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Localized orthodontic space closure for unilateral aplasia of lower second premolars

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SUMMARY The present study aimed to determine whether routine orthodontic space closure can be successfully achieved in patients with unilateral aplasia of the lower second premolars without extracting contralateral or opposing teeth. The dental records and lateral cephalograms of 17 consecutively treated subjects (11 females, 6 males) aged between 14.8 and 19.3 years at the end of active treatment (mean 16.1 years) were analysed. The spaces were closed by 'push-and-pull' mechanics (PPM). Pre- and post-treatment data were compared using a Student's *t*-test.

At the end of active treatment, all parameters (ANB, SNA, SNB, ML/NL, U1–NA, L1–NB, overbite and overjet, upper and lower midline, upper and lower space balance) presented mean values close to accepted norms with satisfactory standard deviations (SDs). Five indicators of success changed significantly: (1) Space closure in the aplastic region was achieved. (2) On the aplastic side, a mean mesial molar relationship of 1.12 (SD 0.18) cusp width (cw) was achieved. The mean alteration from pre- to post-treatment was 1.53 cw (SD 0.29, $P \leq 0.001$). (3) The corresponding values on the contralateral side were 0.02 cw (SD 0.11), with an alteration during treatment of 0.49 cw (SD 0.22, $P \leq 0.001$). (4) The overjet was reduced, on average, by 1.06 mm (SD 1.91 mm) to a mean value of 2.47 mm (SD 0.86 mm, $P \leq 0.05$), and (5) the maxillary incisors were proclined by a mean of 4 degrees (SD 6.21 degrees, $P \leq 0.05$) to 22.41 degrees (SD 5.37 degrees).

Analysis of patient characteristics demonstrated that successful outcomes were routinely achieved in subjects with balanced, vertical or horizontal growth patterns, in those with basal and dental distal and neutral sagittal relationships, and in those with a moderate lack, or excess, of space and balanced space ratios.

Introduction

The diagnosis and management of tooth aplasia are important for paediatric dentists and orthodontists. With a prevalence of 2.5–4 per cent, the lower second premolar is the tooth most commonly affected, after the third molars (Bergström, 1977; Rölling, 1980). A whole range of therapeutic options is available for management of aplasia. Alongside conventional prosthetic/restorative solutions (Shillingburg *et al.*, 1997; Näpängankas *et al.*, 2002), other clinicians have advocated surgical techniques, such as autotransplantation (Josefsson *et al.*, 1999; Jonsson and Sigurdsson, 2004). However, more recent trends have favoured implants (Zuccati, 1993; Eckert and Wollan, 1998; Sabri, 2004).

From an orthodontic viewpoint, it has been suggested that early treatment may allow spontaneous space closure by guiding tooth eruption (Lindqvist, 1980). Svedmyr (1983) suggested extracting the primary second molar prior to eruption of the first molar in order to stimulate mesial eruption of the first molars. However, a diagnosis of aplasia of a lower second premolar in patients under 9 years of age is rarely made (Bergström, 1977; Rölling, 1980).

Other proposals have included extraction of a premolar in the opposing arch with, or without, active orthodontic treatment (Mamopoulou *et al.*, 1996) or extraction of three premolars in the fully dentate quadrants (Joondeph and McNeill, 1971). However, neither of these methods is an established standard treatment protocol due to problems such as residual spacing or midline shifts (Joondeph and McNeill, 1971; Mamopoulou *et al.*, 1996).

There have been numerous arguments against the concept of localized orthodontic space closure without extraction of the contralateral teeth; one of the primary concerns being that inadequate mesial movement of the molars in the aplastic regions may prevent a good buccal occlusion being established. Concern has also been expressed regarding other potential drawbacks such as the development of an increased overjet and overbite, retrusion of the upper and lower incisors and midline shifts (Fiorentino and Melsen, 1996; Sabri, 2004).

To avoid these issues, Northway (2004) proposed 'stepwise' management of developmentally missing lower second premolars. This involved hemisecting the primary second molar followed by removal of the distal and, later, the mesial root. Fiorentino and Melsen (1996) emphasized the need for additional anchorage in conjunction with segmented arch treatment, to ensure maintenance of the anterior relationship.

