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Differences between sliding mechanics with implant anchorage and straight-pull headgear and intermaxillary elastics in adults with bimaxillary protrusion

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SUMMARY The aim of this retrospective study was to determine differences between the outcomes of treatment using implant anchorage compared with straight-pull headgear and intermaxillary elastics in bimaxillary protrusion patients.

The lateral cephalograms of 28 adult orthodontic patients (3 males and 25 females; age, 24.9 ± 5.0 years) who had an Angle Class I malocclusion with bimaxillary protrusion were selected. Group 1 (14 patients; 1 male and 13 females; age, 25.0 ± 5.1 years) received sliding mechanics with implant anchorage and group 2 (14 patients; 2 males and 12 females; age, 24.8 ± 5.1 years) a straight-pull headgear and intermaxillary elastics. Lateral cephalometric radiographs obtained before and after treatment were traced, 13 landmarks identified, and differences in the skeletal and dental changes compared between the groups. Wilcoxon's signed-rank test was used to determine changes within the treatment groups and a Mann–Whitney U-test to evaluate significant differences.

More anchorage loss occurred at the maxillary posterior teeth in group 2 (2.1 mm) than in group 1 (0.1 mm). Closing rotation of the mandible occurred in group 1, while opening rotation of the mandible was observed in group 2. These results suggest that sliding mechanics with implant anchorage may provide absolute anchorage and could control mandibular rotation more than the conventional technique.

Introduction

Obtaining and controlling anchorage is essential for successful orthodontic treatment. Extra- or intraoral appliances, such as headgear and intermaxillary elastics, are used for anchorage control; however, these systems have the disadvantage of relying on patient compliance. Furthermore, while intermaxillary elastics are effective in correcting the antero-posterior relationships of the dentition, undesirable side-effects may occur. Many authors have noted adverse results due to the vertical force vector that is inherent with the use of intermaxillary elastics (Brodie, 1938; Fischer, 1948; Buchner, 1949; Bien, 1951; Holdaway, 1953; Kanter, 1956; Hanes, 1959). This vertical force may cause the maxillary incisors and/or mandibular molars to extrude and may lead to rotation of the occlusal plane as well as an opening rotation of the mandible (Bien, 1951; Kanter, 1956).

The recent introduction of an implant anchorage system using titanium screws and miniplates provides an alternative to the conventional extra- or intraoral appliances that depend on patient compliance (Umemori *et al.*, 1999; Lee *et al.*, 2001; Miyawaki *et al.*, 2003; Kawakami *et al.*, 2004; Kuroda *et al.*, 2004; Sugawara *et al.*, 2004; Iino *et al.*, 2006). It has been reported that this implant anchorage system allows the anterior teeth to be retracted effectively without undesirable side-effects such as anchorage loss (Park and Kwon, 2004; Iino *et al.*, 2006; Choi *et al.*, 2007). However, most have been case reports. There have been only a few studies (Deguchi *et al.*, 2008; Park *et al.*, 2008) to date that have statistically investigated the effectiveness of the implant anchorage system and little statistical evaluation of the treatment effects of the implant anchorage system compared with that of straight-pull headgear and intermaxillary elastics.

The purpose of this retrospective research was to compare skeletal and dental changes in subjects treated with sliding mechanics using an edgewise appliance and implant anchorage compared with those treated with straight-pull headgear and intermaxillary elastics.

Subjects and methods

Twenty-eight adult orthodontic patients (3 males and 25 females; age, 24.9 ± 5.0 years) who had an Angle Class I malocclusion with bimaxillary protrusion and who attended a private orthodontic office from March 1997 to October 2001 were selected. All required extraction of the maxillary and mandibular first premolars on both sides and were diagnosed as maximum anchorage cases. The subjects were divided into two groups. Group 1 subjects gave informed consent (14 patients; 1 male and 13 females; age, 25.0 ± 5.1 years), while those in group 2 did not give informed consent (14 patients; 2 males and 12 females; age, 24.8 ± 5.1 years). Sliding mechanics, using an edgewise appliance (0.018 inch slot) and implant anchorage (Miyawaki *et al.*, 2003), was used in group 1. Orthodontic treatment with straight-pull headgear and intermaxillary elastics (Proffit, 2000) was carried out in group 2. All patients in both groups had been treated by the same clinician and had obtained an adequate overjet, overbite, Class I molar and canine relationship by the end of the treatment period. There were no significant differences between the two groups in any measurement values before treatment with the skeletal pattern and tooth position of both groups being very similar (Table 1).

