Original Article

Lower first permanent molars: developing better predictors of spontaneous space closure

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Summary

Background: First, first permanent molars (FPMs) of poor prognosis are often planned for extraction at an ‘ideal time’ so that second permanent molars (SPMs) erupt favourably to replace them. However for lower FPM extractions, timing is not an accurate predictor of success.

Objective: The aim of this study was to identify additional radiographic factors that could better predict the degree of spontaneous space closure of the lower SPM following FPM extraction.

Methods: Data from a previous study of 127 lower SPMs from 66 patients was re-analysed by incorporating additional radiographic factors. These included calcification stage of the bifurcation of the SPM, position of the second premolar, mesial angulation of SPM in relation to the FPM, and presence of the third permanent molar. Results were analysed using ordered logistic regression.

Results: Only 58 per cent of FPMs extracted at the ‘ideal time’ (SPM development at Demirjian stage E) had complete space closure. The best outcomes resulted from a combination of SPMs not at Demirjian development stage G, together with the presence of mesial angulation of the SPM and presence of the third permanent molar, where 85 per cent of those cases had complete space closure.

Conclusions: Apart from extraction timing of the FPM, consideration must also be given to the presence of the third permanent molar and angulation of the SPM in order to ensure a reliable degree of spontaneous space closure of the lower SPM.

Introduction

The first permanent molar (FPM) is the most caries-prone permanent tooth (1) and is also susceptible to developmental defects such as molar incisal hypomineralization (2). Because of these two conditions, post-eruptive breakdown of FPMs are often significant, resulting in difficult to restore teeth of questionable long-term prognosis. Because of this, affected FPMs are often indicated for enforced extraction in young children in the UK, a treatment modality that places a considerable dental burden on all parties involved. This is especially so if extraction is carried out under general anaesthesia (often indicated when all four FPMs are removed), due to the difficulty in performing such a potentially traumatic chair-side procedure in even healthy children. In a study of 300 children in three dental hospitals in the UK, Albadri et al. (3) found that general anaesthesia was the main method used for FPM extraction in up to 70 per cent of the cases.

Not only is this burden for treatment high; most children are usually discharged with no long-term orthodontic review post-extraction. This is justified by the fact that enforced extraction of FPMs at an ‘ideal time’ (the beginning of radiographic calcification at the second permanent molar bifurcation between ages 8–10) is thought to result in spontaneous space closure of the second permanent molar
(SPM) upon its eruption. This has been described in the UK national guidelines (4) for the past 10 years. Originally, this assumption was based mainly on the results of one retrospective cohort study involving 27 children who had undergone FPM extraction and subsequent follow-up of their developing occlusion (5). However, the lack of further substantial evidence on the predictability of FPM extraction at an ‘ideal time’ especially in the lower arch has prompted a recent update of the national guideline (6), urging more cautious pre-extraction planning.

Recent renewed interest in gaining more evidence has also resulted in the conception of The SIXES (Should I Extract Every Six) dental trial, the first randomized multi-centre study designed to investigate the necessity of compensating extractions of upper FPMs following lower FPM extraction (7). By comparing the resultant occlusion between two groups of patients—the control group where traditionally upper and lower FPMs are extracted, and the intervention group with just lower extractions—the trial has been designed to explore if the burden to patient and dental team can be reduced by producing similar or more predictable outcomes with less treatment. However, because the variable parameter investigated is the extraction of the upper FPM, the effect of timed lower FPM extractions on the resultant occlusion can only be gauged by implication, and not comparison.

In seeking a more direct relationship between upper and lower FPM extractions and spontaneous space closure, Teo et al. (8) conducted a retrospective cohort study assessing the positions of 266 SPMs 5 years after FPM extraction. Comparing basic occlusal relationships, no significant connection was found between patient Angle’s Classification and spontaneous space closure. However, there was a significant difference between upper and lower FPM extractions, whereby 92 per cent of upper extractions resulted in good space closure regardless of timing, as opposed to only 66 per cent of lower FPMs producing favourable results despite extraction at the ‘ideal time’. This result was similar to that found in the earlier study by Jälevik and Möller (5), and suggests that a third of all lower FPM extractions may predispose children to orthodontic correction when older. It follows that more precise success parameters are required in the planning stages to determine not only when but which lower FPMs should be extracted, even before taking into account the effect of compensating upper FPM extractions. Therefore, data was re-analysed from this initial study with regard to other radiographic factors that were not considered initially.

