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The retraction of upper incisors with the PG retraction system

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SUMMARY The aim of this study was to evaluate the effect on the dentoalveolar structures of the application of PG springs for retraction of upper incisors and to compare the outcome with the effect of a closed coil spring retraction system.

Thirty-six subjects with Angle Class I or Class II malocclusions were selected for the study. Each subject had the two upper first premolars extracted and presented a symmetrical extraction space of at least 3 mm distal to the lateral incisors after canine retraction. The subjects were divided into two groups, the PG group with 17 subjects and the coil group with 19 patients. One group had the incisors retracted by PG universal retraction springs, whereas in the other a closed coil spring system was used. The average chronological ages were 18 years 4 months for the PG group, and 18 years 7 months for the coil group. In both groups the springs were activated to produce an initial force of 150 g per side. To examine the type of movement of the anterior and posterior teeth, and the time and rate of space closure, 20 parameters were measured and evaluated statistically with Wilcoxon and Mann–Whitney *U*-tests.

In both groups the incisor retraction was accompanied by mesial movement of the buccal segments. Distal movement of the root apex of the incisors was observed in both groups, although more pronounced in the PG group ($P < 0.01$). A significant incisor intrusion resulting in a decrease in overbite was found in the PG group, whereas the deep bite increased significantly in the coil spring group. The PG spring produced a three-dimensional control in the movement of the upper incisors, so that application of additional intrusive mechanics after completion of the incisor retraction became unnecessary.

Introduction

The position of the upper incisors has a striking effect on the aesthetic appearance of the face and on the function of the stomatognathic system. Retraction of the incisors as part of orthodontic therapy represents a fundamental phase of treatment. The required movement of the incisors can be obtained by segmentation of the fixed appliances or by use of continuous archwires. In the continuous archwire system the driving force is generated from different loops incorporated into the archwire or by adding coil springs and elastics to the system. In the segmented system, the tooth displacement is produced by connecting the segments with active elements, such as retraction springs, coils on cantilevers, or magnets (Jarabak, 1960; Stoner, 1960; Bull, 1966; Ackermann *et al.*, 1969; Ackermann and Musich, 1975; Cadman, 1975; Ricketts, 1976; Ricketts *et al.*, 1979; Burstone, 1982; Root, 1985; Thompson, 1985; Gjessing, 1992, 1994; Türk, 1995).

It has been stated that retraction carried out with continuous archwires may result in extrusion of the incisors, and that this unwanted side-effect can be caused by uncontrolled tipping of the tooth to be retracted or by the vertical forces generated as an adjunct to the moment induced for palatal root torque (Gjessing, 1992). In order to compensate for this unwanted side-effect, it has been suggested that the curve of Spee should be increased or gable bends included in the archwires.

However, the many active and reactive forces produced by a continuous arch can combine to induce extrusion of posterior teeth rather than intrusion of the incisors (Burstone and Koenig, 1988; Haskell *et al.,* 1990; Gjessing, 1992). This disadvantage is accentuated by reduced force control due to friction (Haskell *et al.,* 1990).

The segmented arch allows two points of force application. With this system the required tooth displacement can be obtained by careful selection of the points of force application and by connecting the segments with active elements pre-calibrated to produce the desired balance of forces and moments within a certain range of activation.

The effect of the PG retraction spring on canine distalization has been demonstrated clinically (Dinçer and Işcan, 1994) and with laboratory studies (Gjessing, 1985; Eden and Waters, 1994). The aim of the present study was to evaluate the applicability and effects on the dentoalveolar structures of PG springs when used for retraction of the upper incisors, and to compare the outcome with the effect of a closed coil spring retraction system.

Figure 1 PG universal retraction spring.

Figure 2 Closed coil spring.