The maxillary and mandibular arches length discrepency was −3.6 ± 3.0 and −3.6 ± 2.7 in group 1 and −3.8 ± 3.1 and −4.1 ± 2.8 in group 2. There were no significant differences in maxillary (P = 0.928) and mandibular (P = 0.734) arch length discrepancy between the groups when compared using the Mann–Whitney U-test.

In group 1, titanium screws (1.6 mm in diameter, 8 mm long, Dual-Top; Jeil Medical Corporation, Seoul, South Korea) were used for anchorage. The screws were manually inserted into the buccal cortical bone between the maxillary second premolars and first molars on both sides under local anaesthesia with a screwdriver. The six anterior teeth were then retracted *en masse* using a force of approximately 200 g per side applied from the titanium screws to the maxillary archwire with elastic chains. In the mandible, the canines were retracted with elastic chains, and the remaining space was then closed with sliding mechanics. The archwires used during space closure in the maxillary and mandibular arches were 0.016 × 0.022 inch stainless steel. Three weeks after the placement of the titanium screws, orthodontic force was loaded on the screws. If a titanium screw failed, another was placed in the neighbouring alveolar bone, and treatment was continued. The success rate of the titanium screws was 86 per cent. The titanium screws were removed immediately after treatment with the edgewise appliances. Only vertical elastics were used to settle the occlusion, which did not exceed 2 months.

In group 2, anchorage preparation for uprighting of the mandibular molars was performed with Class III elastics. The maxillary and mandibular canines were retracted using elastic chains with a force of approximately 100 g. Finally, the extraction spaces of the maxillary and mandibular dentition were closed with vertical loops and intermaxillary elastics. Straight-pull headgear, using a headcap and neckstrap, was used to apply a force of approximately 200 g to each side throughout the treatment period. The outer bow of the facebow (Proffit, 2000) was adjusted so that the orthodontic force passed through the centre of resistance of the first molar. The headgear was worn 12 hours a day throughout treatment. The clinical records showed that all patients had excellent compliance.

Cephalometric analysis

Lateral cephalometric radiographs were obtained using a conventional method (Proffit, 2000) before the start and at the end of treatment for all patients. The radiographs were traced by one person (RH), and 13 landmarks were identified (Figure 1) and digitized with a protractor and digital calliper (Digipapro; Mitutoyo, Kawasaki, Japan). Bilateral structures were bisected and their mid-sagittal points were identified.

Angular measurements using the SN plane as a reference line were performed to describe changes in the position of the jaws and incisors in relation to the cranial base (Figure 1A). Dental linear changes were measured based on the following co-ordinates: for the maxillary dentition, the x axis corresponded to the palatal plane, and the y axis was generated by dropping a line from the pterygoid point to the x axis on the cephalometric tracing before treatment (Figure 1B). For the mandibular dentition, the x axis corresponded to the mandibular plane, and the y axis was generated by dropping a line from menton to the x axis on the cephalometric tracing before treatment (Figure 1C). The pre- and post-treatment cephalometric tracings were superimposed by the best-fit method on the zygomatic process of the maxilla (key ridge) and the curvature of the palate in the maxilla, and on the mandibular symphysis and mandibular plane. The obtained co-ordinates were then transferred to the corresponding post-treatment cephalometric tracing. Superimposition was performed according to Bishara (2001).

Statistical analysis

Ten cephalometric radiographs were randomly selected, retraced, and digitized by the same author after a period of one month. Differences between the original and retraced radiographs were statistically analysed using a matched paired t-test. The results of the analysis indicated that there were no statistically significant differences between the original and repeat measurements at the 0.05 level.

All statistical analyses were based on comparison of skeletal and dental changes measured on the pre- and post-treatment cephalometric radiographs. The means and standard deviations were calculated for all variables in both groups. The Wilcoxon signed-ranks test was used to determine changes with treatment within each group, and a Mann–Whitney U-test to evaluate significant differences between the two groups.

