Original Article

Growth and Treatment Changes Distal to the Mandibular First Molar: A Lateral Cephalometric Study

Daniel L. Sable, BPharm, BDSc, MDSc[a]; Michael G. Woods, DDSc, FRACDS, FRACDS(Orth), DOrthRCS(Eng)[b]

Abstract: This study examined space changes occurring distal to the mandibular first molar in growing patients treated using two different approaches. Two groups of 50 patients were selected for the study. The patients in group I were treated with the extraction of mandibular second premolars, whereas those in group II were treated without mandibular premolar extractions, by holding E-spaces with utility arches. Lateral cephalograms taken before and after treatment were used to measure space changes within the mandible. Follow-up written treatment records and radiographs were also examined to ascertain whether the mandibular third molars were ultimately extracted or retained. A greater mean space increase between Xi point and the mandibular first molar was found in boys and girls treated with second premolar extractions. The mean space increase between Xi point and the mandibular first molar, as well as the average increase in total mandibular length, was greater in boys than in girls for both treatment modalities. This reflects a greater amount of growth in boys during the treatment period. The greater mean space increase in the groups treated with second premolar extractions could be attributed to the fact that the first molar generally moved further mesially during treatment in the extraction subjects, whereas in the E-space subjects, the first molars were perhaps held back. It was noted that the mandibular third molars were ultimately more likely to have been extracted in the E-space groups than in the second premolar extraction groups within this sample. (*Angle Orthod* 2004;74:367–374.)

Key Words: Space changes; Posterior arch dimensions; Premolar extractions; Nonextraction treatment; Mandibular third molars

INTRODUCTION

It has long been known that the body of the mandible grows in length by the remodeling of the ramus, with resorption on its anterior border and apposition on its posterior border. The net change is a backward translation in space of the ramus and a lengthening of the body of the mandible.[1] Backward movement of the ramus during growth is essential so that the jaw can accommodate the developing posterior dentition.[2] Space is also created for the developing molars by a general upward and forward direction of eruption.[3]

The mesial migration of the molars that occurs during normal growth is, however, associated with a decrease in arch length through to maturity.[4] Both the backward remodeling of the ramus and the mesial movement of the dentition seem to aid the eruption of the second molars and possibly even the third molars.[3,5] Because orthodontic treatment effects are superimposed on normal growth changes, it seems reasonable to question how different types of orthodontic treatments might influence the potential space for the developing second and third molars. Some types of treatments, for instance, may involve the holding back or even distal positioning of the first molars,[6–8] thereby potentially compromising this space. On the other hand, those treatments involving premolar extractions might potentially increase the available space because the first molars are repositioned mesially.[9,10]

Several authors have formed the view that orthodontic treatment requiring posterior movement of the first and second molars, either by tipping or translation, may limit the space available for the second molars and may result in the impaction of the third molars.[2,11–14] Richardson,[14] for instance, found that orthodontically treated individuals with impacted third molars were more likely to still have intact arches without any previous extractions compared with

[a] Former graduate student, School of Dental Science, The University of Melbourne, Melbourne, Victoria, Australia.

[b] Associate Professor and Head of Orthodontics, The University of Melbourne, Melbourne, Victoria, Australia.

Corresponding author: Michael G. Woods, DDSc, FRACDS, FRACDS(Orth), DOrthRCS(Eng), School of Dental Science, The University of Melbourne, 711 Elizabeth Street, Melbourne, Victoria 3000, Australia
(e-mail: mgwoods@unimelb.edu.au).

Accepted: July 2003. Submitted: March 2003.

those in whom the third molars had erupted. Others have found that the prevalence of third molar impaction is reduced in cases treated with the extraction either of premolars[15–18] or of other teeth.[19–23] Faubion[15] and Richardson,[17] for example, concluded that the extraction of first premolars may provide increased space for the eruption of mandibular third molars.

In contrast to these views, Graber and Kaineg[24] and Williams and Hosila[25] concluded that removal of first premolars probably did not enhance normal eruption of the third molars. Interestingly, Perlow[18] found that the extraction of second rather than first premolars appeared to be more favorable for third molar eruption because this might allow greater forward movement of the first and second molars. From another perspective, Forsberg[26] postulated that because premolar extraction cases may have presented with larger tooth size/arch length discrepancies than nonextraction cases, third molar impaction may still be more likely in extraction cases than in nonextraction cases.

In light of these divergent views, this study was designed to determine whether there are predictable differences in the space changes distal to the mandibular first molar in orthodontic patients treated either by extracting the lower second premolars or by holding E-spaces without premolar extractions. An attempt also was made to ascertain whether the mandibular third molar teeth in this sample were more likely to be eventually extracted in patients treated with the holding of E-spaces (without premolar extractions) compared with those treated with extraction of lower second premolars.