Subjects and methods

Thirty-six subjects with an average age of 18 years 6 months, and demonstrating Class I or Class II malocclusions were selected for retraction of the four maxillary incisors. All patients were undergoing orthodontic treatment with 0.018 standard edgewise mechanics, including extraction of the upper first premolars. At the beginning of incisor retraction, all had completed retraction of the maxillary canines, and a space of at least 3 mm between upper laterals and canines remained to be closed.

From the 36 individuals, 12 girls and five boys were selected for space closure with the PG universal retraction spring (Figure 1) and in the second group, consisting of 17 girls and two boys, space closure was undertaken with closed coil springs mounted on cantilevers (Figure 2).

In both groups, 0.018 × 0.025-inch stainless steel wires were ligated to the canine, second premolar, and molar to form the anchorage units. In the closed coil spring group the buccal segments were joined together with a transpalatal bar. In both groups the four incisors were consolidated with 0.018 × 0.025-inch stainless steel wires to form the anterior segment.

After levelling of the anterior and posterior teeth, the anterior part of the PG spring (RMO 516–517: Rocky Mountain Orthodontics, Denver, Colorado, USA) was adapted and tied to the brackets of the lateral teeth in the first group. The posterior part of the PG spring was placed into the gingivally located molar tube. As described by Gjessing (1985), an initial driving force of 150 g was obtained by pulling the wire distal to the molar tube until the two sections of the double helix of the spring were separated 1 mm.

The activation of the spring was undertaken with a bend at the distal aspect of tube (Mexican tie back). In order to measure the force, a gauge was applied to the mesial leg of the spring before the wire was inserted into the lateral incisor brackets. Control visits were made every 3 weeks during the period of incisor retraction. At each visit the spring was reactivated to approximately 150 g per side.

The second group was provided with a stainless steel closed coil spring, 0.008 × 0.030 inches and 7 mm long. Both ends of this coil spring were tied to gingival extensions on the anterior and posterior segments. These 9-mm long power arms were used to direct the force through the centre of resistance (CRe) of the teeth. The coil spring was activated 4.5 mm to produce an initial force of 150 g per side. Reactivations were performed once every 3 weeks. For each side, the distance between the brackets, i.e. lateral and canine brackets, was measured and recorded during each control visit. The retraction procedure was completed by space closure (Figures 3 and 4).

In order to biometrically compare the effects of the two incisor retraction systems, cephalometric films were taken at the beginning and end of treatment. Local superimpositions of these pre- and post-retraction lateral cephalometric films were carried out with reference to a point in the palatal cortex of the maxilla by one of the researchers. A co-ordinate system was set up on the pre-retraction lateral cephalometric films: the line through Ptm, pterygomaxillary point, and perpendicular to the ANS–PNS plane represented the y-axis and ANS–PNS plane the x-axis. These axes served as references for the local superimpositions, when angular and linear measurements in the horizontal and vertical directions were carried out (Figure 5a,b).

