1</sup> • Carlos Flores-Mir, DDS, DSc<sup>2</sup> • Hossam ElBadrawy, DDS, MSc<sup>3</sup> • Usama Nassar, DDS, MSc<sup>4</sup> • Tarek El-Bialy, DDS, MSc OSci, PhD<sup>5</sup>

**Abstract:** ***Purpose:** The purpose of this study was to consider the available evidence regarding premature loss of primary molars and the implications for treatment planning. **Methods:** Electronic database searches were conducted—including published information available until July 2007—for available evidence. A methodological quality assessment was also applied. **Results:** Although a significant number of published articles had dealt with premature primary molar loss, only 3 studies (including a total combined sample of 80 children) had the minimal methodological quality to be considered for this systematic review. **Conclusion:** A reported immediate space loss of 1.5 mm per arch side in the mandible and 1 mm in the maxilla—when normal growth changes were considered—was found. The magnitude, however, is not likely to be of clinical significance in most cases. Nevertheless, in cases with incisor and/or lip protrusion or a severe predisposition to arch length deficiency prior to any tooth loss, this amount of loss could have treatment implications. (Pediatr Dent 2008;30:297-302) Received June 5, 2007 | Last Revision August 30, 2007 | Revision Accepted August 31, 2007*

KEYWORDS: PREMATURE TOOTH LOSS, MIXED DENTITION, SPACE LOSS, TOOTH MIGRATION, SPACE MANAGEMENT, SPACE MAINTAINER

The etiology of premature loss of primary teeth is most commonly associated with dental caries.<sup>1,2</sup> Other causes of premature primary tooth loss include trauma, ectopic eruption, congenital disorders, and arch length deficiencies causing resorption of primary teeth.<sup>3</sup>

Several studies show that space loss is greater in the mandible than the maxilla<sup>3-5</sup> if a primary second rather than primary first molar is lost,<sup>6,7</sup> if tooth loss occurs at an earlier age,<sup>3</sup> and if it occurs in crowded as opposed to spaced dentitions.<sup>7-10</sup> Ronnerman and Thilander, however, believed that premature exfoliation of primary first molars has only a small etiologic effect on crowding.<sup>11</sup>

The 2006-07 American Academy of Pediatric Dentistry guidelines state that the objectives of space maintenance are to prevent the loss of arch length, arch width, and/or arch perimeter by maintaining the relative position of the existing dentition.<sup>12</sup> While there is not much controversy regarding the need for a space maintainer after the loss of a primary second molar, there are conflicting perspectives associated with the need for clinical management of space loss after early removal

of the primary first molar. Studies generally agree that early loss of the primary mandibular first molar results primarily in distal movement of the primary mandibular canine.<sup>3-5,13-17</sup> In the maxilla, meanwhile, mesial drifting of the primary second molar into the extraction site predominates.<sup>3,13-15</sup>

A large volume of literature exists that deals with the topic of space maintainers, including expert opinions, case reports, reviews, technical documents, and guidelines. While most studies have reported that space loss almost always occurs at the extraction site when a primary first molar is lost prematurely, the magnitude of the loss and the required clinical management is controversial. The apparent paucity of well-designed studies providing clear evidence that supports the use of space maintainers after the loss of a primary first molar warrants a systematic review (SR) of the level and quality of the available evidence.

The objective of this SR was to evaluate the body of scientific evidence concerned with the space changes associated with the premature loss of primary first molars and to analyze the methodological soundness of these studies to draw clinically meaningful conclusions.

Previous reviews examining the clinical evidence supporting space maintainer use are either outdated<sup>3</sup> or have not fully approached the review systematically.<sup>1,3</sup> Furthermore, these reviews called for more research. This SR represents the authors' attempt to use current evidence-based approaches to shed some light on the question of space maintenance needs after the premature loss of a primary first molar.

