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Changes in clinical crown height as a result of transverse expansion of the maxilla in adults

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SUMMARY The risk of developing bony dehiscence and gingival recession may lead clinicians to prefer extraction to expansion in borderline cases. The purpose of this research was to compare changes in clinical crown height that occur at the buccal aspect of the maxillary lateral teeth of adult patients in which the transverse dimension was increased with those occurring if no expansion had been performed. Secondly it was the intention to identify factors increasing the risk of development of gingival recessions.

The material comprised the pre- and post-treatment study casts from two groups of 50 adult patients. In one group an average transverse expansion of 3 mm was performed while in the other no change in the arch width was generated during treatment. Clinical crown heights of the two groups before and after treatment were compared with a Student's *t*-test and correlation analysis was used to determine whether any demographic or treatment-related parameters could be applied to predict an increase in clinical crown height.

The increase in transarch width was greater in males (2.4–3.4 mm) than in females (1.8–2.5 mm), and greater at the level of the premolars than at the molars. No significant increase in buccal crown height could be identified. The increase in width was, however, related to buccal tipping as a positive correlation was found between the amount of expansion and tipping ($P < 0.01$). No detrimental effect of slow maxillary expansion could be demonstrated.

Introduction

The renewed interest in non-extraction treatment with expansion has resulted in widespread concern that expansion beyond certain limits would predispose to bony dehiscence and gingival recession. Especially in the case of non-growing patients, the feasibility of successful palatal expansion has been questioned by several authors (Bishara and Staley, 1987; Proffit, 1993; Vanarsdall, 1994). The increased complexity of the midpalatal suture and the increased rigidity of the adjacent facial sutures, observed with ageing, do not allow for widening of the maxillary complex (Melsen, 1975; Persson and Thilander, 1977). Vanarsdall (1994) also supported the belief that adult palatal expansion was not feasible. In addition it has been stated that expansion of the buccal segments with fixed appliances has limitations and will tend to be unstable, regressing towards pre-treatment widths (Riedel and Brandt, 1976). Orthopaedic expansion of the palate with the use of intra-osseous indicators has been studied in humans (Krebs, 1964; Skieller, 1964; Cotton, 1978; Hicks, 1978) making it possible to differentiate between orthopaedic and orthodontic effects. Their studies confirmed that in adolescents only approximately one-third of movement was skeletal and 65 per cent dental. Following active expansion, separation of the implants that reflected opening of the midpalatal suture was reversed, indicating that the teeth were now being displaced within the maxilla. Vanarsdall (1994) was also of the opinion that the proportion of tooth movement to skeletal change increased with age and more dental tipping is generated with a higher risk for gingival recession. This is in agreement with Northway and Meade (1997) who found that less tooth movement and greater orthopaedic changes in the transverse dimension can be obtained by means of surgically assisted expansion, which for this reason, has to be recommended in subjects with maxillary deficiency and with a tendency for gingival recession. Carmen *et al.* (2000), on the other hand, found more periodontal damage following surgically assisted expansion than in patients who had had only orthodontic expansion. Periodontal damage to the central incisors following surgically assisted expansion was further demonstrated by Cureton and Cuenin (1999). Finally, Handelman (1996, 1997) and Handelman *et al.* (2000) found no statistically significant differences between pre- and post-treatment crown height in a group of adult patients who were treated with a Haas tooth- and tissue-borne palatal expander and a control group of patients who did not undergo rapid palatal expansion.

Based on the literature, no conclusion can thus be drawn regarding the iatrogenic effect of transverse expansion on the periodontium. As expansion is frequently the only alternative to extraction, it was therefore decided to:

1 evaluate the change in clinical crown height occurring at the buccal aspect of the maxillary first and second

premolars and first molar of adult patients in which transverse expansion was part of orthodontic treatment compared with changes if no expansion had been carried out;
2 assess the correlation between gingival recession and the amount of transverse expansion in adult patients;
3 evaluate whether there was any correlation between the degree of tipping and the amount of transverse expansion in adult patients;
4 evaluate whether age had a significant influence on the changes occurring.