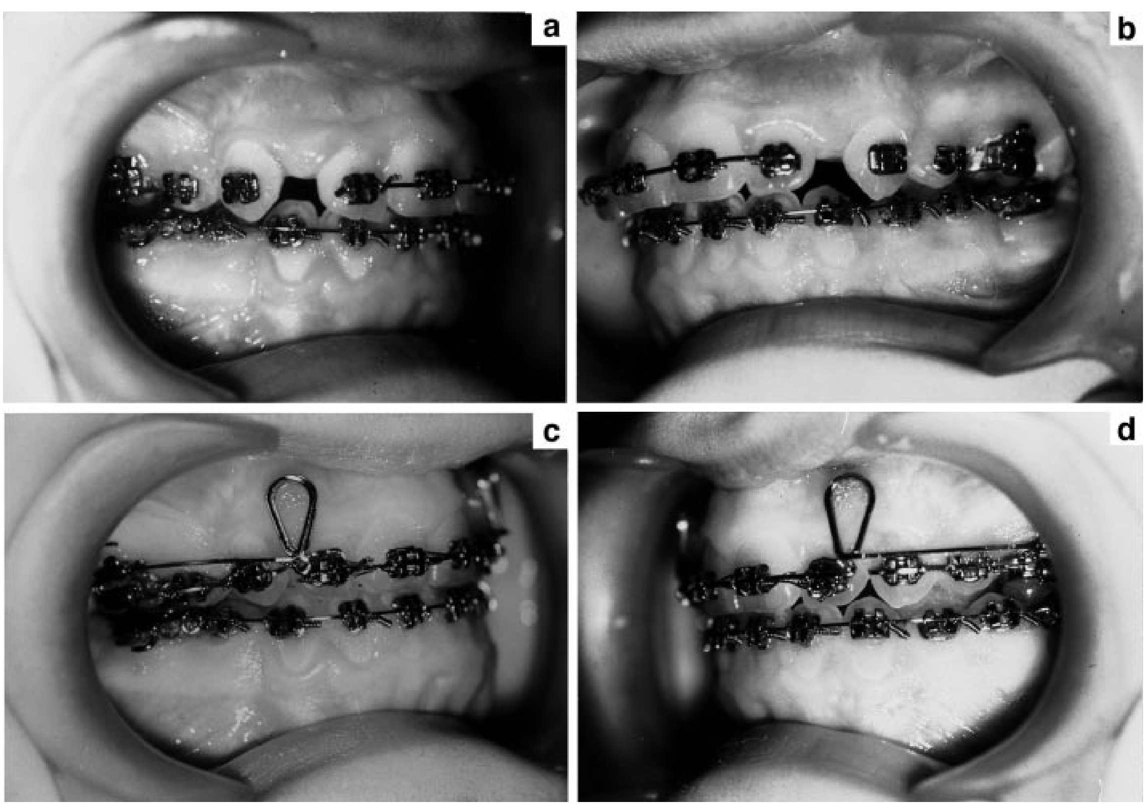

Figure 3 PG universal retraction spring (a,b) before and (c,d) after retraction.