Previous data on successful treatment outcomes secondary to localized space closure without the use of additional anchorage have been limited to case reports (Fines *et al.*, 2003; Sabri, 2004). Only recently was a study presented which allowed statistical evaluation of this treatment modality (Zimmer and Guitard, 2001). These initial results obtained using 'push-and-pull' mechanics (PPM) were encouraging, but revealed limitations such as insufficient molar movement or the development of a midline shift.

The primary aim of the present study was to evaluate, in a sample of consecutively treated subjects, whether isolated orthodontic space closure in patients with unilateral aplasia of lower second premolars can be used as a successful treatment protocol. A secondary aim was to describe the treated patients according to orthodontically relevant dental and skeletal parameters.

Subjects and methods

Patients

This retrospective study was based on analysis of the dental records and lateral cephalograms of 17 consecutively treated orthodontic patients (11 females, 6 males) who had unilateral aplasia of one lower second premolar ($n = 11$ tooth 35, $n = 6$ tooth 45). The mean age at the beginning of treatment was 13.9 years (range 12.7–16.8 years). The mean duration of active treatment was 2.2 years and the mean age at the end of active treatment was 16.1 years (range 14.8–19.3 years). All subjects were treated by one clinician (BZ) and, in all patients aplasia was the primary indication for treatment. There were no other severe dental anomalies and third molar tooth germs were present in all aplastic quadrants.

At the beginning of treatment, on the aplastic side, three patients had a Class I molar relationship, one a Class III molar relationship of 0.25 cusp width (cw), and 13 had a Class II molar relationship (three patients with 0.25 cw, five with 0.5 cw, four with 0.75 cw, and one with 1 cw). The corresponding data for the contralateral, non-aplastic, side were two patients with a Class I molar relationship and 15 patients with a Class II molar relationship (five patients with 0.25 cw, four with 0.5 cw, five with 0.75 cw, and one with 1 cw). The records of a patient included in the study are shown in Figure 1-5.

Mechanics

All patients were treated with a straightwire appliance, with some minor individual modifications. Spaces in the aplastic region were closed using PPM. The characteristic feature of PPM is that conventional space closing mechanics, such as powerchain, closing coils, and closing loops, are avoided, the aim being to minimize retrusive forces on the anterior teeth while maximizing mesial movement of the lower molars.

Wherever possible, space closure was initiated using PPM via an opening coil between the first and second lower molars (Figure 2a–e). Simultaneously, the second molar was prevented from moving distally through the use of a unilateral Class II elastic from the upper canine on the aplastic side (Figure 2f,g). If the eruption of the lower second molar was insufficient, a Class II elastic only was used for mesialization of the first molar. After mesial movement of the first molar was complete, the second molar was mesialized through the use of a Class II elastic. The patients were advised to wear their elastics 24 hours a day. Intermaxillary Class II elastics were also used on the contralateral side if there was a Class II molar relationship to be corrected on that side (Figure 2f,g).