<sup>1</sup>Dr. Tunison is dental student; <sup>2</sup>Dr. Flores-Mir is associate professor, orthodontic graduate program, and director, Cranio-facial & Oral-health Evidence-based Practice Group; <sup>3</sup>Dr. ElBadrawy is professor and head, Division of Pediatric Dentistry; <sup>4</sup>Dr. El-Bialy is diplomate of The American Board of Orthodontics and Associate Professor, Orthodontic Graduate Program; and <sup>5</sup>Dr. Nassar is associate professor and head, Division of Fixed Prosthodontics; all at Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Canada. Correspond with Dr. Flores-Mir at carlosflores@ualberta.ca

**Methods**

**Sources of information.** Several electronic databases were used to conduct a computerized search for available evidence: MEDLINE (from 1950 to week 1 of August 2007), MEDLINE In-process and Other Non-indexed Citations (August 9, 2007), LILACS (from 1982 to July 2007), PubMed (1966 to week 1 of August 2007), EMBASE (from 1988 to week 31 of 2007), Scopus (up to August 9, 2007), and all Evidence-based Medicine reviews (Cochrane Database of Systematic Reviews, American College of Physicians Journal Club, Database of Abstracts of Reviews of Effects, and Cochrane Database of Trial Registration) up to August 9, 2007.

**Search strategy.** Terms used in this literature search were “space maintenance,” “dentition, mixed,” “tooth migration,” “premature tooth loss,” and “tooth extraction/exfoliation/loss.” The selection and specific use of each term inside each database search were made with the help of a senior librarian specialized in health sciences database searches. Details for each database search are available upon request.

The following inclusion criteria were initially chosen to select potential articles from the published abstract results:

1. mixed dentition cases in which space maintenance or space loss appliances was reported;
2. longitudinal studies (at least 2 evaluations over time); and
3. human clinical trials.

Studies with the following criteria were also excluded: (1) syndromic or medically compromised patients; (2) simultaneous surgical intervention; and (3) individual cases or series reports.

**Search and selection process.** The articles that appeared to fulfill the inclusion/exclusion criteria, based on their abstracts, were selected. For abstracts that provided insufficient information to make a selection decision, the entire article was also obtained. Also acquired were articles in the databases that were lacking abstracts but whose titles suggested that the articles could be of relevance.

At this stage, no attempts were made to identify studies lacking adequate control groups to account for normal growth changes. The authors did not expect the abstracts to provide enough detailed information about the use of controls. This would have potentially excluded some articles on the assumption that they did not have controls. Meeting abstracts were not selected, but were used to trace articles when a full article was published later using the same data.

The abstract selection was performed independently by 2 researchers. When differences in selections arose, a consensus was reached through discussion, except regarding the LILACS database, which was only evaluated by only one of the researchers because of language limitation (Portuguese/Spanish).

The selected articles then underwent a further scrutiny. Only articles that satisfied the following additional inclusion

criteria were finally considered: 1) comparable control group; 2) measurements performed just before extractions or within a few days of extraction as well as measurements at later time point(s); and 3) absence of any space maintenance/regaining appliance or other interventions.

Again, 2 researchers independently evaluated the actual articles to determine which articles satisfied these additional selection criteria. An agreement was reached regarding which articles should be finally included in the systematic review. The references from all of the selected articles were also scrutinized for articles which may not have been in the databases due to their early publication date or for any other reason.

**Methodological evaluation.** Articles were scored based on their methodology to evaluate the validity of the study. To accomplish this, modification of a previously used methodological score list was used (Table 1).<sup>18</sup> Previous reports have shown that there is no conclusive evidence stating that the systematic methodological analysis of clinical trials is valid,<sup>19-21</sup> and these reports recommend that researchers should still examine the individual influence of key components of the methodology from selected articles.

Table 1. METHODOLOGICAL SCORE FOR THE CLINICAL STUDIES\*

<b>I. Study design (7 points)</b>
A. Objective—objective clearly formulated
B. Selection criteria—described and adequate
C. Sample size—considered adequate
D. Sample size—estimated before collection of data
E. Baseline characteristics—baseline characteristics similar between groups
F. Timing—prospective
G. Timing—long-term follow-up (>12 mos)
<b>II. Study measurements (3 points)</b>
H. Measurement method—appropriate to the objective
I. Blind measurement—blinding
J. Reliability—described
<b>III. Statistical analysis (5 points)</b>
K. Dropouts—included in data analysis
L. Statistical analysis—appropriate for data
M. Confounders—included in analysis
N. Statistical significance level—P-level stated
O. Variability of data—confidence intervals given

\*Maximum number of points=15.

Additional information for statistical analysis and discussion was sought from the authors in cases where inadequate information existed in the article.