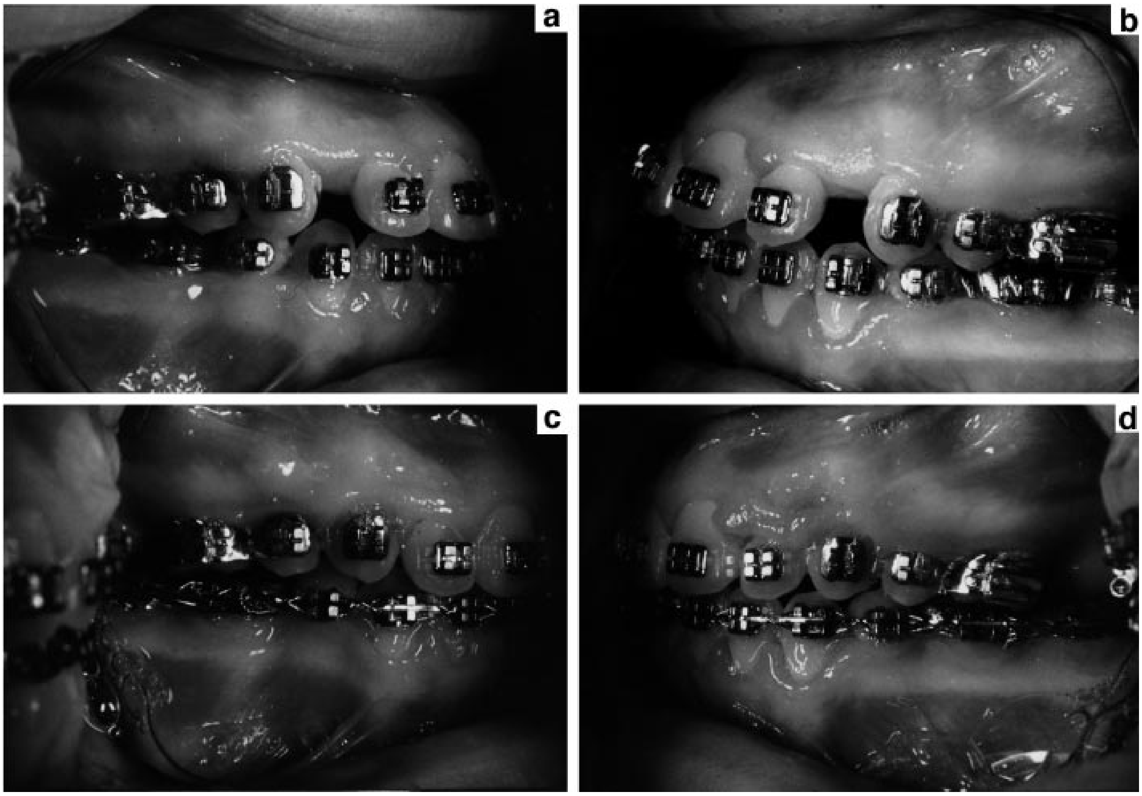

Figure 4 Closed coil spring (a.b) before and (c,d) after retraction.

For both groups the retraction time was registered and the rate of retraction and the centre of rotation (CRo) was calculated. At each control visit the amount of space closure was evaluated by measuring the distance between the mesial border of the canine bracket and the distal border of the lateral incisor bracket. To determine the rate of tooth movement, the total amount of space closure was divided by a unit time of 3 weeks (mm/3 weeks). The displacement of the incisor segment was characterized by determination of the CRo: the point of intersection of the pre- and post-treatment long axes of the central incisor. To measure the location of the CRo, the root apex was accepted as the 0 point. A positive value indicated a location of the CRo above this point, whereas a negative value signified a location below this point. For both groups, a Wilcoxon test was applied to determine the significance of the differences of pre- and post-retraction values; Mann–Whitney *U*-test was used to determine the significance of the mean differences of the pre- and post-retraction values between groups. The size of the method error for measurements was calculated by the formula:

$$\mathrm{Se} \pm \sqrt{\Sigma d^2/2n}$$

where d is the difference between two measurements of a pair and n is the number of double measurements. The method error did not exceed 0.30 mm for any variables investigated.

Results

For both groups, the significance of the differences between pre- and post-retraction (P_1, P_2) are given in Tables 1 and 2. In both groups the $6c$–x distance demonstrated a statistically significant increase ($P_1 < 0.01$ and $P_2 < 0.05$); the $6c$–y distance showed a statistically significant increase ($P_1 < 0.001$ and $P_2 < 0.001$), the $1/x$ angle decreased by a statistically significant amount