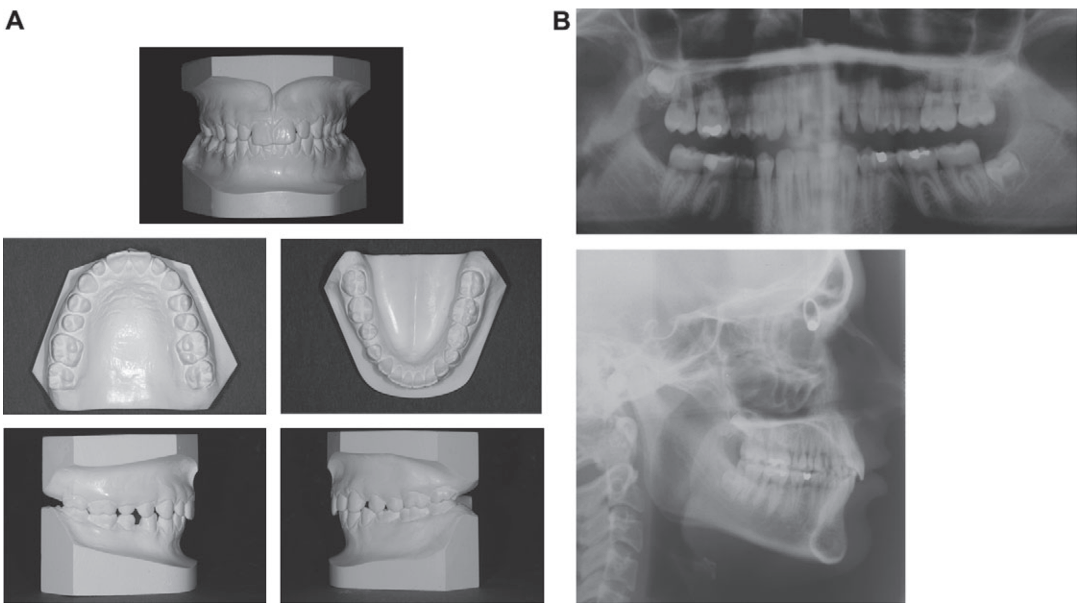

Figure 1 (A) Pre-treatment dental casts and (B) radiographs of a 16.5-year-old female with aplasia.

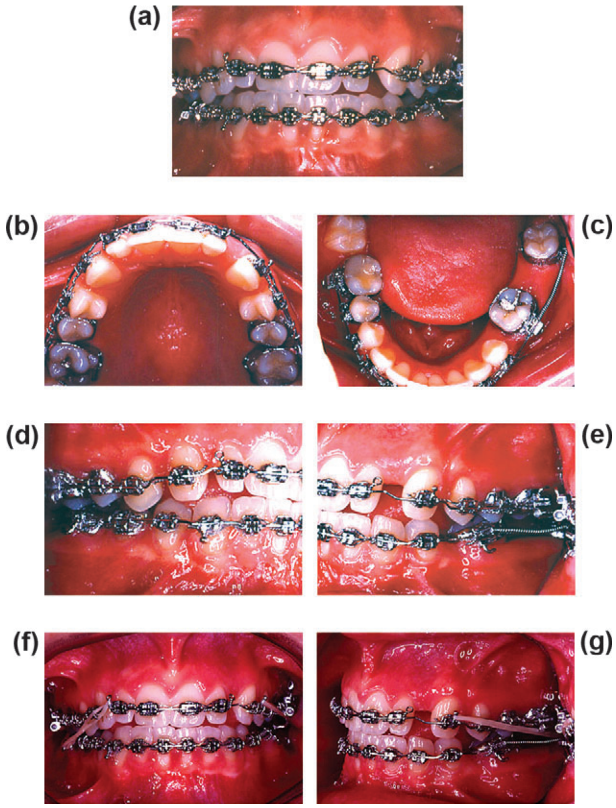

Figure 2 (a–e) The intermediate treatment phase of the patient in Figure 1 after mesialization of tooth 36. The images show slight over-correction of the Class III molar relationship on the aplastic side. Note the generalized spacing. The significant spacing mesial and distal to tooth 36 shows how molar positions and relationships can be altered with push-and-pull mechanics (f,g) with Class II elastics in place. The open coil can be removed and mesialization of tooth 37 initiated.

To correct midline shifts, an intermaxillary elastic, worn at night, was routinely used from the contralateral upper central incisor to the lower canine on the aplastic side. After mesialization of the lower first molar, a Burstone-style lingual arch was fitted to enable transverse adjustments to be made and de-rotation of the molar when required. No other additional intra- or extraoral anchorage measures, apart from a trans palatal arch for crossbite correction in one patient, were used. At the end of active treatment, a bonded retainer was attached from the upper first to the second molar until the lower third molar erupted, to prevent this antagonist-free tooth from over erupting.

Assessment

To enable assessment of the treatment results, the following criteria were utilized (Table 1): space closure in the aplastic region, establishment of a Class III molar relationship of at least 1 cw, a Class I molar relationship on the contralateral side, overbite and overjet within normal range, correct centrelines, and upper and lower incisor inclinations close to normal values. Additional variables examined included: ANB, SNA, SNB, and ML–NL angles; the initial space conditions in the maxilla and mandible (Table 2); and patient growth patterns. Cephalometric measurements used accepted landmarks (Table 3). Overjet and overbite, centreline deviations, and crowding/spacing were measured with callipers (to a precision of 0.1 mm). The initial space conditions in the mandible were determined without giving consideration to the missing tooth.