Firstly, the development of the second premolar within the bifurcation of the primary second molar has been reported necessary for proper guidance upon eruption to prevent distal drifting, rotation or tilting of the premolar into an extracted FPM space (9). Second, the mesial angulation of the developing SPM in relation to the FPM may be associated with increased space deficiency in the lower arch, contributing to more favourable space closure following orthodontic extractions, a relationship which has been investigated inconclusively (10). Lastly, extraction of the FPM has been reported to have a favourable effect on the eruption of third molars by increasing eruption space and decreasing possible impaction (11). Despite this finding, no studies exist to investigate if the converse is also true—that the presence of the third molar leads to a more favourable occlusal development after FPM extraction. Nonetheless, presence of the third molar has been stated as a major consideration in the guidelines for FPM extraction planning (6).

The aim of this report was thus to investigate if the presence of one or more of the three additional radiographic factors described above affected spontaneous space closure of the lower SPM following FPM extraction. These radiographic factors are highlighted in Figure 1 and described as follows:

1: The second premolar is engaged in the bifurcation of the second primary molar.
2: The SPM is mesially angulated in relation to the FPM.
3: Presence of the third permanent molar.

This study’s secondary aim was also to explore the interaction between these three other radiographic factors with the conventional parameter of extraction timing by SPM development stage in order to develop better predictors of success. It sought to validate the finding that FPM extraction at the ‘ideal time’ alone is not significantly associated with spontaneous space closure in the majority of cases; rather it is the presence of the three new radiographic factors alone or in combination with extraction timing that is significantly associated with a favourable outcome.

Materials and methods

This was the second part of an earlier retrospective study conducted by Teo et al. (8), with the inclusion of additional radiographic factors, and assessment of lower FPM extractions only. Details of the earlier study can be found in the previous publication. A total of 127 lower SPMs from 66 healthy patients ages 11–17 years were included in the study, which was conducted at a dental hospital in London, UK. All patients had one or two lower FPMs extracted under general anaesthesia 5 years prior, and were subsequently discharged with no orthodontic review or treatment carried out in the following years. Each patient’s dento-pantomogram taken at the time of FPM extraction was assessed for stage of SPM development using Demirjian’s dental development stages (12), where stage D signified calcification of the SPM crown, stage E the ‘ideal time’ calcification of the bifurcation, stage F the early root, and stage G the late root.

The patients were presently recalled for clinical assessment, where the amount of space closure in each posterior segment corresponding to FPM extraction was recorded. This was done by an intra-oral examination where a periodontal probe was placed occlusally between each tooth distal to the canine. Because the variable assessed was the magnitude of any directional contact-point displacements posterior to the canine, the assessment took into account the presence of angulations or drifting of any tooth from the first premolar up to the third molar. The largest contact-point

Figure 1. Three other radiographic factors that may affect spontaneous space closure.
displacement found was thus recorded and graded using an assessment scale from grade of 1 to 4 (Table 1). This new scale was adapted partially from the Dental Health Component of the Index of Orthodontic Treatment Need or IOTN (13). Grade 1 represented the most favourable outcome (Figure 2a), and grade 4 the least favourable (Figure 2b).

For this study the radiographs were next re-examined and recorded for the presence of the following additional radiographic factors detailed in Figure 1. A week later, the radiographs were reassessed by the primary examiner for reliability.

The data was analysed using ordered logistic regression following the assumption that SPM outcomes were ordered in terms of preferred outcomes using the assessment scale from grade 1 to 4. Statistical tests were conducted using the MASS toolbox in R 1.53 (R Foundation for Statistical Computing). These tests were chosen because they were robust against unbalanced data sets, and because the space closure grades were well ordered, which made ordered logistic regression suitable. Models accounting for SPM development stage, the three additional radiographic factors, or both were compared using analysis of variance (ANOVAs) in order to establish which model was the best fit for the available data.

Results

Out of the 66 patients studied, 37 were female (56 per cent) and 29 male (44 per cent). The mean age of patients at extraction was 9.2 years and the mean age of clinical assessment at the time of the study was 13.8 years. The result of the intra-examiner reliability test for radiographic assessment was 0.98.

Out of the total of 127 lower SPMs assessed at the time of FPM extraction, 17 (13 per cent) SPMs were at developmental stage D, 71 (56 per cent) at stage E, 23 (18 per cent) at stage F, and 16 (13 per cent) at stage G. Out of those extracted at the ‘ideal time’ stage E, 41 SPMs had grade 1 space closure (58 per cent), and 11 had grade 4 (16 per cent). Of those with grade 1 closure, all cases had at least one of the other radiographic factors, with the combined presence of factor 2 and 3 accounting for 12 cases (29 per cent), and the presence of all three factors accounting for 22 cases (54 per cent). Out of the 11 cases showing grade 4 space closures, 4 cases had none of the three factors (36 per cent), and a total of 5 cases had only one factor (45 per cent). Conversely, none of the cases had all three factors combined. Of note was the finding that 11 out of the 13 cases (85 per cent) at SPM developmental stage F that showed grade 1 space closure also concurrently had all three radiographic factors present.

