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Routine treatment of bilateral aplasia of upper lateral incisors by orthodontic space closure without mandibular extractions

Bernd Zimmer and Nasrin Seifi-Shirvandeh
Private Practice, Kassel, Germany

SUMMARY This study aimed to gather statistically validated information on the changes in orthodontic variables in patients with bilateral upper lateral incisor aplasia treated with isolated orthodontic space closure. Data were collected from 25 (15 females, 10 males) consecutively treated, unselected adolescents [mean age at the end of treatment 16.4 years, standard deviation (SD) 1.3] after orthodontic space closure using push-and-pull mechanics (PPM). The changes in the relevant parameters were determined by comparing baseline and final lateral headfilms and casts. Following verification of normal distribution by means of a Kolmogorov–Smirnov test, a two-tailed *t*-test for related data was performed.

SNA, ANB, OcP-NL, OcP-ML, upper space balance, overbite, overjet, bilateral molar relationship, and L1-NB changed significantly ($P \leq 0.05$) during treatment. The changes in overbite, overjet, spatial conditions, and molar relationship were in line with the targeted treatment objectives and within the normal range. Although the change in L1-NB was probably due to treatment, it was not clinically relevant given that the mean final values were close to normal at 22.8 degrees (SD 5.8°) for L1-NB and 95 degrees (SD 8°) for L1-ML.

Isolated orthodontic space closure for bilateral upper lateral incisor aplasia using PPM can be regarded as a valid alternative to prosthetic solutions. Long-term use of Class III elastics does not lead to significant changes in relevant orthodontic parameters.

Introduction

Even during the Iron Age, it was not uncommon that the upper lateral incisors of humans were missing (Nelsen *et al.*, 2001). Nowadays, the upper lateral incisors are the teeth that are either affected by aplasia with the greatest (Silva Meza, 2003; Fekonja, 2005), second greatest (Kokich, 2002; Kokich and Kinzer, 2005; Endo *et al.*, 2006), or third greatest frequency (Ng`ang`a and Ng`ang`a, 2001; Nordgarden *et al.*, 2002), depending on the ethnic groups studied. Data on the prevalence of aplastic lateral incisors as a percentage of the overall number of aplastic teeth, not including third molars, fluctuates between 11.4 (Endo *et al.*, 2006) and 54.1 (Fekonja, 2005) per cent.

When lateral incisor agenesis is present, the upper canines usually erupt far too mesially. The emerging canines tend to resorb the roots of the lateral primary incisors and often the primary canines (Turpin, 2004a). Thus, the therapeutic decision on how to proceed should be made at an early stage (Wexler, 2000). The therapeutic options of choice include orthodontic space closure (Zachrisson and Stenvik, 2004; Kokich and Kinzer, 2005), tooth-supported prosthodontic solutions such as resin-bonded bridges or full crown bridge reconstructions (Nordquist and McNeil, 1975; Trushkowsky, 1995; Robertsson and Mohlin, 2000; Kinzer and Kokich, 2005a), and implant-supported crowns (Trushkowsky, 1995; Thilander *et al.*, 2001; Kinzer and Kokich, 2005b). Autologous tooth transplantation is an additional option (Stenvik and Zachrisson, 1993). The advantages and disadvantages of the various treatment modalities have been the subject of intense debate (Wexler, 2000; Turpin, 2004b; Wilson and Ding, 2004; Zachrisson and Stenvik, 2004; Kokich and Kinzer, 2005). A generally valid decision favouring one or other method is difficult given the variety of factors to be accounted for in the individual situation (Wexler, 2000; Turpin, 2004b; Kokich and Kinzer, 2005). Among other variables, the shape and colour of the canines, the characteristics of the gingiva and periodontium, and the possible treatment time are regarded as relevant in the decision-making process (Rosa and Zachrisson, 2001; Armbruster *et al.*, 2005).

Another important aspect to consider is that orthodontic space closure has a more broad-reaching aim than a prosthetic treatment approach. While prosthetic solutions involve localized measures for achieving space closure in the aplastic area, orthodontic space closure can only be deemed successful when the outcomes of the concurrent dental and skeletal treatment meet the recognized orthodontic standards (Miller, 1990; Biggerstaff, 1992; Van der Linden, 1995; Kokich, 2002; Turpin, 2004a; Kokich and Kinzer, 2005). To date, there are no statistically validated data available on outcomes secondary to orthodontic space closure in patients with upper lateral incisor aplasia.