MATERIALS AND METHODS

The sample for the main part of the study consisted of lateral cephalometric records taken before and after treatment of 100 class I and II patients treated by one experienced orthodontist with preangulated Edgewise appliances (0.018 × 0.028 inches). Patient records were selected to make up each subsample as follows—fifty boys: 25 cases involving the extraction of lower second premolars and 25 cases treated without premolar extractions by holding the E-spaces with utility arches; and fifty girls: 25 cases involving the extraction of lower second premolars and 25 cases treated without premolar extractions by holding the E-spaces with utility arches.

Sample selection

The cases were selected on the basis of the following criteria:

- All patients in the extraction sample had undergone the extraction of mandibular second premolars as part of a comprehensive orthodontic treatment plan. In general, after initial alignment and incisor positioning, residual spaces were closed with sliding mechanics, supported by class II elastics, if necessary.

TABLE 1. Age at Commencement of Treatment and Duration of Active Treatment

Group	n	Age at Commencement of Treatment		Duration of Active Treatment	
		Mean	SD	Mean	SD
Total sample	100	12 y 11 mo	1 y 8 mo	2 y 4 mo	7 mo
Boys	50	13 y 2 mo	1 y 9 mo	2 y 4 mo	7 mo
E-spaces	25	12 y 2 mo	1 y 4 mo	2 y 6 mo	7 mo
Extraction 5s[a]	25	14 y 2 mo	1 y 6 mo	2 y 3 mo	7 mo
Girls	50	12 y 9 mo	1 y 6 mo	2 y 4 mo	6 mo
E-spaces	25	12 y 0 mo	1 y 0 mo	2 y 5 mo	7 mo
Extraction 5s[a]	25	13 y 5 mo	1 y 8 mo	2 y 3 mo	6 mo

[a] 5s indicates mandibular second premolars.

- All patients in the E-space, nonextraction sample had their deciduous mandibular second molars present in the radiographs taken before treatment.
- All cases included a minimum of lateral cephalograms taken before and after treatment in their records.
- The aim of treatment in all cases had been to achieve the finishing goals recommended by Andrews[27] and Roth,[28] although, in case selection for this study, no reference was made to the standard of occlusal finish.

The numbers of subjects in the total population sample and its subgroups are listed in Table 1, along with mean ages at the commencement of treatment and the treatment duration. The mean age of the patient sample at the commencement of treatment was 12 years 11 months. The mean ages of girls and boys were 12 years nine months and 13 years two months, respectively. The sample was of mixed racial background.

The sample for the second part of the study (later extraction of third molars) consisted of retention and follow-up radiographs and written clinical case notes for as many of the patients of the above sample as possible. A total of 82 patient records were included in this part of the study. The sample consisted of 42 patients from the E-space sample (20 boys and 22 girls) and 40 patients from the second premolar extraction sample (19 boys and 21 girls). The available follow-up radiographs were all taken between four and five years after the removal of fixed appliances.

Cephalometric analysis

All cephalometric radiographs were taken with the same cephalostat. Cephalometric landmarks were located by hand and then digitized using Westceph cephalometric software, a customized lateral cephalometric research analysis program written by Mr Geoffrey West of the University of Melbourne. A summary of the cephalometric measurements used in this study is shown in Table 2. Distances and angles were measured using conventional cephalometric landmarks and reference planes (Figure 1). Space changes distal to the mandibular first molar were measured along Ricketts'

TABLE 2. Cephalometric Measurements

Number	Measurement	Definition
1	Mandibular plane angle (°)	Angle formed by the intersection of the Frankfort plane and the gonion-menton line
2	Facial axis angle (°)	Angle formed by the intersection of the basion-nasion line and the facial axis (Pt point-gnathion)
3	Condylion-Gnathion	Distance from condylion to gnathion
4	Articulare-Pogonion	Distance from articulare to pogonion
5	Xi to Distal 6 (mm)	Distance from Xi point to the distal of the mandibular first molar, measured along the corpus axis
6	Distal 6 to symphysis (mm)	Distance from the distal of the mandibular first molar to the most distal point on the lingual cortical contour of the symphysis, measured along the corpus axis
7	Xi to symphysis (mm)	Distance from Xi point to the most distal point on the lingual cortical contour of the symphysis, measured along the corpus axis