A meta-analysis would have been sought if warranted by the quality and quantity of the data.

**Results**

Initially, 79 studies appeared to be potentially appropriate based on their abstracts. Fifty-nine of these articles were located via a hand search of articles not currently indexed by the electronic databases.

Upon reading the complete articles, only 3 (4% of the initially selected abstracts) actually fulfilled the final selection criteria. The remaining 76 articles were rejected due to one or more of the following reasons:

1. measurements not taken immediately before or after extractions;
2. absence of or inadequate controls;
3. articles were review articles or articles giving technical instructions (not studies); and/or
4. no tooth loss occurred in the study.

Further information can be requested from the authors. The methodological quality of the selected articles can be found in Table 2.

In the first selected study, Lin and Chang<sup>5</sup> observed 21 5- to 7-year-old children (average age 6 years, 11 months at the time of extraction) with unilateral extraction of a primary mandibular first molar. Neither the specification of the number of dropouts nor an associated intention-to-treat analysis was stated. Mandibular study casts were made 2 to 3 days post extraction and 8 months post extraction. The space between the canine and first molar (D + E space), arch width (intermolar), arch length, and arch perimeter were measured. The difference between the D + E space on the extraction and control side after 8 months was found to be 1.19 mm ( $P=.03$ ). Arch width increased 0.12 mm ( $P=.10$ ), arch length decreased 0.15 mm ( $P=.18$ ), and arch perimeter decreased 0.68 mm ( $P=.10$ ) 8 months post extraction.

The second study that met the selection criteria was by Kumari and Kumari.<sup>4</sup> They initially intended to examine 40 children but had 10 dropouts. No intention-to-treat analysis was presented. The 30 remaining 6- to 9-year-old children were examined during a 13-month period. All had unilateral extractions of a primary mandibular first molar. Mandibular study models were taken before and immediately after the extraction as well as at 2, 4, 6, and 8 months post extraction. Extraction space (D only), arch width (intermolar), arch length, and arch perimeter were measured on the casts. D space decreased 0.64 mm, 1.3 mm, 1.64 mm, and 1.75 mm at the 2-, 4-, 6-, and 8-month time points. All of these changes were statistically significant ( $P<.001$ ). For the arch width, length, and perimeter, the decreases were not statistically significant at any time point (all  $<0.5$  mm;  $P>.05$ ).

The final study that met the selection criteria examined the loss of a primary maxillary first molar.<sup>22</sup> No intention to treat analysis was presented, and it was not stated how many drop-outs were in the study. Nineteen 4.1- to 7.1-year-old children (average age=5.9 years) had a unilateral extraction; alginate study models were made 2 or 3 days following the extraction and 6 months after the extraction. Measurements on the casts included D + E space, arch width, arch length, arch perimeter, intercanine width, and intercanine length. D + E space was found to decrease from 16.70 mm to 15.62 mm ( $P=.001$ ) on the extraction side, while the control side saw only a change of 16.4 mm to 16.88 mm ( $P=.717$ ). Intercanine width increased from 30.42 mm to 31.29 mm ( $P=.001$ ), arch length decreased from 25.66 to 25.47 mm ( $P=.014$ ), and there were no statistical changes in arch width, arch perimeter, or intercanine length (all had  $P>.05$ ).

**Discussion**

This SR was undertaken to evaluate the scientific evidence concerning space changes in the mixed dentition following the premature loss of a primary first molar. Previous reviews were traditional types<sup>3</sup> or not fully approached systematically.<sup>1</sup> Even the most current review<sup>1</sup> can be considered outdated because almost 10 years has passed since its publication.

Table 2. METHODOLOGICAL SCORE OF THE SELECTED ARTICLES\*

Articles	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Total no. of points	% of the total
Kumari and Kumari, 2006 <sup>4</sup>	1†	1	1	1	0	1	1/2	1	0	0	1	1	0	1	0	9.5	63
Lin and Chang, 1998 <sup>5</sup>	1	1	1	1/2	0	1	1/2	1	0	1	0	1	0	1	0	10	67
Lin et al, 2007 <sup>22</sup>	1	1	1	1/2	0	1	1/2	1	0	1	0	1	0	1	0	10	67

\* A-O indicate the methodological criteria detailed in Table 1.