Therefore, the aim of the present study was to primarily determine whether orthodontic space closure without extraction of permanent mandibular teeth leads to any relevant changes in skeletal and dental parameters and, secondly, whether the stated orthodontic target variables are within the normal range at the end of treatment.

Subjects and methods

Patients

The present retrospective study analyzed the dental records (models, cephalometric radiographs) of 25 orthodontic patients (15 females, 10 males) consecutively treated by one author (BZ) for bilateral aplasia of the permanent upper lateral incisors. The mean duration of active treatment was 2.6 years [standard deviation (SD) 0.8] and the mean age at the end of active treatment was 16.4 years (SD 1.3). The unselected patients enrolled in this study all had finalized treatment outcomes. No patient was excluded prior to commencement of treatment and no patient withdrew before treatment was finished. For all subjects, a manifest aplastic situation was the primary indication for treatment. Isolated orthodontic space closure without extraction of permanent mandibular teeth was chosen by all parents and patients after being informed about the orthodontic, prosthodontic, and implantology alternatives by different specialists. Their reason for choosing isolated orthodontic space closure was to avoid dental restorations and surgical intervention.

As a result, the aplastic patients treated had a variety of skeletal and dental baseline situations, including, among others: skeletal Class I, II, and III relationships (ANB: minimum −3 degrees, maximum 7 degrees, Wits appraisal: minimum −5 degrees, maximum 8 degrees) with dental neutral and distal molar relationships. Vertical deep, neutral, and open skeletal relationships were present (ML-NL: minimum 13.4 degrees, maximum 37.5 degrees) and were concurrent with dental deep bites (maximum: 9 mm) and slightly open bites (minimum: −0.5 mm). The associated overjets were ideal (minimum: 2 mm) to enlarged (maximum: 8 mm). Depending on the type of measurement, incisor inclinations in the maxilla showed a wide range of angulations, ranging from −4.8 to 40 degrees (U1-NA) or 85 to 125 degrees (U1-NL). Similar patterns were found for mandibular incisor inclinations. The minimum values were 16.5 degrees (L1-NB) and/or 85.6 degrees (L1-ML), and the maximum values 35.6 (L1-NB) and/or 109.2 (L1-ML) degrees. The spatial conditions in the maxilla ranged from nearly balanced situations (minimum: 1 mm) to pronounced excesses (maximum: 12.5 mm). The mandibular situations showed moderate crowding (minimum: −4 mm) up to considerable space excess (maximum: 6 mm). The growth types were determined according to the Frankfort box and were similarly varied. At the start of treatment, 11 patients had average growth directions; the growth direction in seven patients was mildly horizontal, in five patients mildly vertical, and in two patients moderately horizontal or vertical.

Method

All patients were treated with a straightwire appliance (Roth, 0.018 inch slot Forestadent, Pforzheim, Germany). If later required, minor modifications were made to achieve an ideal intercuspation in the individual patient. The spaces in the aplastic region were closed using combined push-and-pull mechanics (PPM; Zimmer, 2006; Zimmer *et al.*, 2007). The PPM approach used was designed to avoid exerting any adverse forces on isolated teeth or groups of teeth that were intended to remain *in situ*. One aim of the treatment of upper lateral incisor agenesis is to minimize retrusive forces on the anterior maxillary dentition. On one hand, space closure from the anterior was to be avoided, while guaranteeing maximum movement of the premolars and molars from the posterior into the aplastic regions at the same time. The main characteristic feature of this approach was that conventional Class I space closure mechanics were avoided; in other words, power chains, closing coils, or loops were rarely used between the anterior dentition and the posterior teeth to be mesialized. Instead, space closure was initiated using open coils distal to the canines. This approach obviated the need for additional anchorage elements.