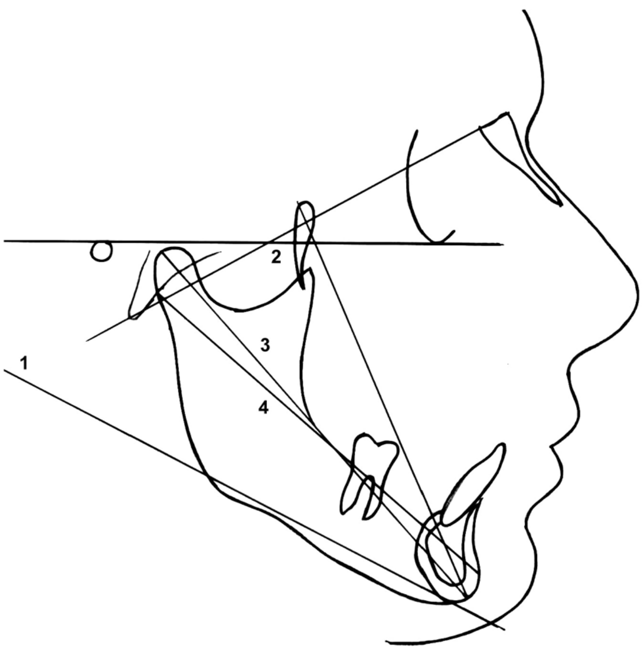

FIGURE 1. Lateral cephalometric measurements (1–4).

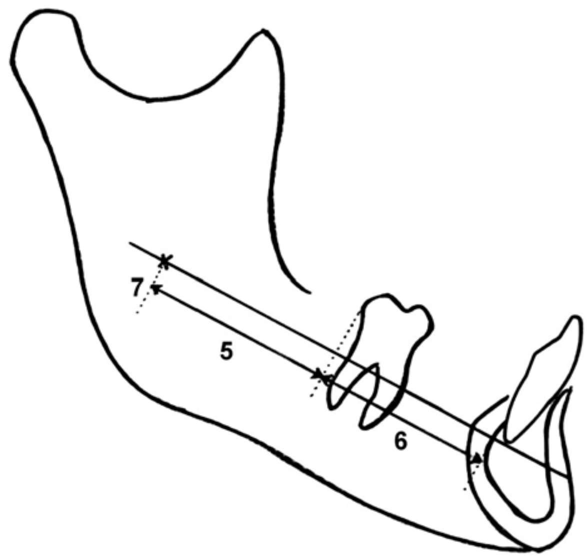

FIGURE 2. Lateral cephalometric measurements (5–7).

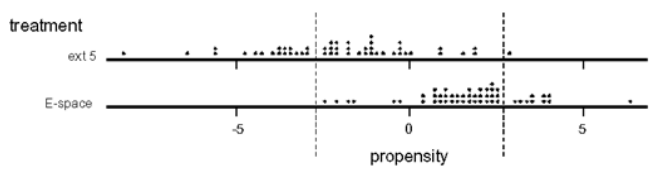

FIGURE 3. Dot plot for propensity score[31] to show the distribution of patients in both treatment groups (ext 5 = lower second premolar extractions; E-space = holding of E-spaces and no premolar extractions).

corpus axis[29] by drawing a tangent from the distal convexity of the tooth perpendicular to the corpus axis and measuring this distance to the Xi point.[29] Space changes mesial to this constructed point were measured along the corpus axis to an offset point tangent to the lingual cortical contour of the mandibular symphysis, which has previously been shown by Bjork[2] to be useful as a stable reference structure. The total distance from the Xi point to the lingual cortical contour of the symphysis was also measured along the corpus axis (Figure 2). The corpus axis has previously been shown to be suitable as a reference for the evaluation of intramandibular change.[30]

Statistical analysis

To distinguish effects due to initial group differences in morphology from actual treatment effects, various pretreatment variables were analyzed using a logistic regression model. The variables analyzed were sex, pretreatment age, facial axis, mandibular plane angle, and Xi-6 distance. Of these variables, sex and mandibular plane angle were included because they were considered to be important at the outset. The other variables were included because they were subsequently found to be statistically significant.