The changes occurring during treatment were assessed by comparing the values at baseline with those at the end of active treatment. Changes in the molar relationships were measured in cw, with a negative sign indicating a distal relationship and a positive sign a mesial relationship.

Centrelines were assessed according to the following criteria: the midline of the philtrum to determine the maxillary centreline, columella nasi (if straight), and the position of the labial fraenum to the incisive papilla and the palatine raphe. The mandibular centreline was assessed relative to the maxillary centreline, as well as to the labial and lingual fraenum (Miller *et al.*, 1979). Centreline shifts to the aplastic side were indicated by a negative sign and those to the contralateral side by a positive sign.

Statistics

Radiographs were traced and digitized by one observer (NSS). Repeated measurements were performed by the same observer to assess reliability. The intraobserver method error was calculated according to Dahlberg's (1940) formula. The values varied between 0.19 and 1.3 degrees for the angular measurements. Repeated calliper measurements on the dental casts showed a variation between 0 and 1.2 mm. A systematic error one-sample *t*-test (Houston, 1983) revealed no significant difference between the first and second measurements. For data evaluation, pre- and post-treatment values were compared using a Student's *t*-test.

Results

Indicators of success

The changes in the two main outcome criteria (i) space closure and (ii) molar relationship on the aplastic side were highly significant ($P \leq 0.001$). Space closure was almost complete, with a mean residual space of just 0.02 mm. It was possible to achieve routine closure of spaces in aplastic regions that measured between 8 and 11 mm (mean 9.3 mm; Figures 3–5). On the aplastic side, there was a change in molar relationship between 1 and 2 cws (mean 1.53 cw). In 11 patients, this involved a mesial relationship of 1 cw. However, in four subjects there was a mesial molar relationship of 1.25 cw and, in two patients a 1.5 cw change was necessary in order to obtain full space closure (mean 1.12 cw; Table 1).

Significant changes were also found in the molar relationship on the contralateral side ($P \leq 0.001$), the overjet

Table 1 Assessment of indicators of success for isolated orthodontic space closure ($n = 17$).

	Pre-treatment		Post-treatment		Post-Treatment − Pre-Treatment		P value
	Mean	SD	Mean	SD	Mean	SD	
Space closure (mm)	9.32	0.83	0.02	0.12	−9.3	0.83	<0.001***
Molar relationship (cw)—aplastic side	−0.41	0.34	1.12	0.18	1.53	0.29	<0.001***
Molar relationship (cw)—contralateral side	−0.47	0.29	0.02	0.11	0.49	0.27	<0.001***
Overbite (mm)	2.71	1.97	2.03	0.72	−0.68	1.83	0.15
Overjet (mm)	3.53	1.62	2.47	0.86	−1.06	1.91	0.04*
Upper midline (mm)	0	0.35	−0.12	0.22	−0.12	0.42	0.26
Lower midline (mm)	−0.21	0.73	−0.37	0.49	−0.16	0.81	0.42
U1–NA (°)	18.41	5.4	22.41	5.37	4.0	6.21	0.02*
L1–NB (°)	28.28	5.79	26.24	6.79	−1.94	7.21	0.28

SD, standard diviation; CW, cusp width. *$P < 0.05$, ***$P < 0.001$.

Table 2 Characteristics of the treated patients ($n = 17$).

	Pre-treatment		Post-treatment		Post-Treatment − Pre-Treatment		P value
	Mean	SD	Mean	SD	Mean	SD	
ANB (°)	4.65	2.09	3.53	1.97	−1.12	1.41	0.005**
SNA (°)	82.07	3.81	81.53	3.45	−0.54	1.92	0.32
SNB (°)	77.42	3.16	78	3.04	0.58	1.66	0.16
ML/NL (°)	24.47	4.62	25	5.22	0.53	2.37	0.37
Upper space balance (mm)	−0.53	2.92	0.5	1.15	0.91	2.35	0.1
Lower space balance (mm)	−0.24	2.22	−0.21	0.53	0.03	2.15	0.96

SD, standard deviation; **$P < 0.01$.

