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Effectiveness of treatment of adult patients with the straightwire technique and the lingual two-dimensional appliance

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SUMMARY The aim of this prospective study was to compare the outcome of orthodontic therapy using two different therapeutic strategies: the labial straightwire (SW) technique and the lingual two-dimensional (2D) technique on the lower dental arch.

The sample included 50 subjects (39 females and 11 males) with a complete dentition and an Angle Class I malocclusion with crowding who were treated non-extraction. The subjects were divided into two groups: group A, consisted of 25 patients (19 females and 6 males), who were treated with the lingual 2D technique, and group B, 25 patients (20 females and 5 males) treated using the labial SW appliance (Roth system). Changes in the position of the lower incisors to the A–Po and mandibular lines were measured on cephalograms and those in the transverse and sagittal planes on individual sectors of the dental arch from 2D images of model casts obtained before and after the active phase of orthodontic treatment. Standard statistical methods were used for evaluation.

Both methods (when used with appropriate indications) showed comparable results. The lingual 2D technique also represents an aesthetically favourable solution for adult patients.

Introduction

Over the last 15 years, there has been renewed interest in lingual orthodontics (Scuzzo and Takemoto, 2003), due to the fact that the demographics of patients have changed. While orthodontics used to focus almost exclusively on children and adolescents (White, 1997), today, it is older people who seek orthodontic treatment, resulting in the development of new treatment methods. Therapy should be aesthetic, brief, and comfortable (Shaw *et al.*, 1985). New technologies make possible the production of small lingual brackets and new adhesive systems (Hohoff *et al.*, 2003). Therapeutic techniques are more accurate as a result of computer-based technology and modern rigid transfer systems. However, problems still persist and many practitioners are reluctant to use the lingual technique (Macchi *et al.*, 1989; Ling, 2005). One problem is related to orthodontic forces on the variable lingual surfaces of the teeth (Geron *et al.*, 2004).

The lingual technique is relatively complicated due to the manufacture of appliances, set-up, bonding, or repeated bonding of loose brackets; check-ups are time consuming (Miyawaki *et al.*, 1999) and the cost of the appliance is high. Simple lingual two-dimensional (2D) appliances can be an alternative—they do not require set-ups (Nidoli *et al.*, 1984), are not as time consuming, and the cost is comparable with that of labial appliances.

Fixed appliance therapy, be it lingual or labial, has some restrictions, e.g. demands on hygiene in order to prevent plaque and the development of carious lesions, and the avoidance of very hard, too sweet, or sticky food. Other discomforts include worsened pronunciation, etc. (Caniklioglu and Öztürk, 2005).

Lingual 2D brackets have a flat profile and are self-ligating. There is no slot in the base of the brackets [unlike the straightwire (SW) technique] and thus can influence inclination, extrusion, and intrusion of teeth. Without other elements, torque movement is not possible, and thus, they are used only in the treatment of selected cases. The placement of lingual 2D appliances on the lingual surface of teeth may have some advantages for adult patients: they meet aesthetic demands and the brackets, due to the flat profile, are very comfortable (Macchi *et al.*, 2004). Moreover, the substantial protective function of saliva on the lingual surface of the teeth means that the risk of caries is reduced.

To assess changes caused by lingual or labial appliances, cephalometric analysis may be used. The positions of the lower incisors to the A–Po and mandibular lines are important for treatment planning and for stability of the results

(Kamínek, 1976). To achieve a stable result, movement of the lower incisors to the A–Po line should not exceed ±2 mm from the original position (Proffit and Fields, 2000; Scuzzo and Takemoto, 2003).

The dental arch is, for each subject, individual (Goldstein, 1965) and for successful treatment and a stable outcome, the original shape of the dental arch must be respected. This may be achieved through selection of an appropriate arch shape.

Gardner and Chaconas (1976) monitored a set of orthodontic patients for 5 years following retention and found that most relapse (58 per cent) was as a result of widening in the area of the lower incisors, the first lower premolars (14 per cent), and in the second premolars, i.e. a narrowed dental arch (31 per cent). However, the molar area showed a stable 2 mm increase in width, which did not change following completion of the retention phase.