The score arising from this logistic regression was used to obtain a propensity score,[31] ie, the ‘‘propensity’’ for one or the other treatment to have been chosen. The dot plot of propensity score for each treatment is shown in Figure 3. The subjects then chosen for the final analysis were those in the two treatment groups for whom the propensity score

TABLE 3. Space Changes in the Mandible with Treatment[a]

	Xi-6 change (mm)			6-symphysis change (mm)		
	Mean	SD	Range	Mean	SD	Range
E-spaces in girls[b]	5.3[c*,d**]	2.1	0.9–9.3	−1.1[c***,d****]	1.7	−3.9–2.4
Ext 5s in girls[e]	5.7[c*,d**]	1.9	2.0–10.0	−3.6[c***,d****]	1.7	−7.3–0.0
E-spaces in boys[b]	6.2[c*,d**]	2.1	1.7–10.0	−0.8[c***,d****]	1.6	−3.6–2.3
Ext 5s in boys[e]	6.5[c*,d**]	2.3	3.1–10.9	−3.4[c***,d****]	1.8	−6.1–0.3

[a] Treatment effect (Ext 5s vs E-spaces) after ANOVA (propensity score) applied: Xi-6 = 2.5 mm per side, 95% confidence interval = (1.28, 3.73) mm; 6-Symphysis = −3.5 mm per side, 95% confidence interval = (−4.51, −2.43) mm.
[b] Holding of E-spaces and no premolar extractions.
[c] ANOVA (original data); * $P \leq .001$; *** $P \leq .001$.
[d] ANOVA (with propensity score applied); ** $P = .0001$; **** $P = .0000$.
[e] Mandibular second premolar extractions.

distribution overlapped. Hence, 20 subjects in the second premolar extraction group (at the low end) and 10 subjects in the E-space group (at the high end) were eliminated from further analysis. The theoretical justification for this decision is that no fair comparison of the treatments can be made for such subjects. In simple terms, the propensity score was used to remove the bias from the selected sample and to reverse engineer the clinician's decision making, ie, the decision to treat a patient with either method because of certain pretreatment characteristics. In this way, differences between the treatment groups can be largely attributed to the different treatment modalities rather than to the patients' pretreatment characteristics. Analysis of variance (ANOVA) was then carried out for the changes in each clinical variable.

Furthermore, following the analysis of space changes occurring within the mandible, an attempt was made to assess whether any relationship existed between the later extraction or retention of third molars and the chosen treatment modality in this sample. In this sample, mandibular third molars were apparently extracted if they became impacted, with or without partial eruption. It was somewhat difficult to obtain complete follow-up data because some patients failed to return during retention while the third molars were still being monitored for eruptive status. Therefore, a decision was taken to quantify the total number of mandibular third molars present in each treatment group rather than to simply assess extraction or retention of these teeth on a ''per patient'' basis.

Third molars present before the commencement of treatment were classified at follow-up as either ''extracted,'' ''definitely kept,'' or ''unknown.'' The unknown category included any of the following situations: where the clinician had anticipated in writing that the patients would keep their third molars (but they had not been formally discharged from treatment) where the clinician was still undecided; or where the patient did not return during retention. A conservative statistical analysis of the likelihood of third molar extractions was then made using Fishers exact test[32] by dividing these results into ''definitely kept'' and ''not definitely kept.''

Error study

To evaluate tracing and measurement errors, the records of 10 patients (20 cephalograms) were selected at random and the experimental procedure repeated approximately four weeks later without reference to the initial data collection. Results of the Student's *t*-test revealed no significant differences between the first and second sets of measurements, at the 5% level of significance ($P \leq .05$) for all variables, except Facial axis ($P = .04$). The mean error for linear and angular cephalometric measurements ranged from 0.33 to 0.79 mm and from 0.56° to 1.38°, respectively.

RESULTS

A summary of space changes occurring in the mandible is presented in Table 3.

Space changes distal to the mandibular first molar

The greatest average increase in space from Xi point to the distal of the mandibular first molar (Xi-6) occurred in the second premolar extraction (''5s'') sample in boys, and the smallest average increase in space occurred in the E-space sample in girls. Mean space increases were observed in the second premolar extraction group (6.5 ± 2.3 mm) in boys, E-space (6.2 ± 2.1 mm) in boys, second premolar extraction group (5.7 ± 1.9 mm) in girls, and E-space in girls (5.3 ± 2.1 mm). The mean differences between the groups were small (less than 2 mm), and there was a large amount of variation among the individuals in all groups.