The relationship between space closure and SPM development was compared on a jittered scatter plot graph. The Y-axis represented the grades of space closure as established in Table 1, with grade 1 being the most favourable and grade 4 the least. The X-axis corresponded to the various stages of SPM calcification based on Demirjian’s developmental stages, where stage E corresponded to the traditionally ‘ideal time’ of FPM extraction. Statistical analysis of the data in Figure 3 demonstrated that FPM extraction at SPM stages D, E, and F was significantly associated with space closure only when compared to stage G.

The relationship between space closure and the presence of the three additional radiographic factors was then plotted and statistical analysis of the results confirmed the visual impression of three distinct levels, as shown in Figure 4. Again, the Y-axis represented the space closure grading, and the X-axis represented factors 1, 2, and 3 singly or in every possible combination. All 12 cases with all three radiographic factors absent showed no grade 1 space closure but a significant association with grade 4 space closure. Grade 1 space

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**Table 1. Grading for the assessment of spontaneous space closure.**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extremely minor malocclusions including contact-point displacements less than 1 mm</td>
</tr>
<tr>
<td>2</td>
<td>Contact-point displacement of teeth greater than 1 mm but less than or equal to 2 mm</td>
</tr>
<tr>
<td>3</td>
<td>Contact-point displacement of teeth greater than 2 mm but less than or equal to 4 mm</td>
</tr>
<tr>
<td>4</td>
<td>Severe contact-point displacement of teeth greater than 4 mm</td>
</tr>
</tbody>
</table>

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**Figure 2.** Most and least favourable occlusion according to grade. (a) Grade 1. (b) Grade 4.

**Figure 3.** Jittered scatter plot comparing space closure with SPM development stage. SPM, second permanent molar.
closure was found in 40 out of 48 (83 per cent) of the cases with all three factors present. The presence of one or more of the three factors was associated with significantly better space closure. Lastly, the combined presence factors 2 and 3 were associated with the most favourable outcomes.

The interaction between SPM development stage and the presence of the three radiographic factors was also analysed. Likelihood ratio comparisons showed that the three radiographic factors accounted for more of the variability in space closure than SPM development stage (LR(DF = 4) stat = 64.93, \( P(\chi) < 0.001 \)). However, the model that compared space closure with both SPM development stage and the three radiographic factors accounted for the most variability. (For SPM versus both: LR(DF = 7) stat = 84.85, \( P(\chi) < 0.001 \).)

Interactions between SPM development stage and the three radiographic factors did not converge. Therefore, the best-fit model accounted for both SPM development stage and the additional three radiographic measures, as shown in Table 2. The level shown in this table represented \( T \)-values separated by more than |2|, such that the outcomes were significantly different from each other.

It can be seen from the table that SPM level 1 includes SPM development stage D, E, and F. SPM level 2 includes SPM stage G. Radiographic level 1 includes 1. none of the factors; or 2. SPM mesially angulated (factor 2) only. Radiographic level 2 includes: 1. second premolar engaged in second primary molar bifurcation (factor 1) only; 2. third permanent molar present (factor 3) only; 3. factors 1 and 2 only; or 4. factors 1 and 3 only. Radiographic level 3 includes: 1. factors 2 and 3 only, or 2. all three factors.

The most favourable outcomes thus came from a combination of SPM measures in level 1, and the radiographic factors in level 3. That is, an SPM development stage not equal to G, combined with the SPM mesially angulated in relation to the FPM, and the presence of the permanent third molar, were associated with the best outcomes. In these cases, 52 of the 61 of the SPMs (85 per cent) had grade 1 space closure. The space closure grades and percentages by SPM and Radiographic levels are further presented in Table 3.

### Discussion

To date, the acceptance of planned FPM extraction as a treatment modality in the UK rests on the assumption that resultant space

![Figure 4](https://academic.oup.com/ejo/article-abstract/38/1/90/2599922/93)

Table 4. Jittered scatter plot comparing space closure and the presence or absence of the other three radiographic factors.