Little *et al.* (1981, 1988) and Little (1999), in an observational study of patients for more than 10 years following the retention phase, concluded that stability is variable in the area of the lower incisors and cannot be predicted before the start of therapy. Observations were made using various measurements, i.e. crowding in the area of the incisors. The cited articles and other studies indicate that the treated dental arch tends to regain its original shape (Felton *et al.*, 1987; BeGole *et al.*, 1998; Davis and BeGole, 1998; Noroozi *et al.*, 2001). Therefore, this should be respected when planning therapy and changes in the dental arch due to the treatment kept to a minimum.

It was the aim of this study to compare and evaluate changes in the lower dental arch following orthodontic therapy using either the SW or the lingual 2D technique.

Subjects and methods

Ethical approval was obtained from the Ethics Committee of the 2nd Medical School of Charles University Prague at the Motol Faculty Hospital.

The study was conducted on a sample of 50 patients who had completed dental growth, in order to exclude any possible change in the lower dental arch. Only patients with an Angle Class I malocclusion with crowding were included. All patients were treated non-extraction and appliances such as the Herbst, Jasper Jumper, or Sabbagh Universal Springs were not used as these could contribute to a change in position of the lower incisors and other measured values.

The patients were divided into two equal-sized groups according to the aesthetic demands of treatment. Group A comprised 25 patients (19 females and 6 males; aged 18–54 years), who were treated using the lingual 2D appliance (duration of therapy 5–28 months) and group B included 25 patients (20 females and 5 males; aged 19–46 years) treated with the labial SW appliance (duration of therapy 7–39 months).

For group A, 2D brackets (Forestadent, St Louis, Missouri, USA) were used, together with NiTi 0.012, 0.014, and 0.016 inch prefabricated arches. A 0.016 inch steel arch was produced for finishing adjustments in tooth position. For group B, Minitrim brackets according to Roth (Dentaurum, Ispringen, Germany) were used with arch sequences of 0.012, 0.016, and 0.017 × 0.025 inches. A 0.016 × 0.022 inch steel wire arch was used for finishing adjustments.

During the initial examination, photographs were taken of the patients both profile and *en face*, together with a cephalogram and plaster casts.

Model measurements

Casts were made for each patient before and after active therapy. The images of the models were captured using a black and white camera with a FireWire interface at a resolution of 1024 × 768 pixels. A Tamron 23FM12 lens (Saitama, Japan) with a focal length of 12 mm was used. Points of interest were marked manually and their 2D image were measured with ImageJ (freeware program: http://rsbweb.nih.gov/ij/) and Matlab (http://www.mathworks.com/products/mat) to avoid errors due to repeated measurement of casts. Parameters that may be affected by orthodontic therapy were measured to determine any changes which may explain the biomechanics of lingual appliances. The dental points measured were: the centre of the lower dental arch in the area of the lower incisors (point A), the tip of the lower canine, buccal cusp of the lower first premolar, mesiobuccal cusp of the lower first molar, centre of the intercanine distance (point B), the centre of the interpremolar distance, and the centre of the intermolar distance (point C).

The measured parameters were: intercanine distance, interpremolar distance, intermolar distance, the distance between points A and B, and the distance between points A and C.

Changes due to orthodontic treatment were evaluated in the areas of the first molars, first premolars, and canines. The position of the lower incisors was also determined. The treatment plan was designed to ensure minimal movement of the lower incisors.

To assess whether the changes in the area of the lower incisors were similar when using the lingual 2D and SW appliances, the distance of the middle of the dental arch in the area of lower incisors (A) to the middle of a line connecting the lower canines (B) and to the middle of a connecting line of the lower first molars (C) was determined. The findings could indicate whether the length of dental arch was changed due only to movement of the lower incisors or whether there were any changes also in the buccal segments of the dental arch. The distance evaluated was BC–B′C′ (Figure 1).

The change in width of the lower dental arch was set as the difference in intercanine distance, interpremolar, and intermolar distances. Observation prior to and after the active phase of therapy gives the change in the width of the dental arch (Figure 2).