Statistical analysis using ANOVA for space change in Xi-6 was consistent with there being an additive effect between sex and treatment. In other words, the effect of treatment is the same for both sexes. There were very significant combined effects of sex, treatment, and treatment duration

TABLE 4. Changes in Xi-Symphysis and Mandibular Length

	Xi-Symphysis (mm)[a]			Co-Gn (mm)[b]			Ar-Pog (mm)[c]		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
E-spaces in girls[d]	4.3	2.1	−0.3–10.1	6.8	2.8	1.4–11.2	6.4	3.0	1.5–13.5
Ext 5s in girls[e]	2.2	2.1	−2.4–7.6	3.4	2.7	−2.2–8.0	3.0	2.5	−1.7–8.5
E-spaces in boys[d]	5.4	2.5	1.4–11.2	10.3	3.1	3.6–16.5	8.7	3.0	4.0–14.7
Ext 5s in boys[e]	3.3	2.1	0.2–6.8	6.8	3.9	−0.5–14.4	6.1	3.0	1.7–14.8

ANOVA; [a] $P = 0.31$; [b] $P = 0.11$; [c] $P = 0.35$.
[d] Holding of E-spaces and no premolar extractions.
[e] Mandibular second premolar extractions.

TABLE 5. Eventual Fate of Mandibular Third Molars (n, %)[a]

	Definitely Extracted	Definitely Kept	Unknown	Total
E-spaces in girls[b]	40 (100%)	0 (0%)	0 (0%)	40 (100%)*
Ext 5s in girls[c]	18 (44%)	6 (15%)	17 (41%)	41 (100%)*
E-spaces in boys[b]	33 (100%)	0 (0%)	0 (0%)	33 (100%)**
Ext 5s in boys[c]	11 (29%)	12 (32%)	15 (39%)	38 (100%)**

[a] Fisher exact test; * $P \leq .05$; ** $P \leq .001$.
[b] Holding of E-spaces and no premolar extractions.
[c] Mandibular second premolar extractions.

($P \leq .001$). The mean sex effect (boys vs girls) was estimated to be 1.4 mm accounting for all other effects.

Once the propensity score had been obtained, ANOVA was reapplied to the adjusted data. This revealed that the mean Xi-6 change was 2.51 mm greater in the second premolar extraction groups than in the E-space groups, adjusted for all other relevant factors. This was highly statistically significant ($P \leq .0001$), with the 95% confidence interval for the true mean effect being 1.28 to 3.73 mm. When viewing the raw data, there seemed to be a greater difference in mean space increase from Xi-6 between the sexes than between treatment modalities. Once again, it is important to note that there was a wide range of individual variation within each of the four groups.

Space changes mesial to the mandibular first molar

The space anterior to the mandibular first molar, measured to the lingual cortex of the mandibular symphysis (6-symphysis), decreased on average in all groups with treatment (Table 3). Larger mean differences were observed between the second premolar extraction and E-space samples for this variable than for Xi point to the first molar. For example, there was a 2.6 mm greater decrease in space (on average) for 6-symphysis in the second premolar extraction group in boys than in the E-space group in boys, compared with only a 0.3 mm average difference in Xi-6 space for the same groups. Likewise, there was a 2.5 mm greater decrease in space (on average) for 6-symphysis in the second premolar extraction group in girls than in the E-space group in girls, compared with only a 0.4 mm average difference in Xi-6 for the same groups of girls.

Once the data were adjusted with the propensity score, ANOVA revealed an average 3.47 mm greater decrease for 6-symphysis in the second premolar extraction groups compared with the E-space groups. This was highly statistically significant ($P \leq .0001$) and, in this case, the 95% confidence interval was −4.51 to −2.43 mm.

Mandibular growth

There was a greater amount of mandibular growth, on average, in the E-space groups than in the second premolar extraction groups for both sexes (Table 4). Condylion-gnathion (Co-Gn) increased by an additional 3.5 mm in boys and 3.4 mm in girls in the E-space groups when compared with the second premolar extraction groups. Likewise, Articular-pogonion (Ar-Pog) increased by an additional 2.6 mm in boys and 3.4 mm in girls in the E-space groups when compared with the second premolar extraction groups.

Eventual fate of the mandibular third molars

From the available 82 records, it was found that 32% of the mandibular third molars in the second premolar extraction sample of boys and 15% in the second premolar extraction sample of girls had definitely been retained in the mouth, whereas 29% and 44% definitely had been extracted. In contrast, 100% of the third molars had definitely been extracted in both E-space groups (Table 5).

A conservative analysis was made using Fisher exact test, by dividing these results into definitely kept and not definitely kept. The sample of boys revealed highly statistically significant differences between the E-space and 5s groups ($P \leq .001$), and the sample of girls also showed statistically significant differences ($P \leq .05$).

DISCUSSION

Treatment ages and duration

The holding of E-spaces obviously requires treatment to be commenced before the E's have exfoliated. By definition, the average age at commencement of treatment is likely to be earlier in the E-space group when compared with the second premolar extraction group. This is indeed reflected in the average ages of commencement for the subjects within this sample. The duration of active treatment was a little greater on average in the E-space groups than in the second premolar extraction groups for both sexes. This might be expected because the clinician would have to wait for the eruption of the second premolars before including them in any appliance system. On the other hand, when mandibular second premolars have been extracted, treatment duration might be increased in some cases because of the need to close residual extraction space. Obviously, many factors can influence treatment duration, and individual variation may explain why the mean durations were not markedly different for the two types of treatments studied here.