Accurate midline positioning was achieved at an early stage using a modification of the technique of Zachrisson (1978) by either inserting a unilateral open coil or two open coils that were activated to varying degrees distal to the right and left canines. After midline establishment and space closure between the upper canines, teeth 13–23 were secured by a figure-of-eight ligature to prevent space developing. Subsequently, the upper premolars and molars were mesialized ‘tooth by tooth’. This was achieved by first applying open coils between the upper first and second premolars to mesialize the first premolars (Figure 1). After mesialization was complete, i.e. the space mesial to the first premolars was closed, they were integrated into the anterior group of teeth, again using a figure-of-eight ligature. Next, the second premolars and, lastly, the first molars were mesialized according to the same technique. This approach increasingly enlarged the anterior group of teeth as treatment progressed, while the position of the open coils shifted to the distal. During this phase, no direct force to the distal was applied to the anterior group of teeth. The initial amount of activation of the open coils varied due to the interbracket distance of between 1 and 3 mm (70–300 cN).

Only the upper second molars could not be mesialized with open coils because third molars were not available as abutments. Depending on the need for anchorage in the anterior group of teeth, this was achieved in various ways. If any residual overjet still existed in the final phase of space closure, making it possible to exert force on the anterior group of teeth, this was carried out using conventional Class I pull mechanics. If, in contrast, the overjet was still ‘normal’, then Class III elastics were used for mesialization of the second molars (Biggerstaff, 1992).

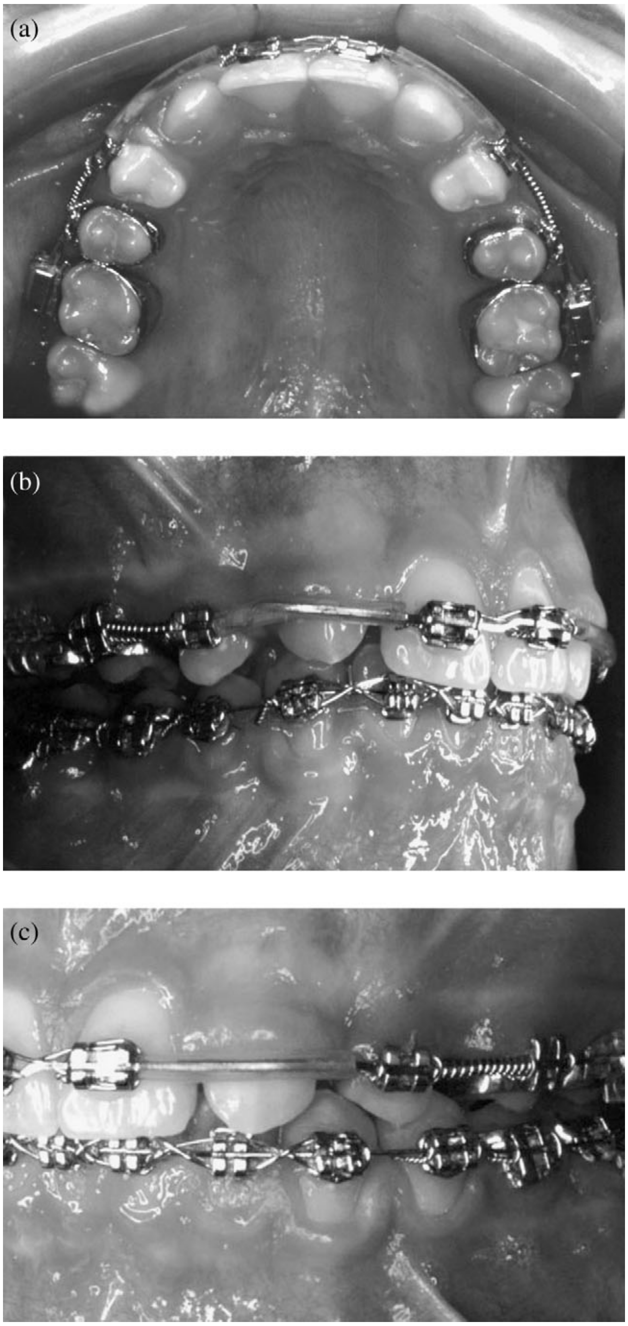

Figure 1 (a–c) Patient L.H.: open coils for mesialization of upper first premolars *in situ*. No conventional unimaxillary closing mechanics were used, thus avoiding any distalizing forces on the maxillary incisors.