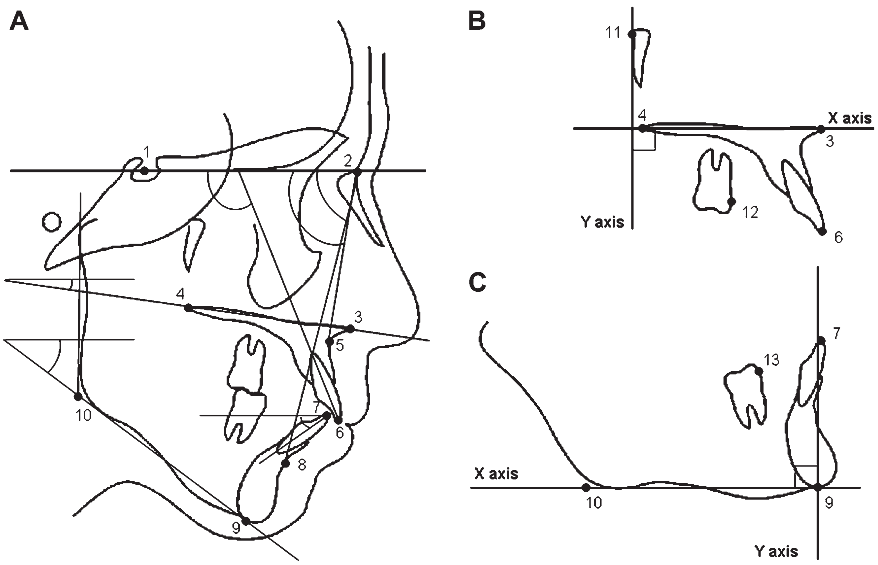

Figure 1 Cephalometric points traced and digitized in the study: (A) (1) sella; (2) nasion; (3) anterior nasal spine; (4) posterior nasal spine; (5) point A; (6) maxillary incisor crown tip, U1; (7) mandibular incisor crown tip, L1; (8) point B; (9) menton; (10) gonion; (11) pterygoid point; (12) maxillary first molar mesial buccal cusp tip, U6; and (13) mandibular first molar mesial buccal cusp tip, L6. The cants of the palatal plane (SN–PP), mandibular plane (SN–MP), and maxillary and mandibular incisors (SN–U1 and SN–L1) were measured using the SN plane as a reference line. (B) The *x* axis corresponds to the palatal plane, and the *y* axis was generated by dropping a line from the pterygoid point to the *x* axis in the maxilla. (C) The *x* axis corresponds to the mandibular plane, and the *y* axis was generated by dropping a line from menton to the *x* axis in the mandible.

Table 1 Comparison of cephalometric measurements before treatment between group 1 (implant anchorage) and group 2 (straight-pull headgear and intermaxillary elastics).

	Group 1		Group 2		*P* value
	Mean	SD	Mean	SD	
Skeletal (°)					
SNA	81.2	3.9	81.1	4.4	0.84
SNB	77.2	4.2	76.4	3.9	0.6
ANB	4.0	1.4	4.7	1.1	0.19
SN–PP	11.1	3.7	11.2	3.5	0.98
SN–MP	39.0	6.8	38.7	5.9	0.95
Dental angular (°)					
SN–U1	111.5	5.8	109.6	6.2	0.35
SN–L1	41.6	5.7	41.4	5.7	0.91
Dental linear (mm)					
Vertical					
U1	−31.3	2.2	−30.4	3.4	0.6
U6	−24.3	1.4	−23.4	3.2	0.27
L1	47.2	3.4	46.3	4.5	0.35
L6	33.7	2.7	34.1	3.6	0.98
Overbite	2.5	2.2	3.7	1.9	0.15
Sagittal					
U1	62.5	4.9	61.7	2.6	0.4
U6	30.5	2.2	27.9	4.9	0.18
L1	−2.4	4.4	0.2	4.4	0.08
L6	−26.0	5.2	−25.6	2.6	0.98
Overjet	6.2	2.1	6.3	2.2	0.93

Results

Statistical analysis was undertaken to determine whether any significant differences existed between groups 1 and 2 before treatment. No significant differences were found for any of the measurements in either group (Table 1).

There were no significant differences in SNA and SN–PP before or after treatment in either group. SNB after treatment was significantly larger ($P < 0.01$) than before treatment, and ANB and SN–MP after treatment were significantly smaller ($P < 0.01$) than before treatment in group 1. Additionally, the sagittal measurement value of U1 and the vertical and sagittal measurement values of L1 and overjet after treatment were significantly smaller ($P < 0.01$) than those before treatment, and the sagittal measurement value of L6 after treatment was significantly larger ($P < 0.05$) than that before treatment (Table 2).