($P = 0.04$), and inclination of the upper incisors ($P = 0.02$). The significant increase in proclination of the upper incisors, as well as the non-significant reduction in proclination of the lower incisors, was a beneficial effect given that close to normal values were achieved at the end of treatment. Nevertheless, there was a wide range of variation as illustrated by standard deviations (SDs) of ±6.21 degrees for upper incisor inclinations (range: −4 to +17 degrees) and ±7.21 degrees (range: −13 to +15 degrees) for the lower incisors (Figure 3). Centreline shifts to the aplastic side in the maxilla (mean −0.12 mm, SD 0.42 mm) and the mandible (mean −0.16 mm, SD 0.81 mm) were minimal.

Patient classification

The sample included patients with ANB values between 1 and 9 degrees (mean 4.65 degrees, SD 2.09 degrees), with a tendency to a Class II sagittal relationship. The values for SNA at baseline (82.07 ± 3.81 degrees) and at the end of treatment (81.53 ± 3.45 degrees) were close to normal values (82 ± 3.5 degrees). The mean value for SNB was 77.42 degrees (SD ±3.16 degrees) at the start of treatment, indicating that the patient sample tended to be retrognathic (normal value 79 ± 3.5 degrees; Table 2).

On average, the vertical relationship (ML/NL angle) was normal both at baseline (24.47 degrees, SD ±4.62 degrees) and at the end of treatment (25 degrees, SD ±5.22 degrees). There was, however, marked individual variation with values ranging from 13 to 33 degrees at baseline (12–32 degrees at the end of treatment). The growth direction was neutral in nine patients, low-grade vertical in four, and horizontal in two. Only one patient exhibited medium-grade vertical growth and one medium-grade horizontal growth.

The analysis of space conditions in the maxilla at baseline showed that patients exhibited space deficits (maximum –5 mm), as well as an excess of space (maximum +6 mm). However, the majority ($n = 11$) had a space balance of ±2 mm (mean: −0.53 mm, SD: ±2.92 mm). In the mandible, there was a mean space balance of –0.24 mm (SD: ±2.22 mm). Maximum medium-grade excesses of space of 4 mm and crowding of −4 mm were observed.

Discussion

Between 11 and 20 years of age, retained primary second molars undergo 60 per cent resorption of their mesial and 46 per cent resorption of their distal roots (Bjerklin and Bennett,

Table 3 Definitions of cephalometric landmarks.

Landmark	Abbreviation	Definition
Nasion	N	The anterior limit of the naso-frontal suture
Subspinale	A	The deepest point on the contour of the maxillary alveolar process between anterior nasal spine and prosthion
Supramentale	B	The deepest point on the contour of the mandibular alveolar process between infradentale and pogonion
Sagittal plane angle	ANB	Angle between nasion, subspinale, and supramentale
Anterior nasal spine	ans	The apex of anterior nasal spine
Spina nasalis posterior	snp	The point of the intersection of the soft palate, the hard palate, and fossa pterygo-palatina
Nasal line	NL	Line through anterior nasal spine and posterior nasal spine
Apex superius	as	The root apex of the most prominent upper incisor
Incision superius	is	The midpoint on the incisor edge of the most labially positioned maxillary incisor
Upper incisor axis	U1	Line through apex superius and incision superius
Gonion inferius	goi	The posterior tangent point of the mandibular inferior border near gonion
Gnathion	gn	The most inferior point of the mandibular symphysis
Mandibular line	ML	Line through gonion inferius and gnathion
Apex inferius	ai	The root apex of the most prominent lower incisor
Incision inferius	ii	The midpoint on the incisor edge of the most labially positioned mandibular incisor
Lower incisor axis	L1	Line through apex inferius and incision inferius