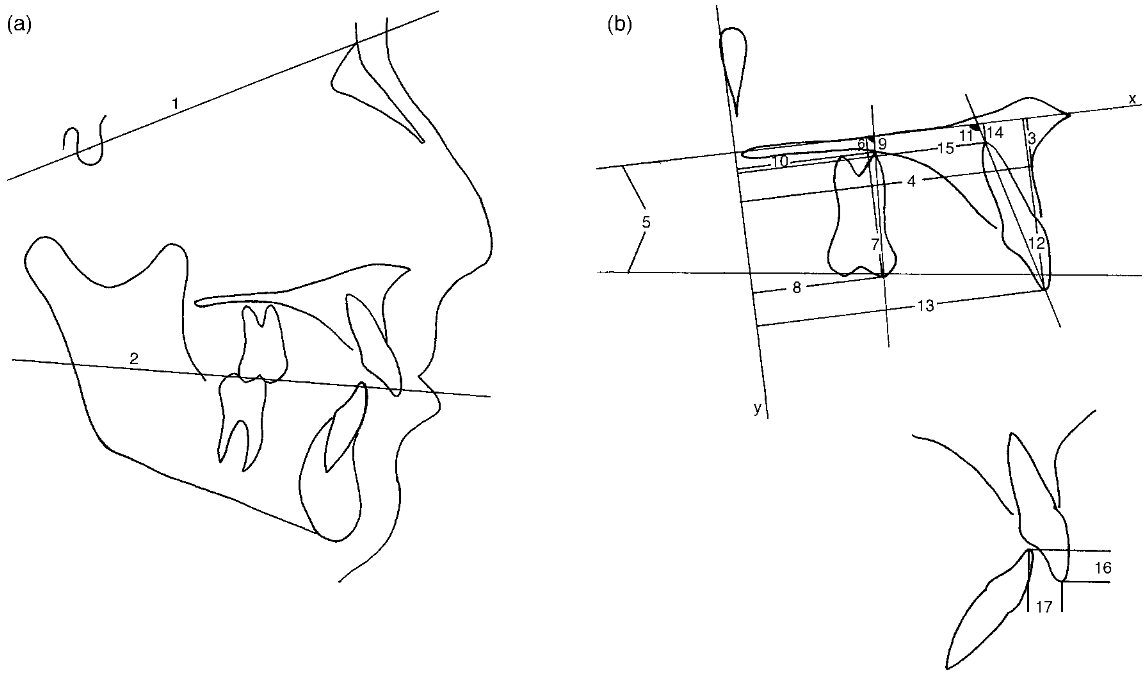

Figure 5 (a,b) Linear and angular points measured on the pre- and post-retraction lateral cephalometric films: (1) SN, reference line drawn from sella turcica to nasion; (2) SN/OP (degree), angle between sella–nasion and occlusal plane; (3) *a–x* (mm), distance between point A and *x*-axis; (4) *a–y* (mm), distance between point A and *y*-axis; (5) OP/*x* (degree), angle between occlusal plane and *x*-axis; (6) 6/*x* (degree), angle between axis of upper first molar and *x*-axis; (7) 6*c–x* (mm), distance between mesio-buccal tubercle of upper first molar and *x*-axis; (8) 6*c–y* (mm), distance between mesio-buccal tubercle of upper first molar and *y*-axis; (9) 6*a–x* (mm), distance between mesio-buccal root of upper first molar and *x*-axis; (10) 6*a–y* (mm), distance between mesio-buccal root of upper first molar and *y*-axis; (11) 1/*x* (degree), angle between axis of upper central incisor and *x*-axis; (12) 1*c–x* (mm), distance between incisal edge of upper central incisor and *x*-axis; (13) 1*c–y* (mm), distance between incisal edge of upper central incisor and *y*-axis; (14) 1*a–x* (mm), distance between apex of upper central incisor and *x*-axis; (15) 1*a–y* (mm), distance between apex of upper central incisor and *y*-axis; (16) overbite, vertical overlap between incisal edges of most anteriorly positioned upper and lower incisors; (17) overjet, horizontal overlap between incisal edge of upper most anteriorly positioned incisor and labial surface of lower most anteriorly positioned incisor.

(P_1 < 0.001 and P_2 < 0.001) and the 1*c–y* distance showed a statistically significant reduction (P_1 < 0.001 and P_2 < 0.001). In the coil group the 6/*x* angle demonstrated a statistically significant increase (P_2 < 0.01), whereas in the PG group the increase was statistically insignificant; the 1*c–x* and 1*a–x* distances demonstrated a statistically significant decrease in the PG group (P_1 < 0.01 and P_1 < 0.01), while no statistical change was observed in the closed coil spring group. In the PG group the 1*a–y* distance showed a statistically significant decrease (P_1 < 0.001). In the PG group the overbite decreased, but this was not statistically significant. In the closed coil spring group, the overbite showed a statistically significant increase (P_2 < 0.01). In both groups the overjet decreased significantly (P_1 < 0.001 and P_2 < 0.001).

The significance of the difference (P_3) between the changes occurring during treatment for both groups is given in Table 3. The 1*c–x* distance was found to be statistically significant between the groups (P_3 < 0.001). The differences relating to the 1*a–x* distance demonstrated a significance between the groups (P_3 < 0.01). The 1*a–y* distance was found to be statistically significant between the groups (P_3 < 0.01). The differences relating to the overbite were found significant between the groups (P_3 < 0.05).