Alongside the desired mesializing forces, the open coils used developed equally strong distalizing forces. The number of teeth distal to the open coils became less over the course of treatment. Therefore, particular attention had to be paid to the position of the posterior anchorage teeth. Since the targeted molar relationship at the end of treatment was 1 cusp width (cw) distal, molar positions approximating this relationship could be regarded as favourable during the space closing phases. Whenever open coils caused the upper molars to migrate to the distal creating a more neutral or even mesial relationship, or the molar relationship was neutral from the beginning, then the early use of Class III elastics was intended to prevent the upper molars from any further distalization or even to mesialize them. The mean duration of Class III elastic wear was 1.3 years (SD ± 0.6). Class I pull mechanics were avoided for as long as possible, unless there was a pronounced overjet which needed to be corrected by retrusion of the upper incisors. Ideally, the elastics were supposed to be worn 24 hours a day. Due to variations in distances between the points of application, a force range of 100–150 cN was determined.

Evaluation

The following variables were recorded to enable evaluation of the changes occurring during treatment: SNA, SNB, and ANB angle, Wits appraisal, molar relationship, overjet for the sagittal relationship, ML/NL, the inclinations of the occlusal plane (bisected occlusal planes, as defined by Downs, 1948) relative to NL and ML, and overbite for the vertical relationship. Other variables recorded were non-occlusion, crossbite, edge-to-edge bite, and midline shifts for the transversal relationship. Midlines were assessed according to the criteria common in orthodontics and prosthodontics (Miller *et al.*, 1979), namely, the midline of the philtrum to determine the maxillary middle, columella (if straight), labial fraenulum, its position to the incisive papilla and the palatine raphe, as well as its course (straight or deviated). The mandibular midline was assessed relative to the maxillary midline, as well as to the labial and lingual fraenula. Negative values were evaluated as a midline shift to the right and positive values as a shift to the left. Additionally, spatial balance in the upper and lower arch and incisor inclinations were determined according to two points in the maxilla (U1-NA and/or U1-NL) and in the mandible (L1-NB and/or L1-ML) (Table 1). Determination of overbite, overjet, midline deviations, and spatial balances was performed with the use of an electronic calliper (Jama, Leichlingen, Germany) with a precision of 0.1 mm.

All variables were determined by analyzing the casts and lateral headfilms and by clinical examination at baseline and end of treatment. To ascertain the changes occurring during treatment, the baseline variables were compared with the findings at the end of treatment. The measurements were taken either in millimetres or degrees of the angle. Only changes in the molar relationship were measured in cw, with a distal relationship being indicated by a negative and a mesial relationship by a positive sign. Accordingly, a Class II relationship of 1 cw equated with −1 and a Class III relationship of 1 cw to +1. As a result, a Class I relationship was the equivalent of a 0 position.

Statistical analysis

The error of the method was calculated by both authors performing two measurements on identical material (10

Table 1 Cephalometric values and model measurements [means and standard deviation (SD)] for the agenesis group.

Parameter	Pre-treatment		Post-treatment		Difference		*P*-value
	Mean	SD	Mean	SD	Mean	SD	
SNA (°)	79.9	2.9	78.3	2.9	−1.6	2.1	0.000*
SNB (°)	76.2	2.7	76.3	2.4	0.1	1.8	0.859
ANB (°)	3.7	2.6	2	2.3	−1.7	2.2	0.000*
Wits (mm)	3.1	2.8	3.1	2.1	0	2.7	0.988
ML-NL (°)	26.2	5.7	25.8	6	−0.4	2.7	0.475
OcP-NL (°)	10.6	4.3	7.4	3.7	−3.2	3.8	0.000*
OcP-ML (°)	15.6	4.3	18.4	4.7	2.8	2.9	0.000*
Upper midline (mm)	−0.2	0.6	0	0	0.2	0.6	0.224
Lower midline (mm)	0.1	0.9	−0.1	0.4	−0.2	1	0.282
Upper midline balance (mm)	6.8	2.9	0.1	0.4	−6.7	2.9	0.000*
Lower space balance (mm)	−0.5	2.5	−0.2	0.4	0.3	2.5	0.561
Overbite (mm)	2.9	2.1	1.8	0.5	−1.1	2	0.013*
Overjet (mm)	4.3	1.7	2.4	0.8	−1.9	2.1	0.000*
Molar relationship right (cw)	−0.6	0.4	−1.2	0.2	−0.6	0.3	0.000*
Molar relationship left (cw)	−0.5	0.4	−1.2	0.2	−0.7	0.4	0.000*
U1-NA (°)	22.1	9.8	23.5	4.5	1.4	4.5	0.477
U1-NL (°)	107.8	8.7	107.6	4.4	−0.2	8.8	0.883
L1-NB (°)	25.9	5.5	22.8	5.8	−3.1	6.7	0.023*
L1-ML (°)	97.2	6.6	95	8	−2.2	6.4	0.102