Subjects and methods

The study was performed retrospectively on records from a series of patients treated at the Department of Orthodontics, University of Aarhus. The study group fulfilled the following criteria:

1 aged between 18 and 50 years;
2 treated with full fixed appliances in combination with transverse expansion performed by lingual arches or quadhelices as a solution for crowding;
3 absence of craniofacial anomalies, such as cleft lip and palate;
4 absence of orthognathic surgical intervention;
5 dental casts of good quality available before and after treatment.

The control group fulfilled the same criteria but had no change in the transverse dimension.

The number of patients to be included was determined by a power calculation on the basis of the following assumptions: a two-sided significance level of 0.05 (2α) to be used and a power of the test of 0.80 per cent ($1 - \beta$) required against a mean increase in recession following treatment of 0.5 mm (δ). From a study by Handelman *et al.* (2000), the accompanying standard deviation was estimated to be 0.89 mm. The minimum number of subjects required in each group was thus found to be (Armitage and Berry, 1995):

$$n = 2 \times \sigma^2 \times f(\alpha, \beta)/(\mu_1 - \mu_2) = 49.4,$$

i.e. 50 subjects for each group.

The pre- and post-treatment study casts from a total of 100 patients, 50 females and 50 males, with a mean age of 29.6 and 30.5 years, respectively, were included in the study.

The total sample comprised (Table 1):

1. The expansion or study group included 50 subjects, 25 females and 25 males, who had undergone transverse expansion for the resolution of crowding;
2. The non-expansion or control group included 50 subjects, 25 females and 25 males, who were treated without a significant increase in the transverse dimension.

Table 1 Sex and age distribution of all subjects in the study and control groups.

Group	Gender	Number	Age (years)		
			Mean	SD	Range
Study	Male	25	28.7	8.26	18.0–44.9
	Female	25	30.2	9.1	18.6–47.0
Control	Male	25	30.7	7.4	20.0–44.8
	Female	25	30.6	7.9	18.3–47.5

SD, standard deviation.

Method

All measurements were performed on the study casts with a Polhemus 3Space/3Draw three-dimensional digitizer system (Polhemus, Colchester, Vermont, USA). For each reference point, three co-ordinates (X, Y, Z) were stored in the computer connected to the digitizer. The parameters studied were calculated from these co-ordinates using a software program written in Turbo Pascal (Borland, Scotts Valley, California, USA) and included linear measurements of the maxillary width and the clinical crown height buccally, and angular measurements of the interpremolar and molar inclination.

The width of the maxillary arch at the first premolar level was calculated as the distance between the geometric centres of the crowns of the two first premolars. The same procedure was applied for estimation of the width of the maxillary arch corresponding to the second premolar and at the first permanent molar (Figure 1a). The clinical crown height was measured on the buccal side as the distance between the buccal cusp tip and the most apical point of the gingival margin (Figure 1b).

The interpremolar and intermolar angulation was calculated as:

$$\theta = \sin^{-1} \{(a - b)/(c + d)\},$$

where a = the distance between the left and right geometric midpoints of the buccal and palatal deepest points on the gingival margin; b = the distance between the left and right geometric midpoints of the buccal and palatal cusp tips; c = the distance between the left geometric midpoint of the buccal and palatal cusp tips and the geometric midpoints of the buccal and palatal deepest points on the gingival margin; d = the distance between the right geometric midpoint of the buccal and palatal cusp tips and the geometric midpoints of the buccal and palatal deepest points on the gingival