A significant difference of retraction time was found between the groups (P_3 < 0.01). In the PG group the retraction rate was higher (1.07 mm/3

Table 1 Comparison of the differences between pre- and post-retraction values in the PG group (n = 17).

	Pre-retraction			Post-retraction			
	Mean	SE	SD	Mean	SE	SD	P_1
SNA	80.06	0.97	4.01	80.15	0.97	4.00	NS
SN/OP	18.59	1.35	5.58	18.03	1.24	5.12	NS
a–x	6.79	0.29	1.20	6.94	0.29	1.18	NS
a–y	54.18	0.79	3.26	54.15	0.81	3.32	NS
OP/*x*	8.59	1.00	4.14	7.76	1.05	4.31	NS
6/*x*	88.59	1.88	7.74	89.92	1.68	6.93	NS
6*c–x*	25.12	1.53	6.32	25.56	1.51	6.24	**
6*c–y*	28.50	1.04	4.27	29.41	1.11	4.60	***
6*a–x*	7.59	1.17	4.83	7.85	1.21	4.97	NS
6*a–y*	29.74	0.86	3.55	29.91	0.84	3.45	NS
1/*x*	113.56	1.83	7.54	108.06	1.75	7.21	***
1*c–x*	32.53	0.62	2.58	31.85	0.64	2.65	**
1*c–y*	59.71	1.42	5.86	56.21	1.17	4.84	***
1*a–x*	8.79	0.61	2.51	7.88	0.61	2.51	**
1*a–y*	49.62	0.85	3.49	48.41	0.82	3.40	***
Overbite	2.82	0.38	1.55	2.71	0.33	1.36	NS
Overjet	6.59	0.48	1.98	3.76	0.30	1.25	***

SE = standard error of mean, SD = standard deviation, P_1 = significance; NS = non-significant.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 2 Comparison of the differences between pre- and post-retraction values in the Coil group (n = 19).

	Pre-retraction			Post-retraction			
	Mean	SE	SD	Mean	SE	SD	P_2
SNA	78.42	0.50	2.16	78.26	0.50	2.19	NS
SN/OP	17.32	0.93	4.04	17.58	0.91	3.97	NS
a–x	4.87	0.58	2.52	5.03	0.61	2.68	NS
a–y	50.61	0.84	3.66	50.45	0.82	3.59	NS
OP/*x*	8.63	1.03	4.49	8.87	1.00	4.35	NS
6/*x*	81.18	2.29	9.99	83.84	1.94	8.47	**
6*c–x*	25.61	0.57	2.50	26.03	0.62	2.70	*
6*c–y*	27.08	0.80	3.49	28.08	0.85	3.72	***
6*a–x*	6.06	0.54	2.34	6.21	0.53	2.31	NS
6*a–y*	27.00	0.82	3.56	27.11	0.80	3.48	NS
1/*x*	112.26	1.81	7.89	105.29	1.44	6.29	***
1*c–x*	31.61	0.83	3.62	31.92	0.79	3.45	NS
1*c–y*	54.84	1.06	4.62	51.39	0.99	4.31	***
1*a–x*	11.29	0.89	3.86	11.45	3.83	3.82	NS
1*a–y*	46.55	0.75	3.28	46.34	0.72	3.14	NS
Overbite	2.63	0.35	1.54	3.32	0.33	1.44	**
Overjet	6.87	0.40	1.76	3.82	0.21	0.90	***

SE = standard error of mean, SD = standard deviation, P_2 = significance, NS = non-significant.
*$P < 0.05$; **$P < 0.01$; ***P < 0.001.

Table 3 The mean changes during the retraction period and comparisons between the groups.