Space changes in the mandible

It is not surprising that the greatest mean increase in Xi-6 occurred in the second premolar extraction sample of boys, whereas the smallest mean increase occurred in the E-space sample of girls. With the extraction of second premolars, the first molars might be expected to move mesially, either intentionally for class II molar correction or with unintentional lower anchorage loss. In contrast, treatment involving the holding of E-spaces would usually require the first molars to be held back in their pretreatment positions as much as possible, preventing them from moving mesially during treatment.

The greater mean increase in Xi-6 in boys than in girls might also be expected because boys of this age would normally have more pubertal growth remaining than girls of a similar age. It is well accepted that, on average, girls undergo the pubertal growth spurt and reach maturity approximately two years earlier than do boys.[32] Thus, one would have expected Xi point to have been relocated posteriorly to a greater extent in boys.

These findings would be consistent with those of Richardson,[5] who observed that the greatest increases in space distal to the first molar seem to occur in the presence of a large amount of overall mandibular growth and a relatively forward direction of eruption of the molars. Bjork et al[34] had also determined that the backward-directed eruption of a dentition is an important factor in the etiology of third molar impaction. The results of this study, therefore, seem to indicate that both sex and the type of treatment performed are important factors associated with space changes between Xi point and the mandibular first molar. To assess space availability for the eruption of the mandibular third molars, some authors[35,36] have measured the distance from the Xi point to the distal aspect of the lower second molar. Forsberg et al[36] found that the final distance from Xi to the second molar was significantly smaller on average in a group of subjects in whom third molars had to be extracted than in those in whom third molars had been allowed to erupt. Furthermore, just as in this study, Forsberg et al found significantly greater distances between Xi and the second molar after treatment in boys than in girls.

A change in the distance from Xi-point to the symphysis is really only a measure of mandibular growth, and it is unlikely to be affected by treatment because these landmarks are not generally believed to be amenable to direct treatment change. Any differences could instead be attributed to the fact that the subjects within the E-space groups were, on average, treated earlier and for longer times than those in the second premolar extraction groups. This implies that a greater amount of mandibular growth would have occurred during the treatment period. Such an explanation would also apply to differences between boys and girls and to changes in Co-Gn and Ar-Pog.

Mandibular third molars

Even by conservative analysis, the respective rates of eventual mandibular third molar extractions were found to be significantly different in the E-space and 5s groups. In the second premolar extraction sample of boys, 32% of the mandibular third molars were definitely kept, and in the second premolar extraction sample of girls, 15% of the mandibular third molars were definitely kept. Therefore, it could be stated that in the second premolar extraction sample of boys, an absolute maximum of 68% of the mandibular third molars were extracted, and in the second premolar extraction sample of girls, an absolute maximum of 85% of the mandibular third molars were extracted.

In contrast, from the available E-space records, it can be seen that all the mandibular third molars in both E-space groups had been extracted. Taking these figures into account, it would seem that the statistically significant differences in third molar extraction rates within this study sample would be highly clinically significant. In this sample, when E-spaces were held during orthodontic treatment without premolar extractions, the mandibular third molars were significantly more likely to have become impacted and, therefore, eventually to have been extracted. This would be consistent with the findings of Faubion,[15] Dierkes,[37] and Richardson,[14,38] all of whom noted that the prevalence of third molar impaction is reduced, but not eliminated, in cases treated with the extraction of premolars. In contrast, Staggers et al[39] analyzed improvement in third molar angulation and eruption during and after orthodontic treatment and found no significant differences between groups treated with or without first premolar extractions, suggesting that factors other than first premolar extractions might influence third molar angulation and eruption. Interestingly, however, all the patients in their sample were categorized as dentally and skeletally class I. Staggers et al[39] therefore stated that there was no need to protract the mandibular molars to attain a class I molar relationship. They went on to suggest that if the study subjects had been categorized instead as dental class II and mandibular molar protraction had consequently been encouraged to correct the molar relationships, even more favorable changes in mandibular third molar angulation might have been observed. Further work in this area might involve the assessment of the amount of pretreatment crowding, the pretreatment molar relationship, and the desired posttreatment lower incisor position.