† Satisfactorily fulfilled the methodological criteria (2 points); partially fulfilled the methodological criteria (1 point); or did not fulfill the methodological criteria (0 check point).

A significant number of initially selected articles came from the hand search (75%) based on references from retrieved articles. Almost all of them were older than 1966 and, therefore, not indexed by electronic databases.

Only 3 of the 79 studies fulfilled all of our selection criteria.<sup>4,5,22</sup> Even then, the level of evidence was not high,<sup>23</sup> with all of them calling for further research.<sup>4,5,22</sup>

Studies were selected only when measurements were taken just before extractions or within a few days of extraction, as well as measurements taken at later time point(s). This criterion excluded a few studies that may have been otherwise considered. Inclusion of records in which the premature loss could have happened several months or weeks before measurements were taken were considered biased. This is because immediate changes produced weeks after the extraction could not be differentiated from changes that occurred over a period of months. The studies by Northway et al<sup>24,25</sup> are worth mentioning in this regard; they reported changes from a longitudinal growth study with a specific quantification for losses of first or second primary molars (D and E), or both. The magnitude of the reported changes did not differ greatly from the numbers and changes reported in the 3 selected studies. Had they had a more sound methodology, they could have potentially added some more weight to the results obtained from the selected articles.

All 3 selected studies challenged the need for space maintainers after premature loss of primary first molars because their results did not show a clinically significant loss of arch perimeter or arch width.<sup>4,5,22</sup>

It is important to note that the observation of space loss at the extraction site does not directly imply that these changes were solely due to the tooth loss. Normal occlusal changes have to be considered. Thus, adequate controls are imperative; studies without them were not included. A lack of consideration of normal dental arch changes overestimates the magnitude of the changes related to tooth loss. The reason for this is that during normal dental development the primary canines are usually distalized during the eruption of the permanent lateral incisors.<sup>26</sup>

Since significant space loss was noted at the extraction sites<sup>4,5,22</sup> but not in the arch perimeter, width, or length, the question arises regarding which arch dimensions should have the greatest weight in determining the benefits of space maintainers. Many clinicians believe that the benefits of space maintainers (and thus indications as well) vary between patients and that empiric placement based on early tooth loss is contraindicated.<sup>1,15,27</sup>

Furthermore, interproximal caries is one of the most common causes of space loss.<sup>28</sup> In the event of the extraction of a severely decayed primary tooth, space loss may have occurred before the extraction. Thus, pretreatment planning, including a mixed dentition analysis, is vital before fitting a space maintainer,<sup>27</sup> as in some cases there may be indications for active space gainers or extractions.<sup>12</sup> In cases with severe

crowding of anterior teeth, space maintainers could prevent the transfer of the anterior crowding to the premolar region.<sup>15</sup>

Tooth drifting depends on space conditions, eruption path and time, intercuspatation, and dental age at the time of extraction.<sup>15</sup> In 1965, Seward<sup>13</sup> used serial cephalometric radiographs to determine whether space closure occurs by mesial or distal movement from teeth adjacent to the extraction site. In the maxilla all the spaces were closed by mesial migration of posterior teeth into the extraction site. In the mandible for space losses greater than 2 mm the spaces were closed mainly by distal movement of the teeth mesial to the extraction site. Several authors have confirmed his findings since that time.<sup>3-5,13-17</sup>

Regarding the extraction of primary maxillary first molars, the mesial movement of more distal teeth predominates.<sup>13,15</sup> Lin et al, however, found that the primary incisors and primary canines drifted distally, causing the D + E space reduction.<sup>22</sup> In the mandible, distal movement of the canine and incisors as well as mesial movement of the permanent first molar and the primary second molar occurs, with the distal movement predominating.<sup>4,5,13,15-17</sup>

A point that has to be carefully considered is the impact of individual occlusal characteristics on space loss. In the introduction, it was stated that the location of the premature tooth loss impacts the amount of potential space loss. It has been shown that space loss is greater in the mandible than the maxilla,<sup>3-5</sup> if tooth loss occurs at an earlier age,<sup>3</sup> and in crowded as opposed to spaced dentitions.<sup>7-10</sup> The degree of occlusal interdigitation could also play a role in the amount of space loss; occlusal schemes involving a lesser degree of interdigitation are more likely to allow anteroposterior movement of teeth.<sup>26</sup>

Differential lip pressures in the various malocclusions may also be important. It seems logical to propose that Class II, division 2 malocclusions will have greater lip forces that maintain the retroclination of the upper incisors and, thus, lip forces may contribute to increased space loss should a primary molar loss occur. Some research seems to indicate that incisor position determines resting lip pressure, and patients with retroclined incisors and smaller overjets have lower lip pressures.<sup>29,30</sup> However, other studies cite Class II division 2 malocclusions as being associated with the greatest amount of perioral force.<sup>31</sup> Thus, it is difficult to make firm conclusions as to whether lip pressure would play a significant role in the etiology of space loss.