*$P < 0.05$.

cephalograms) independent of one another. The second researcher (NSS) was blinded to the aim and design of the study. The second series of measurements took place after an interval of 4 weeks. A *t*-test, conducted to determine if there was any systematic error (Houston, 1983), did not show any significant differences between the two measurements. Casual errors were calculated according to the formula of Dahlberg (1940) showing a mean variation of 0.2 degrees (SD 0.4) for angular and of 0.3 mm (SD 0.3) for linear measurements. The pre- and post-treatment findings and their changes were compiled as descriptive statistics by determining the means and SDs. The data were evaluated by means of a Kolmogorov–Smirnov test in order to check for normal distribution. The changes in the study variables were then subjected to a two-tailed test of the means by running a *t*-test for related data. A significant effect was assumed if the probability of error was equal to or less than 5 per cent.

Results

The following variables changed significantly ($P \leq 0.05$): SNA, ANB, OcP-NL, OcP-ML, upper space balance, overbite, overjet, molar relationship on both sides, and L1-NB. The changes in upper space balance, molar relationship, overjet, and overbite were all in line with the treatment objectives. There were no significant changes in SNB, Wits appraisal, ML-NL, upper and lower midlines, or lower space balance. Moreover, maxillary incisor inclination did not undergo any significant change regardless of whether it was measured as U1-NA or U1-NL. This also applied to mandibular incisor inclination, when measured according to L1-ML.

At the end of treatment, the following variables had nearly ideal values and/or were within 1 SD (Table 1): SNB, ANB, Wits appraisal, OcP-NL, OcP-ML, upper midline, lower midline, upper and lower space balance, overbite, overjet, U1-NA, U1-NL, L1-NB, and L1-ML. The final values for SNA and molar relationships on the right and left were not within normal range. Figure 2 shows a typical treatment outcome routinely achieved by PPM and Figure 3 demonstrates the alterations of skeletal and dental structures during the course of treatment.

Discussion

The present study collected data on patients with bilateral aplasia of the upper lateral incisors treated by isolated orthodontic space closure without mandibular extractions. Even though no patient selection took place before treatment, the final cephalometric values and model findings proved generally to be close to normal values and involved treatment-related changes that, for the major part, coincided with the targeted treatment objectives. Therefore, this uncommon approach to treat skeletally different patients identically over a long time with Class III elastics in order to achieve space closure in the upper arch does not lead to undesired changes in the great majority of dental and cephalometric parameters.

At the end of treatment, only three variables were above normal values (±1 SD): SNA and right and left molar relationship. It was not surprising that molar relationship was above normal values because the treatment objective was to close space in the maxilla by creating a bilateral distal molar relationship. What was not in agreement with