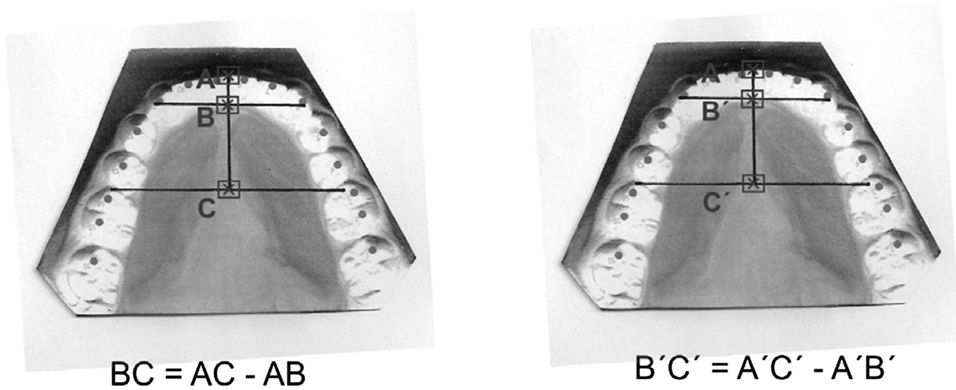

Figure 1 Measurement of the change in the length of the dental arch before (A, B, and C) and after (A′, B′, and C′) treatment: point A, A′—centre of the lower dental arch in the area of the lower incisors; point B, B′—centre of intercanine distance; and point C, C′—centre of intermolar distance.

Measurement of cephalometric values

Cephalograms were obtained for all patients before and after the active treatment phase using the same cephalostat (Planmeca, Helsinki, Finland). The following points: pogonion (Po), sella (S), gnathion (Gn), and points A, C, and C′ and the following planes: ML, A–Po line, and C–B, C′–B were used

The following values were measured pre- (T1) and post- (T2) treatment:

1. The position of the lower incisor to the A–Po and mandibular lines (Figure 3),
2. The position of the lower incisor apex. For this measurement, points C and B were constructed. Point B was set as the point of intersection of the connecting line between A–Po point and M–L and point C as the intersection of the lower incisor axis and the ML (Figure 4).

All values were then compared, and movement of the lower incisor through the action of forces of the lingual or labial bracket was evaluated. The following possible combinations were determined (Figure 5): the incisal edge of the lower incisor moves buccally and the apex of the lower incisor moves distally resulting in inclination of the tooth; the incisal edge of the lower incisor moves distally and the apex of the lower incisor moves labially resulting in inclination of the tooth (Figure 5). The incisal edge and lower incisor apex are shifted in the same direction (distal or buccal), resulting in bodily tooth movement.

To determine the error of the method, the radiographs were manually measured twice with a 1 month interval. Wilcoxon's test showed no statistically significant measurement errors.

Statistical evaluation

'R' software version 2.9.2 (freeware: http://www.r-project.org by R Development Core Team, 2009) was used for statistical evaluation of the data. The arithmetic mean of the measured parameters at T1 and T2 and the differences between them were summarized for each method separately with statistical parameters such as median and interquartile deviations. A two-sample Wilcoxon test was then used to compare the two methods. Non-parametric tests and the related summary statistics were chosen with regard to the distribution pattern of the observed symptoms/data. Significance was set at 5 per cent.

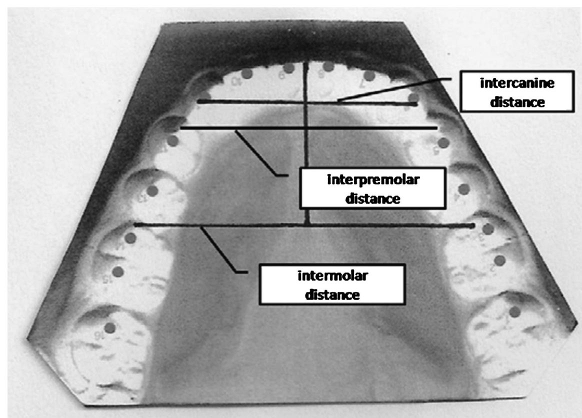

Figure 2 Measurement of distance on the study casts.