If it is true that different treatment methods and extraction patterns lead to different total space conditions within the lower arch, the above evidence might challenge the notion of the so-called nonextraction treatment philosophies often found in the literature.[8,40] Contemporary clinicians need to consider whether these proposed treatment strategies really are nonextraction or whether they simply are courses of treatment performed without the extraction of premolars.

A number of authors have questioned previously whether nonextraction treatment is a misrepresentation of what is required to correct clinical problems and whether with such proposals, third molars are simply nonaccountable.[13,41] Vaden and Kiser[13] stated the problem as follows: ''When discussing the posterior dimension of the mouth, it is important to note that when nonextraction treatment is touted, 32 teeth must be maintained in the mouth. The extraction of third molars is a therapeutic decision. If a patient has to have third molars extracted, it is extraction treatment, not nonextraction treatment.'' Begg[42] similarly proposed that in Stone Age man, attritional reduction in the lengths of the dental arches left more space at the distal ends of the arches for the eruption of the third molars. He reasoned that third molar impaction in modern man could be attributed to insufficient mesial movement of the posterior dentition due to lack of proximal attrition, leading in turn to an imbalance between tooth and jaw size.

Contemporary treatment protocols involving molar distalizing mechanics, the holding of E-spaces, and even arch expansion may, for various dental and facial reasons, be sound approaches to the correction of individual malocclusions. All clinicians need to acknowledge, however, that these techniques do not necessarily create space to accommodate all the teeth. Rather, they would seem to involve a ''borrowing'' of space for alignment, and in most people, this borrowed space may need to be paid back in the form of other extractions after active treatment.[6] Put more simply, these so-called nonextraction approaches may only relocate the crowding more posteriorly. Despite many advances in orthodontic diagnosis and treatment over the last century, it seems that for the majority of our patients, we are yet to meet the challenge of retaining 32 teeth in good alignment and functional occlusion in the long term.

CONCLUSIONS

Taking into account the limitations of any lateral cephalometric study, the following conclusions can be drawn from this work:

- There are likely to be greater increases in the space distal to the mandibular first molars in growing patients treated with the extraction of mandibular second premolars than in growing patients treated with the holding of the E-spaces.
- Greater space increases are likely to be seen, with either type of treatment, in boys when compared with girls of similar age because boys would normally have a greater amount of potential mandibular growth remaining.
- Considerable individual variation is likely to be seen both in the amount of forward movement of the mandibular first molars and in the space increase distal to the first molars in patients treated with either approach.
- The individual variation in response to growth and treatment is likely to be due to some combination of different individual facial and occlusal objectives, different choices of treatment mechanics, and the different individual pretreatment dentofacial characteristics.
- Mandibular third molars would seem to be significantly more likely to become impacted, with or without partial eruption, in those patients treated with the holding of E-spaces without premolar extractions than in those treated with the extraction of mandibular second premolars.

REFERENCES

1. Enlow DH. *Handbook of Facial Growth.* 3rd ed. Philadelphia, Penn: WB Saunders; 1990:57–77.
2. Bjork A. Prediction of mandibular growth rotation. *Am J Orthod.* 1969;55:585–599.
3. Bjork A, Skieller V. Normal and abnormal growth of the mandible. A synthesis of longitudinal cephalometric implant studies over a period of 25 years. *Eur J Orthod.* 1983;5:1–46.
4. Bishara SE, Jakobsen JR, Treder J, Nowak A. Arch length changes from 6 weeks to 45 years. *Angle Orthod.* 1998;68:69–74.
5. Richardson ME. Lower third molar space. *Angle Orthod.* 1987; 57:155–161.
6. Woods MG. Mandibular arch dimensional and positional changes in late mixed dentition Class I and II treatment. *Am J Orthod Dentofacial Orthop.* 2002;122:180–188.
7. Brennan MM, Gianelly AA. The use of the lingual arch in the mixed dentition to resolve incisor crowding. *Am J Orthod Dentofacial Orthop.* 2000;117:81–85.
8. Gianelly AA. A strategy for nonextraction Class II treatment. *Semin Orthod.* 1998;4:26–32.
9. Shearn BN, Woods MG. An occlusal and cephalometric analysis of lower first and second premolar extraction effects. *Am J Orthod Dentofacial Orthop.* 2000;117:351–361.
10. Kim T, Artun J, Behbehani F, Artese F. Prevalence of third molar impaction in orthodontic patients treated nonextraction and with extraction of 4 premolars. *Am J Orthod Dentofacial Orthop.* 2003;123:138–145.
11. Ricketts RM, Turley P, Chaconas S, Schulhof RJ. Third molar enucleation: diagnosis and technique. *J Calif Dent Assoc.* 1976; 4:50–57.