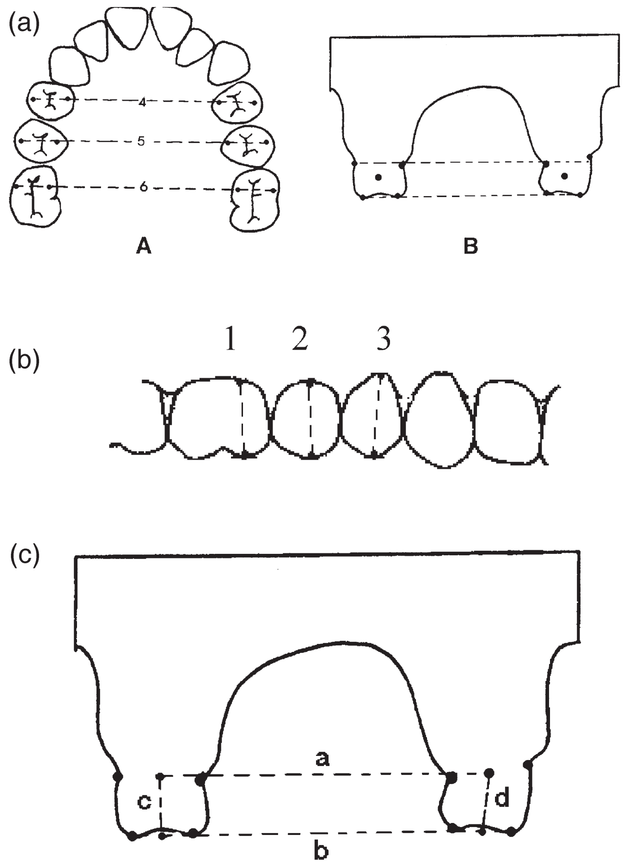

Figure 1 Definition of (a) the width of the maxillary arch in the transverse plane, (b) crown height and (c) tipping angle, averaged for left and right teeth. The reference points used for (a), (b) and (c) were the midpoints between the cusp tips and the most marginal point of the buccal surface and for (c) cusp tips and the most marginal point of the lingual surface.

margin. With this definition, a single angle was calculated, expressing on average bilateral tipping (Figure 1c).

The changes in each of these parameters occurring during treatment were calculated as the difference in the value assessed on the study casts before and after treatment.

Statistics

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) and comprised a descriptive and an analytical part. The statistical description of the parameters included mean, standard deviation and range. A comparison of the two groups before and after treatment was undertaken with a Student's *t*-test. The changes occurring during treatment within the study and the control groups were evaluated with a paired *t*-test.

Linear regression analysis was performed in order to evaluate the role of age and the amount of expansion in the generation of a gingival recession.

Measurement error

The error of the method was determined by performing double measurements on 12 sets of casts with an interval of 3–4 weeks. The error of the method ($S(i)$) was calculated according to $S(i) = \sqrt{(\Sigma d^2/2n)}$, with d being the difference between the first and second measurements and n the number of double measurements (Table 2).

Results

The pre-treatment measurements revealed that the arch width of the study group was narrower than the control group in the premolar region for both males and females. The groups on the other hand did not differ with respect to arch width in the molar region. The study and control groups were likewise comparable with respect to crown height, age and sex distribution (Table 3).

When evaluating the effect of treatment on the transverse dimension of the maxillary arch, it could be confirmed that a significant increase in width had occurred during treatment in the experimental group, whereas no significant changes were observed in the control group (Table 3). The expansion was most pronounced anteriorly at the level of the first premolars and least corresponding to the first molars. When evaluating expansion in the two genders separately, there was a larger mean expansion for male patients than females. In males, the average expansion ranged from 3.4 mm measured at the level of the first premolars to 2.4 mm at the level of the first molars. The corresponding values for females were 2.5 and 1.8 mm, respectively (Figure 2a, Table 3).

A change in crown height as a result of treatment could not be verified in either of the two groups. No statistically significant difference at the level of the premolars and first molars was found between the study and control groups, with the exception of the first molars in females This difference was, however, too small to be clinically relevant (Figure 2b, Table 4).

The change in buccolingual inclination was reflected in the angulation between the corresponding teeth on the right and left sides. A statistically significant change

Table 2 Error of the method $S(i)$ and standard deviations (SD) for 12 pairs of teeth in which crown height, transpalatal width and angulation were measured twice.