A distinction must be made between the extraction of primary molars before and after the eruption of the permanent first molar. Kisling determined that after the age of 7.5 to 8 years (and thus after eruption of the permanent first molars), space maintainers need not be inserted when a primary first molar loss occurs.<sup>15</sup>

There is agreement that space loss decreases over time. In studies with multiple measurements at various time periods, Kumari and Kumari<sup>4</sup> stated that this decreased rate began 4 months post extraction. Cuoghi,<sup>17</sup> on the other hand, found

most space loss occurs in the first 6 months, but suggested observing space loss for 12 months. This suggests that if a space maintainer is not placed shortly after the loss of the primary tooth, the opportunity to prevent space loss at the extraction site may have passed.

Another factor worth considering is that some space may be regained during mixed dentition dental changes. Although this is not the case once permanent first molars move mesially, it can happen due to the eruption path of the incisors and natural expansion of the primary canines during the eruption of the permanent laterals.<sup>26</sup> This may explain why a few studies have shown that some space loss is regained, and this is postulated to be related to eruption of succedaneous teeth.<sup>7,17,32</sup>

Even when space loss occurs, as was shown in the selected studies, the magnitude of the loss has to be considered. An important clinical question arises concerning statistically significant space loss vs clinically significant space loss. Therefore, a loss of around 1.5 mm in a mandibular quadrant or 1.0 mm in a maxillary quadrant may be statistically significant, but yet not clinically significant. In certain clinical situations, this amount of space loss could have treatment implications. In cases with an incisor or lip protrusion or an accentuated curve of Spee, a loss of 3 mm (1.5 mm loss bilaterally) may impact treatment planning and contribute to the need for extraction(s). The clinical significance of potential space loss may only be determined after a clinical analysis of occlusal characteristics and consideration of all of the factors which may impact space relationships. Clinical significance cannot be generalized to all patients, but must be determined for each individual patient.

It is also important to note that statistically significant space changes can be well defined and quantified, but clinically significant changes may not be easy to define due to lack of agreement among professionals regarding the amount of space loss that may be considered clinically significant. To gain clinically relevant data, the prevention of malocclusion would be a better endpoint for a study regarding space maintainers. Such studies, however, would be difficult to perform due to ethical considerations.

## Conclusions

Based on this study's results, the following conclusions can be made:

1. A reported immediate space loss of 1.5 mm per side in the mandible and 1 mm in the maxilla when normal growth changes were taken into consideration was found after the loss of primary first molars.
2. The magnitude of the loss is of questionable clinical significance in most clinical situations. In cases with incisor and/or lip protrusion or severe arch length deficiencies, however, this amount of space loss may have treatment implications.
3. Sample sizes and methodological quality of the selected articles are limited.

## Acknowledgments

Dr. Flores-Mir is supported by an American Association of Orthodontics Foundation Award (Subtenly, Baker, Eastman Teaching Fellowship Award).