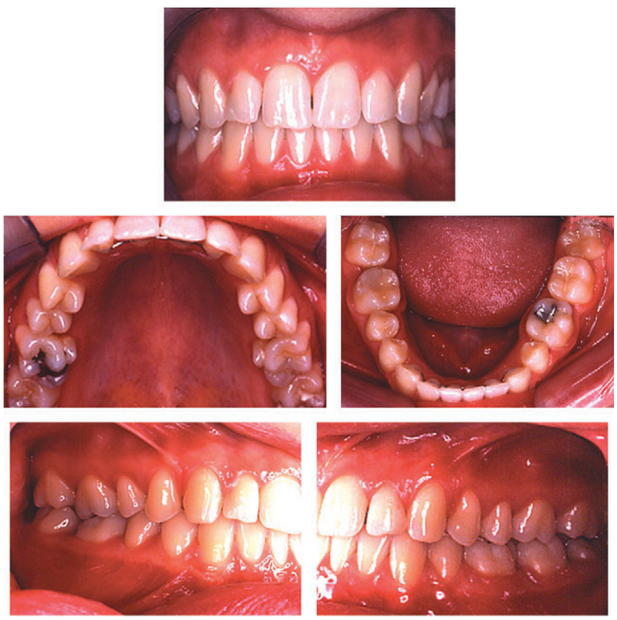

Figure 3 Post-treatment intraoral views. Due to microdontia of teeth 12 and 22, preliminary composite restorations have been placed.

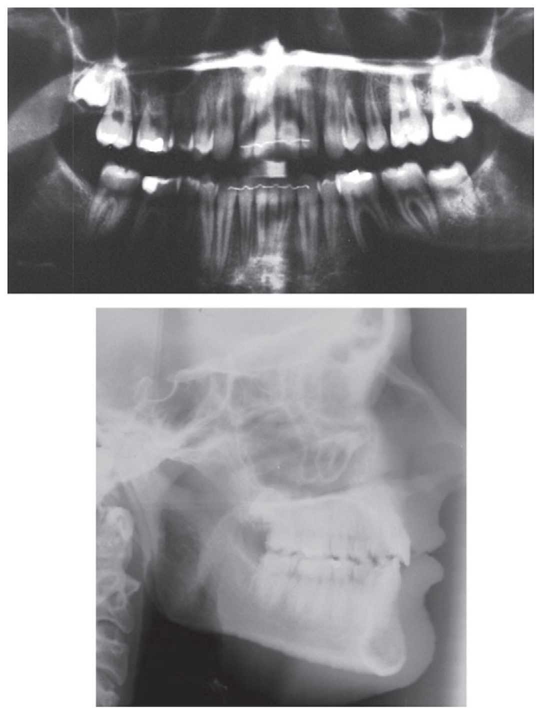

Figure 4 Post-treatment radiographs.

2000). For this reason, those authors reported a good long-term prognosis for primary second molars in subjects with missing second premolars. Indeed, Ith-Hansen and Kjaer (2000) found that from 16 years of age, 64.5 per cent of patients had retained primary molars which did not require extraction and showed no signs of severe root resorption or significant infraocclusion. It may, therefore, be sensible to refrain from prosthodontic or orthodontic therapy in adolescents when the tooth is caries free and has a favourable root situation.

On the other hand, over-eruption and tipping of adjacent teeth and/or ankylosis of the primary tooth are comparatively common complications (Bjerklin and Bennett, 2000). Under these circumstances, composite restorations, extractions, and the subsequent wear of space maintainers may be necessary (Kurol and Thilander, 1984; Kokich, 2002). If ankylosis is detected before growth of the alveolar process is complete, a prosthodontic or prosthetic implant

Figure 5 Intraoral views 2 years after end of active treatment with fully erupted third molars.

solution cannot be performed immediately, and patients may be required to wear space maintainers for several years (Fines *et al.*, 2003).

In patients with retained and ankylosed primary teeth, there may be a poor buccal occlusion due to missing occlusal contacts between the primary tooth and its antagonist, premature contacts due to an over-erupted antagonist, or a disturbed occlusal relationship caused by wires from space maintainers. However, occlusal problems occur when second primary molars develop infraocclusion and space maintainers are necessary. Occlusal problems can exist solely by the fact that, in the presence of an otherwise ideal occlusion, the first molar remains in a distal relationship (Wheeler, 1984). As a consequence, the decision to maintain a primary molar with a view to a later prosthodontic solution is associated with occlusal compromise, either temporarily or permanently.