	$S(i)$	SD
Crown height left (mm)	0.48	0.77
Crown height right (mm)	0.25	0.92
Transpalatal width (mm)	0.70	2.00
Angulation (degree)	2.59	5.03

The standard deviations were calculated on the first series of measurements.

Table 3 The initial value and the amount of change in transpalatal width in the study and control groups and separately for males and females.

Group	Gender	Tooth	Initial width (mm)			Change in width (mm)		
			Mean	SD	Range	Mean	SD	Range
Study	Male	First premolar	34.2	2.3	29.4–38.2	3.4*	1.8	1.2–8.2
		Second premolar	37.0	2.8	34.4–44.4	2.8*	1.3	1.0–6.1
		First molar	44.1	2.5	39.8–48.5	2.4*	1.3	1.0–6.6
	Female	First premolar	32.5	2.8	26.3–36.8	2.5*	1.0	1.0–5.0
		Second premolar	37.0	3.9	29.9–43.8	2.2*	1.0	1.0–4.5
		First molar	41.6	4.1	32.9–48.2	1.8*	0.8	1.0–3.6
Control	Male	First premolar	37.6	2.0	33.6–40.9	–0.2	1.6	–4.3–1.0
		Second premolar	40.7	2.6	35.9–44.9	–0.3	0.6	–1.7–0.8
		First molar	44.2	4.6	27.2–51.9	–0.2	0.7	–2.1–1.0
	Female	First premolar	36.2	2.3	32.2–41.7	0.0	1.2	–3.6–1.0
		Second premolar	40.1	2.8	34.2–45.6	0.0	0.9	–2.4–1.0
		First molar	43.8	3.9	29.7–49.4	–0.5	1.2	–4.2–1.0

SD, standard deviation.
*Statistically significant difference at $P < 0.05$ between the groups.