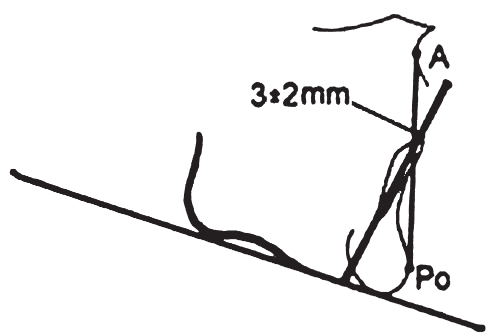

Figure 3 Position of the lower incisors relative to the mandibular line.

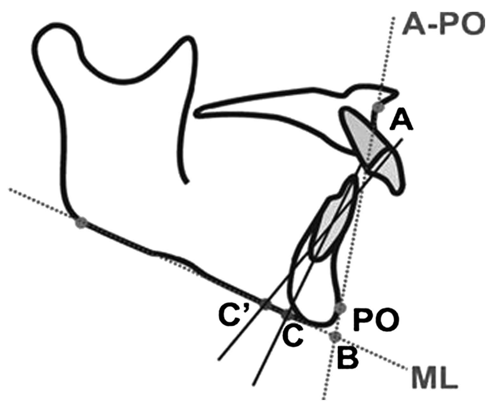

Figure 4 Construction of points C and C′.

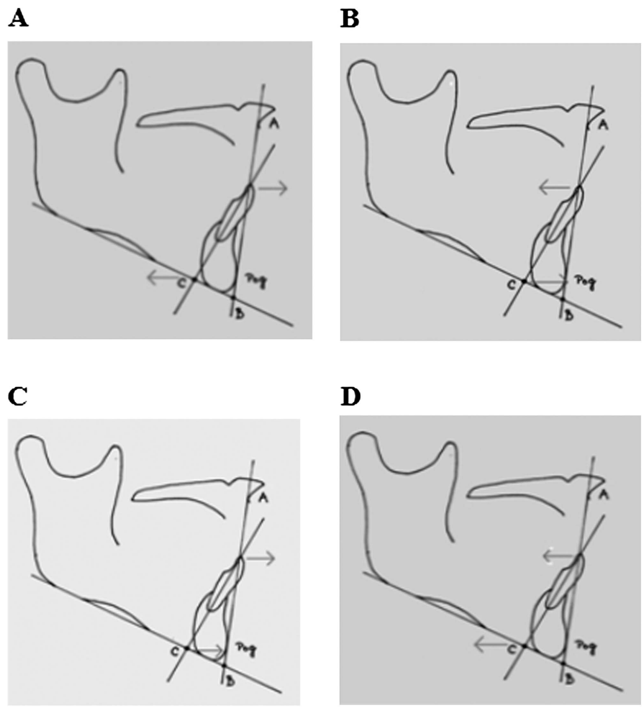

Figure 5 Tooth inclination (A and B) and bodily tooth movement (C and D).

Results

Cephalometric values

The median change in the position of the lower incisor relative to the A–Po line, ML, and the distance between B–C and B–C′ (apex position) between T1 and T2 were not statistically significant, meaning that less than 50 per cent of patients showed values of individual parameters that were lower at T2 (Table 1).

The change in the position of the lower incisor relative to the A–Po line, when using the 2D technique, was outside the recommended interval of −2; 2 mm in only one patient (4 per cent), while this occurred in seven patients (28 per cent) when using the SW technique. The recommended change is −5; 5 degrees in the position of the incisors relative to the ML. When using the 2D technique, five patients (20 per cent) were outside the interval and for the SW technique 12 patients (48 per cent; Table 2).

When the findings were evaluated according to the change in the position of the incisors relative to A–Po, and the change in distance between B–C and B–C′ (apex position), incisor inclination was recorded with the 2D appliance in 18 patients (72 per cent) and with the SW appliance in six patients (24 per cent). Bodily movement occurred with the 2D appliance in four patients (16 per cent) and with the SW in 18 patients (72 per cent).