12. Bishara SE, Andreasen G. Third molars: a review. *Am J Orthod.* 1983;83:131–137.
13. Vaden JL, Kiser HE. Straight talk about extraction and nonextraction: a differential diagnostic decision. *Am J Orthod Dentofacial Orthop.* 1996;109:445–452.
14. Richardson ME. The etiology and prediction of mandibular third molar impaction. *Angle Orthod.* 1977;47:165–172.
15. Faubion BH. Effect of extraction of premolars on eruption of mandibular third molars. *J Am Dent Assoc.* 1968;76:316–320.
16. Kaplan RG. Some factors related to mandibular third molar impaction. Angle Orthod. 1975;45153–45158.
17. Richardson ME. The effect of mandibular first premolar extraction on third molar space. *Angle Orthod.* 1989;59:291–294.
18. Perlow J. A full light-arch technique utilizing Bull's principles of extraction treatment with emphasis on twenty-eight teeth. *Am J Orthod.* 1964;50:81–98.
19. Richardson ME, Richardson A. Lower third molar development subsequent to second molar extraction. *Am J Orthod Dentofacial Orthop.* 1993;104:566–574.
20. Lawlor J. The effects on the lower third molar of the extraction of the lower second molar. *Br J Orthod.* 1978;5:99–103.
21. Rindler A. Effects on lower third molars after extraction of second molars. *Angle Orthod.* 1977;47:55–58.
22. Silling G. Development and eruption of the mandibular third molar and its response to orthodontic therapy. *Angle Orthod.* 1973;43:271–278.
23. Orton-Gibbs S, Crow V, Orton HS. Eruption of third permanent molars after the extraction of second permanent molars. Part 1: assessment of third molar position and size. *Am J Orthod Dentofacial Orthop.* 2001;119:226–238.
24. Graber TM, Kaineg TF. The mandibular third molar—its predictive status and role in lower incisor crowding. *Proc Finn Dent Soc.* 1981;77:37–44.
25. Williams R, Hosila FJ. The effect of different extraction sites upon incisor retraction. *Am J Orthod.* 1976;69:388–410.
26. Forsberg CM. Tooth size, spacing and crowding in relation to eruption or impaction of third molars. *Am J Orthod.* 1988;94:57–62.
27. Andrews LF. The six keys to normal occlusion. *Am J Orthod.* 1972;62:296–309.
28. Roth RH. Functional occlusion for the orthodontist. Part III. *J Clin Orthod.* 1981;15:182–198.
29. Ricketts RM. A four step analysis to distinguish orthodontic changes from natural growth. *J Clin Orthod.* 1975;4:208–228.
30. Cook AH, Sellke TA, BeGole EA. The variability and reliability of two maxillary and mandibular superimposition techniques, Part II. *Am J Orthod Dentofacial Orthop.* 1994;106:463–471.
31. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrika* 1983;70:41–55.
32. Altman DG. *Practical Statistics for Medical Research.* London, UK: Chapman & Hall; 1991:253–257.
33. Taranger J, Hägg U. The timing and duration of adolescent growth. *Acta Odontol Scand.* 1980;38:57–67.
34. Bjork A, Jensen E, Palling M. Mandibular growth and third molar impaction. *Trans Eur Orthod Soc.* 1956:164–197.
35. Erdem D, Ozdiler E, Toygar Memikoglu U, Baspinar E. Third molar impaction in extraction cases treated with the Begg technique. *Eur J Orthod.* 1998;20:263–270.
36. Forsberg CM, Vingren B, Wesslen U. Mandibular third molar eruption in relation to available space as assessed on lateral cephalograms. *Swed Dent J.* 1989;13:23–31.
37. Dierkes DD. An investigation of the mandibular third molars in orthodontic cases. *Angle Orthod.* 1975;45:207–212.
38. Richardson ME. The development of third molar impaction. *Br J Orthod.* 1975;2:231–238.
39. Staggers JA, Germane N, Forston WM. A comparison of the effects of first premolar extractions on third molar angulation. *Angle Orthod.* 1992;62:135–138.
40. Alexander RG. Treatment and retention for long-term stability. In: Nanda R, Burstone CJ, eds. *Retention and Stability in Orthodontics.* Philadelphia, Penn: WB Saunders; 1993:115–133.
41. Godfrey K. Prophylactic removal of the asymptomatic third molar: a review. *Aust. Dent J.* 1999;44:233–237.
42. Begg PR, Kesling PC. *Begg Orthodontic Theory and Technique.* 3rd ed. Philadelphia, Penn: WB Saunders; 1977:21–22.