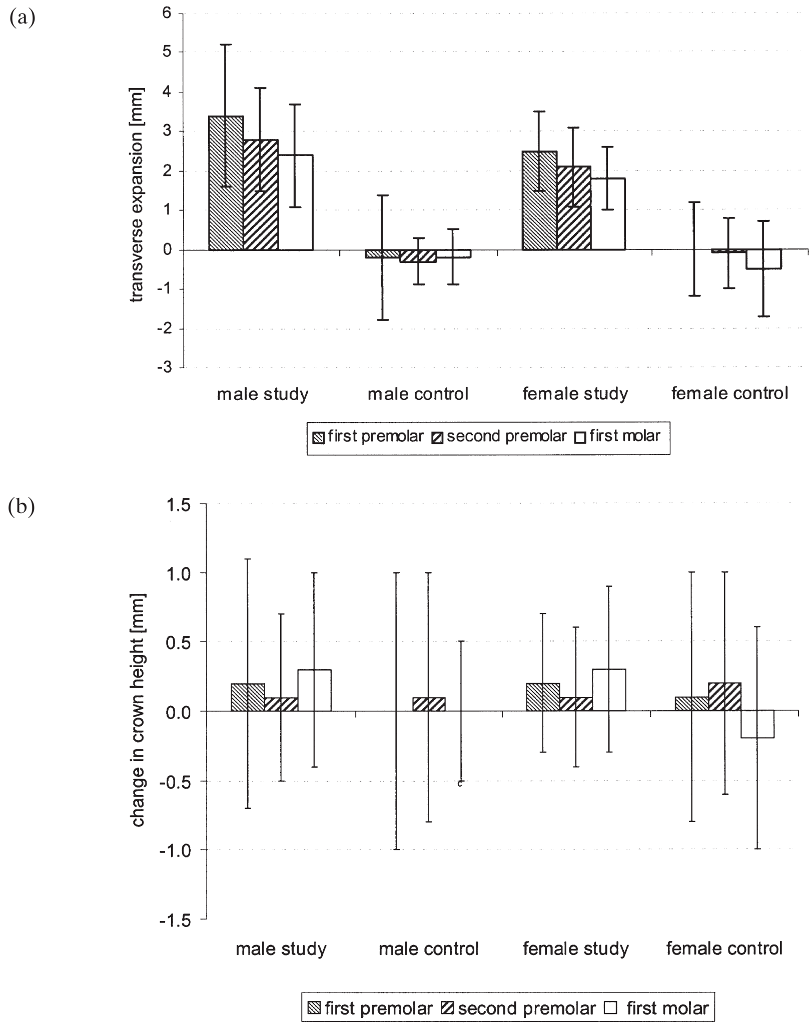

Figure 2 Bar charts of the mean and standard deviations of (a) the amount of transverse expansion and (b) the change in crown height for the first and second premolars and the first molars in the study and control groups, and separately for males and females.

Table 4 The initial value and the change in crown height in the study and control groups and separately for males and females.

Group	Gender	Tooth	Initial crown height (mm)			Change in crown height (mm)		
			Mean	SD	Range	Mean	SD	Range
Study	Male	First premolar	8.3	0.9	6.8 – 10.5	0.2	0.9	–1.6 – 3.2
		Second premolar	7.3	1.1	5.4 – 9.9	0.2	0.6	–1.2 – 1.6
		First molar	7.1	1.1	5.6 – 9.6	0.3	0.7	–1.0 – 1.7
	Female	First premolar	7.7	1.0	6.1 – 10.5	0.1	0.5	–0.6 – 1.1
		Second premolar	6.9	1.1	5.2 – 8.7	0.0	0.5	–0.7 – 1.1
		First molar	6.5	1.3	3.6 – 9.1	0.2*	0.6	–0.9 – 1.2
Control	Male	First premolar	7.8	1.3	5.7 – 10.6	0.0	1.0	–3.0 – 1.5
		Second premolar	7.4	1.2	5.2 – 10.3	0.1	0.9	–2.6 – 1.9
		First molar	7.1	1.4	5.2 – 11.7	0.0	0.5	–1.1 – 1.2
	Female	First premolar	8.0	1.0	5.6 – 10.0	0.1	0.9	–1.5 – 2.7
		Second premolar	7.1	0.9	5.2 – 9.2	0.2	0.8	–1.2 – 2.7
		First molar	6.9	1.1	4.9 – 8.6	–0.2	0.8	–2.6 – 1.0

SD, standard deviation.
*Statistically significant difference at $P < 0.05$ between the groups.

Table 5 The initial value and the change in inclination of the teeth in the study and control groups.

Group	Gender	Tooth	Initial inclination (degrees)			Change in inclination (degrees)		
			Mean	SD	Range	Mean	SD	Range
Study	Male	First premolar	–5.8	5.2	–19.6 – 4.1	7.4*	4.6	0.4 – 19.2
		Second premolar	2.4	6.4	–14.1 – 16.7	5.2*	5.5	–9.8 – 12.4
		First molar	8.8	7.6	–18.1 – 24.1	3.4*	6.5	–11.3 – 26.7
	Female	First premolar	–7.3	5.5	–20.2 – 5.0	6.8*	3.0	2.2 – 13.9
		Second premolar	–0.1	7.3	–10.3 – 19.3	6.9*	4.9	–2.5 – 14.1
		First molar	8.8	5.9	0.1 – 21.7	1.3	3.9	–8.0 – 10.1
Control	Male	First premolar	–1.9	4.9	–9.4 – 6.8	1.1	4.1	–8.0 – 8.0
		Second premolar	4.9	4.9	–5.5 – 13.0	0.2	8.8	–30.2 – 19.0
		First molar	11.1	5.1	–4.5 – 17.6	–0.7	5.9	–8.5 – 20.1
	Female	First premolar	–3.4	5.1	–14.3 – 8.8	0.8	4.0	–7.9 – 5.9
		Second premolar	1.9	7.1	–9.8 – 17.0	1.9	5.7	–8.0 – 16.1
		First molar	10.9	5.6	1.2 – 20.9	–0.3	4.5	–6.9 – 10.1

SD, standard deviation.
*Statistically significant difference at $P < 0.05$ between the groups.

in the inclination of the premolars and first molars was found in the study group, where more buccal tipping had occurred, whereas no significant change could be verified in the control group (Table 5).