Comparison of the two techniques and their impact on the parameters measured on the cephalograms was carried out using the two-sample Wilcoxon rank test. The results in the form of the point estimate of the difference in the location parameters from one therapeutic method to the other (the related non-parametric 95 per cent confidence interval (CI): the *P*-value) were as follows: the position of incisors to A–Po 0.75 mm (95 per cent CI 0–2; $P = 0.032$), the position of incisors to ML −1.50 degrees (95 per cent CI -5 to 2; $P = 0.420$), and the distance of incisor apex CB–C′B′ −0.50 mm (95 per cent CI −2 to 2; $P = 1.000$). The appliances resulted in significantly different findings but only in the position of the incisors relative to the A–Po line ($P < 0.05$).

Measurements of the 2D study model images

The distances between the molars, premolars and canines, point A and the first molar, point A and the canine, and the length of the lateral segment were measured. Therapy usually caused an increase in the values of all six parameters. Single parameters showed greater values in more than half of the subjects after therapy, no matter which technique was used. The only exception was the change in length of the lateral segment with the 2D appliance—an increase in values was recorded but in only 48 per cent of patients (Tables 3 and 4).

Table 4 gives the results of the signed rank test focused on whether the median of change was non-zero (two-sided version) or positive (one-sided version). It can be seen that statistically significant changes occurred in two parameters (the distance between point A and the first molar and the distance between point A and the canine) when using the 2D appliance and in only one parameter (intermolar distance) when using the SW appliance. The increase in distance measured in all three parameters was confirmed.

According to Proffit and Fields (2000), movement of the canines up to 1 mm, i.e. a change within the interval (−1 to 1 mm) is stable. Thus, both methods produced similar results. The interval was not exceeded in 12 (48 per cent) patients with either technique. For the 2D appliance, the movement of the canines of three (12 per cent) patients was

Table 1 Cephalometric analysis: the characteristics of the parameters (median ± interquartile deviation) measured on the cephalograms pre (T1) and post (T2) treatment with the two-dimensional (2D) and straightwire (SW) appliance.

Parameters	Therapy	T1	T2	Change (T2−T1)
Position of the incisors relative to A–Po (mm)	2D	2.0 ± 2.0	2.0 ± 3.0	1.0 ± 0.5
	SW	2.0 ± 2.0	2.0 ± 3.0	0.0 ± 1.5
Position of the incisors relative to mandibular line (°)	2D	96.0 ± 11.0	97.0 ± 9.0	1.0 ± 2.0
	SW	92.0 ± 12.0	97.0 ± 11.0	2.0 ± 3.5
Distance of incisor apex CB–C′B (mm)	2D	18.0 ± 5.0	19.0 ± 3.0	0.0 ± 2.0
	SW	17.0 ± 4.0	18.0 ± 6.0	1.0 ± 1.5

Table 2 Cephalometric analysis: the number and percentage of patients with stable incisors (±2 mm to A–Po and ±5 degrees to ML) treated with either the two-dimensional (2D) lingual or the straightwire (SW) appliance.

Parameters	Therapy	Below the interval (%)	Stable result (%)	Above the interval (%)
Position of the incisors relative to A–Po (mm)	2D	1 (4)	24 (96)	0 (0)
	SW	5 (20)	18 (72)	2 (8)
Position of the incisors relative to mandibular line (°)	2D	2 (8)	20 (80)	3 (12)
	SW	4 (16)	13 (52)	8 (32)

Table 3 Study model images: basic characteristics (median ± interquartile deviation) of parameters measured.

Parameters	Therapy	T1	T2	Change (T2−T1)
Intermolar distance (mm)	2D	47.11 ± 4.17	46.43 ± 3.98	0.13 ± 0.38
	SW	46.21 ± 3.55	46.60 ± 4.46	0.10 ± 0.64
Interpremolar distance (mm)	2D	31.12 ± 3.50	31.74 ± 2.08	0.58 ± 0.93
	SW	30.22 ± 2.69	30.86 ± 2.95	0.55 ± 0.82
Intercanine distance (mm)	2D	25.81 ± 1.91	26.54 ± 2.04	0.59 ± 1.04
	SW	25.28 ± 1.79	26.40 ± 1.74	0.43 ± 1.04
Distance between point A and the first molar (mm)	2D	32.99 ± 2.99	33.71 ± 4.73	0.58 ± 0.44
	SW	32.01 ± 3.51	32.39 ± 3.79	0.27 ± 1.93
Distance between point A and the canine (mm)	2D	5.02 ± 1.69	5.60 ± 1.13	0.55 ± 0.50
	SW	5.29 ± 1.80	5.82 ± 1.66	0.53 ± 0.72
Lateral segment (mm)	2D	27.79 ± 2.26	28.47 ± 2.25	−0.07 ± 0.37
	SW	27.06 ± 2.98	27.07 ± 2.71	0.14 ± 1.38

Pre (T1) and post (T2) treatment with the two-dimensional (2D) and straightwire (SW) appliances.