	PG group (n = 17)			Coil group (n = 19)			
	Mean difference	SE	SD	Mean difference	SE	SD	P_3
SNA	–0.09	0.12	0.48	0.16	0.12	0.53	NS
SN/OP	0.56	0.55	2.28	–0.26	0.37	1.59	NS
a–x	–0.15	0.17	0.70	–0.16	0.11	0.47	NS
a–y	0.03	0.10	0.41	0.16	0.09	0.41	NS
OP/*x*	0.82	0.46	1.91	–0.24	0.41	1.80	NS
6/*x*	–1.24	0.75	3.08	–2.66	0.69	2.99	NS
6*c–x*	–0.44	0.13	0.56	–0.42	0.18	0.77	NS
6*c–y*	–0.91	0.19	0.80	–1.00	0.19	0.85	NS
6*a–x*	–0.26	0.14	0.59	–0.15	0.10	0.45	NS
6*a–y*	–0.18	0.21	0.86	–0.11	0.15	0.66	NS
1/*x*	5.50	0.75	3.07	6.97	0.74	3.22	NS
1*c–x*	0.68	0.18	0.73	–0.32	0.18	0.79	***
1*c–y*	3.50	0.37	1.51	3.45	0.41	1.78	NS
1*a–x*	0.91	0.24	0.97	–0.16	0.16	0.71	**
1*a–y*	1.21	0.20	0.83	0.21	0.19	0.84	**
Overbite	0.12	0.22	0.93	–0.68	0.16	0.71	*
Overjet	2.82	0.42	1.73	3.05	0.33	1.42	NS
Retraction time	9.35	0.66	2.71	12.26	0.70	3.07	**
Rate	1.07	0.08	0.32	0.93	0.02	0.11	NS
CRo	10.65	3.48	14.35	2.29	1.45	6.32	*

SE = standard error of mean, SD = standard deviation, P_3 = significance, NS = non-significant.
*P < 0.05; **P < 0.01; ***P < 0.001.

weeks) than in the coil spring group; however, this difference was not statistically significant. Comparison of the mean CRo values between the groups demonstrated a statistically significant difference ($P_3 < 0.05$; Figure 6).

Discussion

Orthodontic therapy, including fixed appliances with continuous archwires and sliding mechanics, has the following disadvantages: lack of force control due to friction between bracket and archwire, and lack of vertical control. The multiplicity of actions and reactions between archwire and brackets makes the system indeterminant (Burstone and Koenig, 1976; Burstone, 1982).

The segmented technique has been designed in an attempt to overcome these disadvantages. This biomechanical system allows for two points of force application and calculation of a force system to accomplish the required displacement of the segments. Furthermore, the system can be monitored in such a way as to avoid friction, so that a very precise loading of the segments is effected (Burstone, 1982).

Although numerous incisor retraction mechanics have been described and applied, a limited number of studies investigating the clinical effects of these mechanics have been reported in the literature. Therefore, the present study was undertaken to clinically compare the application of two different retraction systems.

An initial force of 150 g per side (1.5 N) was applied in both systems and resulted in a significant movement of the upper incisors. In both groups the springs were activated every 3 weeks. Gjessing (1992) maintains that an initial force of 100 g per side is sufficient for upper incisor retraction. However, Ricketts *et al.* (1979) state that 180 g is the total optimal force necessary for upper incisor retraction.

In this study, an upward and backward movement of the upper incisors in the PG group and backward movement of the upper incisors in the closed coil spring group occurred. As a result, a reduction of the overbite was observed in the