The interpremolar angle at the level of the first premolars changed on average 7.4 degrees in males and 6.8 degrees in females, at the level of the second premolars it was 5.2 degrees in males and 6.9 degrees in females and 3.4 degrees in males and 1.3 degrees in females between the first molars.

The relationships between the changes in crown height, inclination, age, gender and amount of expansion were evaluated by means of linear regression analysis. Only non-significant correlations were found for the change in both crown height and tipping, when age was used as the independent variable (Table 6). However, when with amount of expansion was used as the independent variable, correlations were generally stronger (Table 7). The change in crown height was significantly correlated to the amount of expansion for the first premolars in females. The magnitude of the correlation coefficients indicated that at the most 25 per cent of the changes in crown height could be attributed to changes in the amount of expansion. Furthermore, statistically significant correlations were found between the amount of expansion and tipping of all teeth with the only exception being the second premolars and first molars in females (Table 7).

Table 6 Correlation coefficients between age, as the independent variable, and the treatment-related parameters.

	Tooth	Male	Female
Crown height	First premolar	0.17	0.14
	Second premolar	0.10	0.02
	First molar	0.10	0.19
Tipping	First premolar	0.28	0.37
	Second premolar	0.09	0.12
	First molar	0.12	0.12

Table 7 Correlation coefficients between the amount of change in transpalatal width, as the independent variable, and the treatment-related parameters.

	Tooth	Male	Female
Crown height	First premolar	0.16	0.49*
	Second premolar	0.07	0.05
	First molar	0.40	0.31
Tipping	First premolar	0.47*	0.54*
	Second premolar	0.40*	0.08
	First molar	0.43*	0.02

*Significant at $P < 0.05$.

Discussion

The results of the present study did not demonstrate any relationship between the development of gingival recession and the amount of transverse expansion in adults. The mean increase in crown height in the study group was 0.16 mm compared with 0.03 mm in the control group. The changes in clinical crown height during treatment did not differ statistically between the study and control groups, with the exception of the first molars in females; this difference was, however, less than 0.5 mm and thus not clinically relevant.

The two groups did not differ with respect to age, gender or crown height at the start of treatment. The method could be considered valid as its error was smaller than the standard deviation of the measured variables. The lack of difference in the change in crown height between the two groups could, therefore, neither be ascribed to the sample studied nor to the method applied.

It could be argued that the expansion performed was small compared with that of Vanarsdall and Herberger (1987), who expanded on average 8.5 mm. The results, on the other hand, corroborate those of Greenbaum and Zachrisson (1982) and Handelman (1996), both of whom reported expansions similar to those in the present study. The lack of correlation between the amount of expansion and the increase in crown height indicates that gingival health also plays a role. This has already been pointed out by others (Wennström, 1987, 1996; Wennström *et al.*, 1987; Kallestal and Matsson, 1990; Serino *et al.*, 1994). The subjects in the present investigation were all part of the general hygiene programme run for the patients in the graduate programme.