## References

1. Brothwell DJ. Guidelines on the use of space maintainers following premature loss of primary teeth. *J Can Dent Assoc* 1997;63:753, 757-60, 764-6.
2. Ngan P, Alkire RG, Fields H Jr. Management of space problems in the primary and mixed dentitions. *J Am Dent Assoc* 1999;130:1330-9.
3. Owen DG. The incidence and nature of space closure following the premature extraction of deciduous teeth: A literature review. *Am J Orthod* 1971;59:37-49.
4. 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;24:90-6.
5. Lin YT, Chang LC. Space changes after premature loss of the mandibular primary first molar: A longitudinal study. *J Clin Pediatr Dent* 1998;22:311-6.
6. Breakspear EK. Sequelae of early loss of deciduous molars. *Dent Rec (London)* 1951;71:127-34.
7. Ronnerman A. The effect of early loss of primary molars on tooth eruption and space conditions: A longitudinal study. *Acta Odontol Scand* 1977;35:229-39.
8. Clinch LM, Healy MJR. A longitudinal study of the results of premature extraction of deciduous teeth between 3-4 and 13-14 years of age. *Dent Pract (Bristol)* 1959;9:109-27.
9. Richardson ME. The relationship between the relative amount of space present in the deciduous dental arch and the rate and degree of space closure subsequent to the extraction of a deciduous molar. *Dent Pract Dent Rec* 1965;16:111-8.
10. Davey KW. Effect of premature loss of primary molars on the anteroposterior position of maxillary first permanent molars and other maxillary teeth. *J Dent Child* 1967;34:383-94.
11. Ronnerman A, Thilander B. A longitudinal study on the effect of unilateral extraction of primary molars. *Scand J Dent Res* 1977;85:362-72.
12. American Academy of Pediatric Dentistry Clinical Affairs Committee. Guideline on management of the developing dentition and occlusion in pediatric dentistry. Reference Manual 2006-07. *Pediatr Dent* 2006;28:157-69.
13. Seward FS. Natural closure of deciduous molar extraction spaces. *Angle Orthod* 1965;35:85-94.
14. Kislung 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;46:34-8.

15. 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;46:300-6.
16. Johnsen D. Space observation following loss of the mandibular first primary molars in mixed dentition. *J Dent Child* 1980;47:24-7.
17. Cuoghi OA, Bertoz FA, de Mendonca MR, Santos EC. Loss of space and dental arch length after the loss of the lower first primary molar: A longitudinal study. *J Clin Pediatr Dent* 1998;22:117-20.
18. Flores-Mir C, Major MP, Major PW. Soft tissue changes with fixed functional appliances in Class II, division 1. *Angle Orthod* 2006;76:712-20.
19. Juni P, Witschi A, Bloch R, Egger M. The hazards of scoring the quality of clinical trials for meta-analysis. *JAMA* 1999;282:1054-60.
20. Juni P, Altman DG, Egger M. Systematic reviews in health care: Assessing the quality of controlled clinical trials. *BMJ* 2001;323:42-6.
21. Verhagen AP, de Vet HC, de Bie RA, Boers M, van den Brandt PA. The art of quality assessment of RCTs included in systematic reviews. *J Clin Epidemiol* 2001;54: 651-4.
22. Lin YT, Lin WH, Lin YTJ. Immediate and six-month space changes after premature loss of a primary maxillary first molar. *J Am Dent Assoc* 2007;22:117-20.
23. Eccles M, Freemantle N, Mason J. Using systematic reviews in clinical guideline development. In: Egger M, Smith G, Altman D, eds. *Systematic Reviews in Health Care: Meta-analysis in Context*. 2<sup>nd</sup> ed. London, UK: BMJ Books; 2000:400-9.
24. Northway WM, Wainright RL, Demirjian A. Effects of premature loss of deciduous molars. *Angle Orthod* 1984;54:295-329.
25. Northway WM. The not-so-harmless maxillary primary first molar extraction. *J Am Dent Assoc* 2000;131:1711-20. Erratum in: *J Am Dent Assoc* 2001;132:154.
26. van der Linden FPGM. *Development of the Dentition*. Chicago, Ill: Quintessence Publishing Co; 1983.
27. Qudeimat MA, Fayle SA. The longevity of space maintainers: A retrospective study. *Pediatr Dent* 1998;20: 267-72.
28. Terlaje RD, Donly KJ. Treatment planning for space maintenance in the primary and mixed dentition. *J Dent Child* 2001;68:109-14.
29. Thuer U, Ingervall B. Pressure from lips on teeth and malocclusion. *Am J Orthod Dentofacial Orthop* 1986;90: 234-42.
30. Luffingham JK. Pressure exerted on teeth by the lips and cheeks. *Dent Pract Dent Rec* 1968;19:61-4.
31. Posen A. The influence of maximum perioral and tongue force on the incisor teeth. *Angle Orthod* 1972;42: 285-309.
32. Weber FN. Prophylactic orthodontics. *Am J Orthod* 1949;35:611-35.