For group 2, SNB was significantly smaller ($P < 0.01$) after treatment, and ANB and SN–MP were significantly larger ($P < 0.05$). The vertical and sagittal measurements of U1 and overjet post-treatment were significantly smaller ($P < 0.05$) than pre-treatment; the same was true for the vertical measurement of U6 and the vertical and sagittal measurement of L1 ($P < 0.05$). The sagittal measurement of U6 and the vertical and sagittal measurement of L6 after treatment were significantly larger ($P < 0.01$; Table 3).

Comparison of changes with treatment in groups 1 and 2 showed that SNB was significantly larger ($P < 0.001$), while ANB and SN–MP were significantly smaller ($P < 0.001$) in group 1. Furthermore, closing rotation of the mandible was observed in group 1, while opening rotation was seen in group 2. The changes in the vertical measurements of U1 and U6 in group 2 were significantly smaller ($P < 0.01$) than those in group 1 (Table 4). The change in the sagittal measurements of U6 and L6 in group 2 was significantly larger ($P < 0.05$) than in group 1.

Table 2 Treatment changes with implant anchorage.

	Pre-treatment		Post-treatment		*P* value
	Mean	SD	Mean	SD	
Skeletal (°)					
SNA	81.2	3.9	81.0	3.9	0.23
SNB	77.2	4.2	77.6	4.2	0.006**
ANB	4.0	1.4	3.3	1.2	0.007**
SN–PP	11.1	3.7	11.1	4.0	0.8
SN–MP	39.0	6.8	37.5	6.9	0.001***
Dental angular (°)					
SN–U1	111.5	5.8	101.2	5.2	0.001***
SN–L1	41.6	5.7	48.4	5.3	0.001***
Dental linear (mm)					
Vertical					
U1	−31.3	2.2	−30.8	2.5	0.45
U6	−24.3	1.4	−23.6	1.7	0.11
L1	47.2	3.4	44.6	2.3	0.002**
L6	33.7	2.7	34.3	2.6	0.06
Overbite	2.5	2.2	3.3	0.7	0.28
Sagittal					
U1	62.5	4.9	56.4	5.0	0.001***
U6	30.5	2.2	30.6	2.3	0.56
L1	−2.4	4.4	−5.5	4.1	0.001***
L6	−26.0	5.2	−24.8	5.4	0.030*
Overjet	6.2	2.1	3.3	0.6	0.001***

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 3 Treatment changes with straight-pull headgear and intermaxillary elastics.

	Pre-treatment		Post-treatment		*P* value
	Mean	SD	Mean	SD	
Skeletal (°)					
SNA	81.1	4.4	80.9	4.2	0.22
SNB	76.4	3.9	75.2	3.9	0.005**
ANB	4.7	1.1	5.7	1.5	0.003**
SN–PP	11.2	3.5	11.6	3.8	0.14
SN–MP	38.7	5.9	39.8	5.9	0.023*
Dental angular (°)					
SN–U1	109.6	6.2	98.6	5.5	0.001***
SN–L1	41.4	5.7	46.0	5.9	0.001***
Dental linear (mm)					
Vertical					
U1	−30.4	3.4	−32.6	3.6	0.01*
U6	−23.4	3.2	−24.4	2.9	0.028*
L1	46.3	4.5	44.9	4.6	0.008**
L6	34.1	3.6	35.3	3.1	0.007**
Overbite	3.7	1.9	3.5	0.9	0.69
Sagittal					
U1	61.7	2.6	54.7	3.8	0.001***
U6	27.9	4.9	30.0	4.5	0.001***
L1	0.2	4.4	−1.8	5.4	0.049*
L6	−25.6	2.6	−23.3	2.3	0.001***
Overjet	6.3	2.2	3.4	0.8	0.001***

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 4 Comparison of treatment changes between group 1 (implant anchorage) and group 2 (straight-pull headgear and intermaxillary elastics).