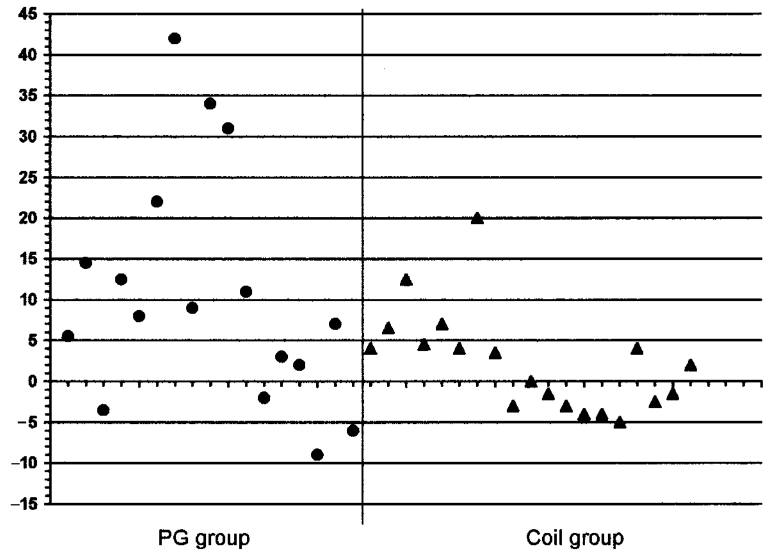

Figure 6 Location of centres of rotation in the PG and coil groups.

PG group (Table 3). It has been reported that the vertical force responsible for this intrusion is approximately 10 g on each side by initial activation of the PG spring and that the intrusive force increases to 25 g after 1.2 mm of space closure (Gjessing, 1994).

Reduction of the overbite by upward and backward translation of the upper incisor segment was documented clinically and radiographically by Gjessing (1994). In that study, the PG springs were activated to 150 g initially and reactivated every 4 weeks. In the present investigation, the backward movement of the upper incisor roots was more pronounced in the PG group than in the closed coil spring group (Table 3, Figure 6). It was observed that the CRo of the PG group was located at more favourable distances above the apices of the incisors when compared with the CRo in the coil group, indicating that the inclination of the incisors was more favourable in the PG group. Even though the inclination of the upper incisors for both groups was the same at the beginning of retraction, in the coil group it was observed to be more upright at the completion of retraction. This uprighting of the upper incisors was due to the location of the CRo.

Gjessing (1992, 1994) states that translation of the anterior segment occurs when the moment-to-force ratio equals the average vertical distance between the centre of the lateral brackets and the centre of resistance, which is 9–10 mm. After 0.3 mm of space closure with the PG spring, the M/F ratio increased from 7 to 10, where the anterior segment, i.e. the incisors, move from controlled tipping though translation to uprighting.

As can be seen (Table 3), from the point of retraction time a significant difference between the two groups was found. Gjessing (1994) states that space closure of 1.2 mm takes place in 4–6 weeks by 100 g initial activation. In this study, this was found to be 1.07 mm for 3 weeks in the PG group and 0.93 mm for 3 weeks in the closed coil spring group by 150 g initial activation. This retraction in the PG group was faster, even though a statistically significant difference was not found between the groups.

During the retraction of the upper incisors, a loss of anchorage with a tipping movement of the molar teeth was observed in both groups. The comparison of both groups shows no statistically significant differences, since in the coil group transpalatal arches were used. In the segmental arch technique, the use of transpalatal arches and/or an increase in the moment-to-force ratio in the posterior segment has been proposed, in order to reinforce the anchorage of the posterior segment (Burstone, 1982; Gjessing 1994).

Conclusions

The results of the present study show that:

1. Backward movement of the upper incisor roots was more pronounced in the PG group as compared with the coil spring group.
2. The centres of rotation were located at a more favourable distance above the apices in the PG group.
3. Retraction time was faster in the PG group (1.07 mm for 3 weeks) as compared with the coil spring group (0.93 mm for 3 weeks), although no statistically significant difference was found.
4. A decrease of overbite in the PG group was observed, whereas this increased in the coil spring group.

In conclusion, the present study showed that three-dimensional controlled movement of the upper incisors can be obtained by application of the PG universal retraction spring as the active element of segmented arch mechanics. The amount of overbite reduction at completion of the incisor retraction makes the use of additional intrusive mechanics unnecessary.

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