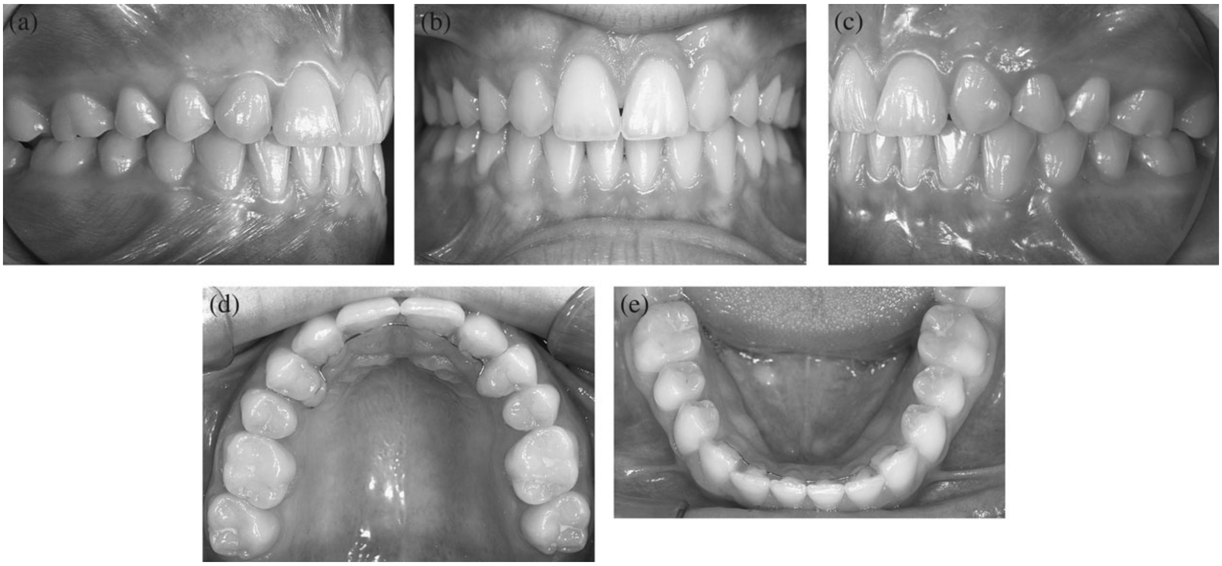

Figure 2 (a–e) Patient L.H.: typical intraoral situation after isolated space closure in situations with aplasia of upper lateral incisors using ‘push-and-pull’ mechanics.

the declared treatment objectives was the mean reduction in SNA of −1.6 degrees. This alteration is, however, unlikely to have been due to mechanic-related causes; firstly, because no mechanics were used that might have had a potential growth inhibiting effect on the maxilla, and, secondly, the upper incisor inclination was not reduced, confirming that stabilization of the maxillary anterior dentition was achieved. Hence, the observed effect might be explained by a growth deficit in the region of point A associated with dental agenesis. An alternative explanation might be that different growth-related changes took place in the anterior base of the skull in both groups which led to the corresponding positional changes in point N (Thilander *et al.*, 2005).

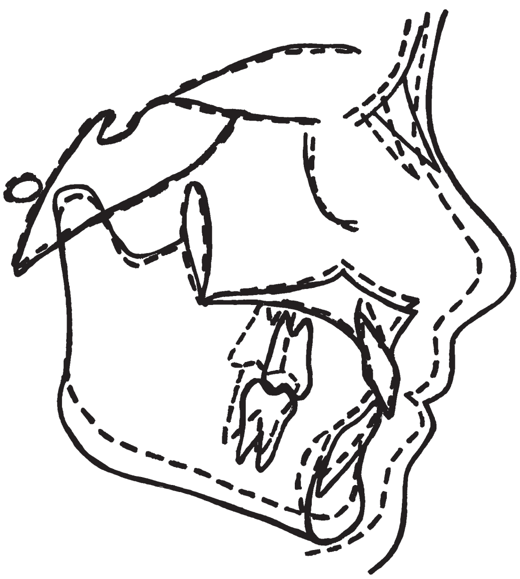

Figure 3 Patient L.H.: superimposition of pre- (dashed) and post-treatment continuous cephalometric tracings showing stability of the upper and lower incisors during orthodontic space closure.

A point of interest with regard to long-term use of Class III elastics is lower incisor inclination. Both, L1-NB and L1-ML, showed reductions but were close to the normal values at the end of treatment. Basically, reductions in the lower incisor inclination can be attributed to anterior rotation of the mandible and a reduction in MP–SN angle (Chung and Wong, 2002) that has been described as the result of the physiological growth processes (Tsai, 2003). However, the extent of the decrease in inclination of around 3.1 (L1-NB) and 2.2 (L1-ML) degrees on average in this study shows that the transposition of anchorage created by the Class III elastics to the lower arch probably did have an effect on the lower anterior dentition; however, this effect can also be deemed acceptable given that the mean inclination relative to NB of 22.8 degrees at the end of active treatment was only slightly less than the normal value of 24 degrees. Moreover, measurement of the mandibular incisors relative to the mandibular plane (L1-MP) showed a mean final angle of 95 degrees which was ideal. Changes of this magnitude should not have any adverse impact on aesthetic outcomes, as has been demonstrated after treatment with a variety of conventional mechanics (Saelens and De Smit, 1998).