Table 2. Best-fit model = SPM by radiographic factors + SPM development stage.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>( T ) value</th>
<th>( P ) value</th>
<th>Level</th>
<th>2.5% Conf. int.</th>
<th>97.5% Conf. int.</th>
<th>DF</th>
<th>Statistical power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1 versus none</td>
<td>−2.27</td>
<td>0.024*</td>
<td>2</td>
<td>−4.77</td>
<td>−0.44</td>
<td>7</td>
<td>0.66</td>
</tr>
<tr>
<td>Factor 2 versus none</td>
<td>−1.62</td>
<td>0.11</td>
<td>1</td>
<td>−4.34</td>
<td>0.36</td>
<td>3</td>
<td>0.61</td>
</tr>
<tr>
<td>Factor 3 versus none</td>
<td>−2.28</td>
<td>0.026*</td>
<td>2</td>
<td>−4.46</td>
<td>−0.43</td>
<td>12</td>
<td>0.66</td>
</tr>
<tr>
<td>Factor 1 and 2 versus none</td>
<td>−2.32</td>
<td>0.021*</td>
<td>2</td>
<td>−4.34</td>
<td>−0.46</td>
<td>9</td>
<td>0.67</td>
</tr>
<tr>
<td>Factor 1 and 3 versus none</td>
<td>−3.01</td>
<td>0.0026*</td>
<td>2</td>
<td>−5.41</td>
<td>−1.20</td>
<td>10</td>
<td>0.87</td>
</tr>
<tr>
<td>Factor 2 and 3 versus none</td>
<td>−5.13</td>
<td>&lt;0.001*</td>
<td>3</td>
<td>−7.79</td>
<td>−3.33</td>
<td>20</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>Factor 1, 2, and 3 versus none</td>
<td>−5.97</td>
<td>&lt;0.001*</td>
<td>3</td>
<td>−7.89</td>
<td>−4.01</td>
<td>47</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>SPM stage D versus F</td>
<td>1.26</td>
<td>0.20</td>
<td>1</td>
<td>−0.60</td>
<td>2.75</td>
<td>21</td>
<td>0.27</td>
</tr>
<tr>
<td>SPM stage E versus F</td>
<td>0.00</td>
<td>1.00</td>
<td>1</td>
<td>−1.19</td>
<td>1.24</td>
<td>11</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>SPM stage G versus F</td>
<td>3.65</td>
<td>&lt;0.001*</td>
<td>2</td>
<td>1.37</td>
<td>4.46</td>
<td>27</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Statistical power calculated from \( T \), confidence intervals, and degrees of freedom. Conf. int., confidence interval; DF, degrees of freedom; SPM, second permanent molar.

* Significant, \( \alpha = 0.05 \).
nonetheless most accurately reflected the over-arching goal of the study: to investigate the factors that would reduce the dental burden of lower FPM extractions not just at the time of treatment, but also with regards to the need for future correction.

As expected based on the original study, extraction of FPMs at the 'ideal time' of SPM development stage E, although associated with spontaneous space closure, only resulted in a satisfactory outcome in slightly over half the cases. Applying the new grading to assess space closure however resulted in a lower percentage of 'ideal' space closure (58 versus 66 per cent). More importantly, the results here did not demonstrate that extraction at the 'ideal time' of SPM development stage E was itself ideal over stage D, which is considered too early, or stage F which is considered too late. The timing of FPM extraction is thus not as important a factor as once thought.

However, the results from analysis of the three other radiographic factors provided compelling evidence that the combined presence of mesial angulation of the SPM in relation to the FPM and the presence of the third permanent molar are a stronger indicator of spontaneous space closure than SPM development stage. Despite the small sample size, the results were both statistically significant ($P < 0.001$) and had high statistical power ($P > 0.99$). This is essentially because the presence of the three radiographic factors meant the difference between an 85 per cent favourable space closure and a 0 per cent favourable space closure. Clinically, this suggests that patients exhibiting none of the three other radiographic factors must be monitored long-term should enforced FPM extraction be done, with the view for orthodontic correction at a later stage. Conversely, FPM extractions carried out in patients exhibiting all three factors may lead to a much higher degree of successful space closure.

Although SPM development stage was not in itself a strong predictor of favourable space closure, the interaction between it and the other three radiographic factors also suggests that both SPM development stage, mesial angulation of the SPM, and the presence of the third molar should still be evaluated in tandem to ensure the best possible outcomes. Because the third molar may not be radiographically visible before 8 years of age, the confirmation of its presence and subsequent extraction of the FPM at a later age (such as at the early root calcification of SPM development stage F) may lead to equal, if not more predictably favourable outcomes. It may thus be prudent to delay extractions until all three radiographic factors can be properly evaluated, but up to before the point when the half the root of the SPM is fully developed.

In this re-analysis, statistical models using ordered logistic regression went a step further with the new radiographic factors, and were compared to each other using best-fit ANOVA. This was in order to identify whether SPM development stage or a combination of these other three factors provided the best fit for the data, and so explained the most variance. Because the sample size of the study was still relatively small, a validation of these findings on a larger pool of prospective patients would be ideal. Nonetheless, these results provide new evidence to support the recent revision in the national guidelines on enforced FPM extractions. They strongly suggest that a combination of radiographic factors other than developmental timing should be examined to better ensure a successful orthodontic outcome—a process that would no doubt benefit all children who undergo such procedures in the future.

References