Table 4 Study model images: changes in parameters monitored pre (T1) and post (T2) therapy using two-diemnsional (2D) and straightwire (SW) appliances.

Parameters	Therapy	Reduction (%)	Increase (%)	*P*-value (two-sided)	*P*-value (one-sided)
Intermolar distance (mm)	2D	8 (32)	17 (68)	0.108	0.054
	SW	12 (48)	13 (52%)	1.000	0.500
Interpremolar distance (mm)	2D	8 (32)	17 (68)	0.108	0.054
	SW	5 (20)	20 (80)	0.004	0.002
Intercanine distance (mm)	2D	9 (36)	16 (64)	0.230	0.115
	SW	10 (40)	15 (60)	0.424	0.212
Distance between point A and C (mm)	2D	5 (20)	20 (80)	0.004	0.002
	SW	10 (40)	15 (60)	0.424	0.212
Distance between point A and B (mm)	2D	6 (24)	19 (76)	0.015	0.007
	SW	10 (40)	15 (60)	0.424	0.212
Lateral segment (mm)	2D	13 (52)	12 (48)	1.000	0.655
	SW	11 (44)	14 (56)	0.690	0.345

Table 5 Study model images: comparison of the impact of the two therapies on parameters measured.

Parameters	Estimate	Confidence interval	*P*-value
Intermolar distance (mm)	0.080	−0.55 to 0.7	0.769
Interpremolar distance (mm)	−0.300	−1.35 to 0.54	0.453
Intercanine distance (mm)	0.290	−0.63 to 1.27	0.548
Distance between point A and the first molar (mm)	0.155	−0.95 to 1.25	0.799
Distance between point A and the canine (mm)	−0.180	−0.77 to 0.57	0.655
Lateral segment (mm)	−0.075	−0.66 to 0.63	0.799

below the interval and for 10 subjects (40 per cent), it was above the interval. Using the SW appliance, the change in canine position was less than −1 mm in four (16 per cent) cases and greater than 1 mm in nine (36 per cent) cases.

The final comparison of the effects of the lingual 2D and the labial SW appliances carried out using the two-sample Wilcoxon test and related non-parametric CI are shown in Table 5. Minor differences can be observed among therapies in the changes of six measured distances, but these were not statistically significant.

Discussion

In order to achieve a relatively stable treatment outcome it is important to maintain the shape of the dental arch, especially the intercanine distance (Riedel, 1960, 1976). Therefore, it is appropriate to use individual arch dimensions both in the SW and in the 2D appliances (Kamínek and Stefkova, 1995; Rubin, 1999). However, some authors believe that universal arches may be used during the initial stage of levelling (McLaughlin and Bennett, 1999; McLaughlin *et al.*, 2001).

In the patients in the present study, individualized archwires were used during the early stage of levelling. When patients were treated with the SW technique, the initial levelling wire was either a prefabricated NiTi superelastic arch (diameter 0.012 inches) or an individualized multistrand steel wire (diameter 0.0175 inches). For patients treated with the lingual 2D method, individualized CuNiTi 0.012 ‘mushroom’ arches were used. Subsequent stages of therapy (for both methods) followed the treatment plan, and the choice of archwire was made on an individual basis.

It was found out that the 2D lingual method was less time consuming (2D: 14.6 ± 6.98 months, SW: 15.44 ± 7.38 months). The more favourable biomechanical effect of orthodontic forces may be an important contributing factor to the shorter duration of therapy. The effects of orthodontic force are influenced by the position of the lingual brackets closer to the axis running through the centre of resistance of the tooth (Macchi, 1996; Scuzzo and Takemoto, 2003).