When choosing the method for this investigation it was assumed that the occurrence of gingival recessions would cause an increase in crown height that could be measured on the study casts taken before and after treatment. An increased crown height reflects a loss of buccal periodontal attachment. Crown height measurements can be considered an indirect method of estimation of gingival recession, but they are also subject to inaccuracies, as they are influenced by both attrition of the crown and gingival hyperplasia. Moreover, it does not consider pocket depth; it is possible, in fact, for the gingival tissue to be intact, while masking an underlying bone dehiscence detectable only on clinical examination (Karring *et al.*, 1982). The indirect method, applied in the present investigation, has, nevertheless, been used in similar studies (Vanarsdall and Herberger, 1987; Northway and Meade, 1997; Handelman *et al.*, 2000). Greenbaum and Zachrisson (1982), on the other hand, used different criteria. They examined the levels of periodontal supporting structures located at the buccal aspects of the maxillary first molar directly in the oral cavity, using four periodontal parameters, including the level of marginal alveolar bone, attachment levels (from the cemento-enamel junction), probing depths, and the width of keratinized gingiva. As this requires a clinical examination of the patients, it cannot be carried out in a retrospective study. In addition, the clinical examination would also be flawed by the day-to-day variability of the health status of the periodontium. In order to minimize the potential error represented by the presence of attrition of the crown, the width of the maxillary arch at the first premolar level was calculated as the distance between the geometric centres of the crowns of the two first premolars. In the same way the width of the maxillary arch at the second premolar and at the first permanent molar levels was calculated. The actual measuring technique used in the present study was different from previous investigations. Greenbaum and Zachrisson (1982) used a fine tipped divider and measured the distance between the edges of the lingual gingival margin at the distolingual groove of both maxillary molars. Handelman (1997) and Handelman *et al.* (2000) recorded the internal width of the maxilla by measuring the distance between the cervical margins of the crown at its greatest convexity at the level of the premolars and, when measuring at the level of the molars, used a point on the cervical margin adjacent to the lingual groove of the molars. Northway and Meade (1997) registered the mean of the intermolar distances between the mesiolingual cusp tips of the canines and premolars and the distance between the buccal grooves of the first molars with a dial calliper, while Vanarsdall (1987) measured the maxillary dental arch width with an electronic digital calliper between the tip of the cusps at the level of the canine, the tip of the buccal cusps at the level of the first and second premolars, and the central fossa of the first molar. Compared with the methods of the above-mentioned authors, the method used in the present study has a high reproducibility. The parameters were the result of three-dimensional digitizing and not a reading of a one-dimensional parameter, which can in theory be taken with a change in orientation, which may influence the result.

Compared with previous studies, the method used for the estimation of crown tipping was also different. Crown tipping was calculated as the difference between the intersection of the long axis with a line connecting the buccal and lingual tips and a line connecting the buccal and lingual gingival points (Figure 1). In this way the calculation of the crown in tipping was less dependent on the morphology of the crown tips. In fact, the introduction of gingival points allowed the determination of the long axes of the crowns. The influence of changes occurring at the level of the crown tips was thus minimized. The use of a digitized system, moreover, ensured the total avoidance of errors due to manual measurements (Solow, 1966).

When evaluating the results of the present investigation, several factors may flaw the conclusions, which differ from those of other studies. The sample size was not very large, but it can be excluded that the lack of significant differences was due to too small a sample size, as the power calculation showed that 50 patients was a number which ensured reliable statistical analysis. Other investigations (Greenbaum and Zachrisson, 1982; Vanarsdall, 1987; Handelman, 1997; Handelman *et al.*, 2000) which focused on the same problem, did not justify the size of their sample which, compared with the present one, seemed to be less homogeneously distributed according to age, sex and size.

Most of the studies cited in the introduction focused on rapid expansion (Haas, 1970). In answering the question regarding the possibility of widening the maxillary arch in adult patients without generating iatrogenic damage, the method used for expansion is less relevant, as the main issue is to generate space. The type of palatal expansion performed in this study was a slow type (Cotton, 1978; Hicks, 1978). The appliances used were quadhelices or transpalatal arches with long arms, in combination with cantilevers in full fixed appliance treatment. The three-dimensional control was, however, only partially successful as mild tipping took place. This was, on the other hand, comparable with tipping found by Handelman *et al.* (2000). It was not possible to evaluate the influence of treatment time as graduate students treated the patients and their course and vacation schedule may have prolonged treatment. The average treatment time of adult patients was 24 months, ranging from 15 to 30 months.

Conclusion

In borderline cases, moderate transverse expansion of 1–5 mm is an acceptable alternative to extractions to solve space problems, even in adults. This conclusion is, however, only valid if the expansion is carried out under three-dimensional control while maintaining a healthy periodontal status.

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