In particular, the PPM used were able to guarantee stabilization of upper incisor inclination during treatment in practically an ideal way. To increase anchorage in the anterior dentition, Speck (2004) proposed open coils in conjunction with tip-edge mechanics. Zachrisson (1978) also used open coils to achieve partial space closure and to correct a midline shift in patients with missing upper incisors. Biggerstaff (1992) and Waldron (2004) used Class

III elastics for treating upper lateral incisor agenesis for ensuring anchorage in the anterior region. The combination of the two elements to avoid force application on groups of teeth requiring maximum anchorage has previously been proven to be the key to treating lower second premolar agenesis without extraction of contralateral teeth (Zimmer, 2006; Zimmer *et al.*, 2007). In contrast to conventional space closure mechanics that rely on unimaxillary elastics, coils, or loops, the use of PPM does not involve retrusion of the upper incisors (Hang, 2004), although the central incisors have a comparatively weak anchorage value compared with the dissimilar posterior groups of teeth intended for mesialization.

By controlling upper incisor inclination (mean alterations: U1-NA 1.4 degrees, U1-NL −0.2 degrees), it was possible to ideally adjust not only the overbite but also the overjet, irrespective of the baseline situation. The aim was to achieve a normal anterior relationship and complete space closure in the maxilla in patients with a variety of space conditions in the maxilla and mandible; therefore, the mean molar relationship had to be adjusted slightly more distally than 1 cw. In patients with otherwise ideal intercuspation in the incisor and premolar regions, this can largely be explained by a discrepancy in width between the somewhat narrower mesiobuccal cusp of the upper first molar and the second premolar.

Long-term wear of Class III elastics is always associated with the question concerning the consequences of these mechanics. The observation that the usual growth-related increase in SNB (Ochoa and Nanda, 2004) was not found in the present sample might suggest that the mechanics had inhibitory skeletal growth effects. However, the possible difference compared with untreated 'normals' (mixed male and female group) was less than 1 degree (Ochoa and Nanda, 2004), indicating that any influence on the development of point B can only be regarded as a trend. The assumption that Class III elastics had a rather minor effect on skeletal sagittal variables is supported by the observation that this study group proved to have similar, non-significant changes in Wits values. It should additionally be noted that causal interpretations of changes in both variables are fraught with uncertainty, given that changes in SNB (Hussels and Nanda, 1984; Pancherz and Sack, 1990) as well as Wits appraisal (Del Santo, 2006) can also be affected by morphological, non-treatment related factors.

In agreement with Jacobson *et al.* (1974), a flattening of the occlusal plane was found in the aplastic group after long-term wear of Class III elastics. However, it is unlikely that the significant changes in the inclination of the occlusal plane to NL and/or ML that caused a counter-clockwise rotation of the occlusal plane were mainly attributable to the effect of Class III elastics. This assumption is supported by Suzumura *et al.* (1989) who found a reduction in the SN occlusal plane angle after fixed appliance treatment and with Chang *et al.* (1993) who demonstrated that anterior rotation of the occlusal plane is a common growth effect in untreated subjects. Above all, the reduction in ML-NL contradicts the assumption that wearing of Class III elastics might lead to molar extrusion, and consequently to a downward rotation of the mandible and an anterior open bite. Since long-term wear of Class III elastics is virtually exclusively indicated for the treatment of Class III patients, validated evidence on their skeletal and dental effects is only available for this patient population. Notably, Ferro *et al.* (2003) observed good stability in overbite and overjet. In the light of the different skeletal situations at baseline and the various concomitant treatment objectives, their results cannot be unconditionally compared with those of the patient sample in the present study.

Conclusions

After treatment of upper lateral incisor agenesis by PPM without previous patient selection, nearly all relevant variables were normal at the end of treatment. Thus, the long-term use of Class III elastics, which is an essential part of PPM, had only minor dental and skeletal effects. Therefore, isolated orthodontic space closure for bilateral upper lateral incisor aplasia by PPM can be regarded as a valid alternative to prosthetic replacements. It has substantially broadened the spectrum of indications for orthodontic solutions in the correction of dental aplasia.

Address for correspondence

Dr Bernd Zimmer
Private Practice
Teichstrasse 24
34130 Kassel
Germany
E-mail: bzimmerkfo@aol.com

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