Measurements of the position of the incisors to the A–Po line showed a change of over 2 mm in only one patient with 2D treatment compared with the original position. When using the SW technique, changes exceeding the recommended interval were found in seven patients (28 per cent). However, Kamínek (1976) considered a change in the position of the lower incisors relative to A–Po within an interval of ±3 mm to be stable. This requirement was met by all the 2D patients and by 19 SW patients (76 per cent). It can be concluded that treatment outcome is stable with the 2D as well as with the SW appliance.

The shape of the dental arch should change only minimally during treatment. In particular, intercanine distance values should be stable as changes in this area tend to relapse. In the 2D group, the median change in the distance between the lower canines measured on the study models was 0.59 mm (±1.04 mm) or in relative terms 2.2 per cent (±4.1 per cent). In the SW group, it was 0.43 mm (±1.04 mm) or in relative terms 1.6 per cent (±4.1 per cent). These changes were statistically insignificant. Alterations in the area of the molars and premolars were almost similar.

An important difference was recorded in the anterior segment of the dentition—the arch was significantly longer in the SW group (interquartile deviation of 1.38 versus 0.37 mm in the 2D group). This is represented by the values of the distance between the incisal point and a line connecting the first molars, the distance between the incisal point and the middle of the canines, and the position of the lower incisor relative to the A–Po and MLs on the cephalograms. Kotas (2007) explained this fact not only as a result of inclination of the incisors during the first phase of treatment but also due to an increased bite when the curve of Spee is levelled thus extending the dental arch.

The present results correspond to the findings of most investigations that report an increase in transverse width, both in the canine and premolar areas (Gardner and Chaconas, 1976; Little *et al.*, 1981, 1988, Sadowsky, 1993).

Analysis of changes in the position of the lower incisors relative to the ML (interquartile deviations) showed more substantial differences with the SW technique (3.5 versus 2.0 degrees with the 2D technique). Labial inclination of the lower incisors during levelling with the SW appliance (60 per cent of the patients in the present study) can be explained by the fact that the so-called ‘weak incisors’ cannot resist the spring effect of levelling arches and they therefore protrude before the end of the levelling phase. With the 2D appliance, mild intrusion of the lower incisors occurred due to placement of the brackets near to the axis running through the centre of resistance, which is then followed by protrusion of the crowns of the lower incisors (Macchi *et al.*, 2004; Kotas, 2007).

When using the 2D technique, changes in protrusion are not as extensive as with the SW technique. However, root movement with the 2D appliance was not due to bracket torque as this movement is not possible in slotless brackets.

These changes probably appear only during the levelling phase as a result of tooth inclination (Macchi *et al.*, 2004).

When using the SW technique, the initial inclination of the lower incisors to the ML according to the median position (± interquartile deviation) was 92 ± 6 degrees at T1, with a change in position of 1 ± 2 degrees and a change in position of the apex of the lower incisors of 1 ± 1.5 mm. Changes occur due to the biomechanical principles of the method used, apart from those in the apex area of the lower incisors, which are the result of levelling; root torque is expected due to the values inserted into the bracket slot when the SW technique is used. However, the results suggest a substantial loss of torque and greater inclination of the incisors. It is assumed that the loss of torque is primarily due to clearance between the cross-sections of the bracket slot and archwire and also to the fact that the force operates on a small surface (Proffit and Fields, 2000). It may be also due to the fact that the slot size of the manufactured brackets is not as accurate, resulting in further loss. The most precise dimensions and values inserted into the bracket slot are to be found in those constructed individually, with the aid of CAD/CAM software and robots.

Conclusions

The advantages of the 2D lingual appliances in adult patients are:

1. The biomechanics of 2D lingual brackets (placed closer to the axis passing through the centre of resistance of the tooth) results in a reduction in treatment time. Active treatment using 2D appliances was 14.6 ± 6.98 months and with SW appliances 15.44 ± 7.38 months.
2. The main disadvantage of 2D appliances is that they should be used only in indicated cases and not in the orthodontic treatment of skeletal abnormalities. However, in certain subjects, use of 2D appliances can achieve results comparable with SW appliances.

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