From the aspect of longevity, the prosthodontic and implant options which are currently available for the management of missing teeth have yielded high success rates. Eckert and Wollan (1998) reported a 10-year implant survival rate of 95 per cent. This therapy appears to be more successful than conventional fixed restorations which showed a success rate of 84 per cent for the same period (Näpängankas *et al.*, 2002). However, one obvious disadvantage is that implants cannot be inserted until growth has been completed.

The long-term results of autotransplants show similar success rates. Josefsson *et al.* (1999) reported a success rate of 92 per cent, but only after 4 years. Jonsson and Sigurdsson (2004) reported a 92.5 per cent rate after 17 years and Czochrowska *et al.* (2002) found that 90 per cent of the transplanted teeth remained *in situ* after 26 years. However, the overall success rate was classified as 79 per cent, because two transplants had ankylosed and a further two did not meet the outcome criteria. There are three main disadvantages of autotransplantation. Firstly, this treatment modality is subject to time constraints and can only be performed when the root has reached, but not exceeded, a specific developmental stage. This means that radiographic monitoring is required to establish the correct time for transplantation. Secondly, a suitable donor tooth such as a premolar or third molar must be available, which is not always the case. Thirdly and finally, it involves surgical intervention.

In contrast to the above options, the purely orthodontic concept of attempting localized space closure represents an attractive alternative. There is an extensive 'window of time' and, apart from the extraction of one primary tooth, it obviates the need for surgical intervention. The success of this method is determined by the fact that space closure in the aplastic region can be achieved routinely and successfully by mesial movement of the distal teeth. In the majority of the subjects, mesial movement of the molars by 1 cw was achieved. The fact that greater mesial movement was required in one-third of the patients in order to achieve complete space closure can be explained by a width discrepancy between the missing second premolar and the mesio-buccal cusp of the lower first molar intended to replace it. In no subject did the more mesial position lead to a compromised occlusal result, but nevertheless it highlights a new and unexpected problem that could in some case necessitate interdental stripping procedures. However, the fact that even more mesial molar positions than 1 cw can be established, when necessary, demonstrates the potential of PPM. One of the consequences of unilateral space closure was additional space gain in the retromolar region on the aplastic side, as reported in previous studies (Zimmer and Guitard, 2001; Zimmer and Rottwinkel, 2002). It has been shown that this situation is associated with an 82 per cent eruption rate of third molars on the aplastic side after 4 years and 94 per cent after 8 years (Zimmer, 2006).

The results were achieved purely by utilizing PPM which, unlike conventional methods of space closure, avoids applying traction to the anterior teeth. This method avoided some of the side-effects in the anterior region described in previous studies (Mamopoulou *et al.*, 1996) and thereby obviated the use of additional anchorage (Fiorentino and Melsen, 1996).

It was noticeable that there was proclination in both arches and retraction of the anterior dentition was clearly avoided. Given that Class II elastics were utilized, the fact that there was a protrusive change in the maxillary inclination indicates that the maxillary dentition provides sufficient anchorage for this therapeutic option. In the mandible, changes in incisor inclination, in comparison with recognized standards, showed a retrusive trend, although there was large individual variation.

Since neither an increased ML/NL angle nor a significant reduction in overbite occurred as a result of Class II elastic wear, it is likely that occlusal activity prevented molar extrusion and downward rotation of the mandible. Minor centreline shifts to the aplastic side were observed in a number of patients and this may be regarded as one of the adverse effects of this treatment modality. As the magnitude of such changes was relatively small (mean of –0.12 in the maxilla and –0.37 mm in the mandible) and the maximum change was only 1 mm, these appear to have minimal clinical relevance. This is supported by Kokich *et al.* (2001), who reported that orthodontists do not rate centreline deviations in the maxilla as aesthetically unattractive until the deviation exceeds 3 mm, and Johnston *et al.* (1999) demonstrated that only 56 per cent of laypersons become aware of dental and facial midline discrepancies greater than 2 mm.

Conclusions

Localized space closure utilizing PPM offers orthodontists a treatment option which avoids dental restorations and surgery and has few side-effects. Analysis of the clinical data suggests that this treatment modality is indicated for the majority of patients affected with aplasia.

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