	Group 1		Group 2		*P* value
	Mean	SD	Mean	SD	
Skeletal (°)					
SNA	−0.3	0.8	−0.2	0.6	0.73
SNB	0.5	0.5	−1.1	1.2	0.001***
ANB	−0.7	0.7	1.0	0.9	0.001***
SN–PP	0.0	2.0	0.4	2.1	0.19
SN–MP	−1.5	1.2	1.1	1.5	0.001***
Dental angular (°)					
SN–U1	−10.3	5.8	−11.1	5.9	0.67
SN–L1	6.8	2.1	4.6	3.0	0.06
Dental linear (mm)					
Vertical					
U1	0.4	1.8	−2.2	2.4	0.004**
U6	0.7	1.6	−1.0	1.6	0.008**
L1	−2.6	1.8	−1.4	1.8	0.31
L6	0.6	1.0	1.3	1.4	0.33
Overbite	0.7	2.4	−0.2	1.7	0.54
Sagittal					
U1	−6.2	4.1	−7.0	3.4	0.57
U6	0.1	0.5	2.1	1.3	0.001***
L1	−3.1	1.8	−2.0	3.1	0.31
L6	1.3	1.3	2.5	1.3	0.035*
Overjet	−2.9	1.9	−2.9	2.3	0.87

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Discussion

The change in the sagittal measurement of U6 in group 2 was significantly larger than in group 1. There was no significant difference between the sagittal measurement of U6 pre- and post-treatment in group 1, thus confirming that the titanium screws provided absolute anchorage. The extraction spaces were closed with elastic chains from the titanium screws to the hooks on the archwire in group 1, resulting in no retraction force on the maxillary molars in the mesial direction. Therefore, no maxillary molar anchorage loss occurred in group 1.

SNB after treatment in group 1 was significantly larger than before treatment, while SN–MP was significantly smaller and closing rotation of the mandible was observed. These results are in agreement with those of Upadhyay *et al.* (2008). A correlation has been reported between mandibular rotation and mesial movement of the mandibular molars with orthodontic treatment (Ahn and Schneider, 2000), and that closing rotation occurs due to mesial movement of the molars (Park and Kwon, 2004). In the present study, the sagittal measurement of L6 after treatment was significantly larger than before treatment, and the mandibular molars moved mesially in group 1. Intrusion of molars is known to influence closing rotation of the mandible (Park and Kwon, 2004). Vertical change of U6 was significantly larger than that in group 2, and U6 tended to intrude a mean of approximately 1 mm in group 1. Additionally, in 10 subjects in group 1, vertical measurement of U6 after treatment was larger than before treatment. These results indicate that closing rotation of the mandible might have occurred due to mesial movement of the mandibular molars and intrusion of the maxillary molars in group 1.

With regard to maxillary molar intusion in group 1, sliding mechanics with absolute anchorage produced rotation of the entire dentition around the centre of resistance, and the vertical intrusive force acts on the molars if the line of retraction force is exerted below the centre of resistance (Jung and Kim, 2008). The centre of resistance for the entire maxillary dentition is approximately halfway from the root apex to the alveolar bone crest between the first and second premolars (Teuscher, 1978). In the present study, titanium screws were placed between the maxillary second premolars and first molars close to the alveolar bone crest. Therefore, the maxillary molar tended to intrude in the implant anchorage group because the line of retraction force was exerted below the centre of resistance of the maxillary dentition.

In contrast, in group 2 after treatment, SNB was significantly smaller and SN–MP was significantly larger, and opening rotation of the mandible was observed, although the maxillary and mandibular molars moved mesially. Downward movement of the maxilla and extrusion of the teeth are important factors in opening rotation of the mandible (Ricketts, 1976; Teuscher, 1978), and the maxillo-mandibular incisors and molars are extruded by the vertical force vector of Class II or III elastics (Proffit, 2000). In the present study, Class II and III elastics were used during treatment, and U1 and U6 were significantly extruded in group 2. Therefore, opening rotation of the mandible might have occurred as a result of extrusion of the maxillary dentition, as reported in previous studies (Ricketts, 1976; Teuscher, 1978; Proffit, 2000).

In a previous investigation comparing sliding mechanics with titanium screws and the Tweed–Merrifield technique (Park *et al.*, 2008), statistically significantly less maxillary molar anchorage loss occurred in patients treated with titanium screws than in those treated with the Tweed–Merrifield technique, a result similar to that of the present research. However, in the previous study, there were no significant differences in the vertical measurements of the maxillary incisors and first molars between the patients treated with titanium screws and the Tweed–Merrifield technique (Park *et al.*, 2008). With the latter technique, a high-pull J-hook is used instead of Class III elastics for anchorage to counteract the side-effects of Class II elastics such as extrusion of the maxillary incisors (Merrifield, 1986). Furthermore, retraction forces on the maxillary anterior teeth were applied from the titanium screws to long arm hooks soldered on the archwire in the patients with titanium screws. This is probably the reason why, in contrast to the present study, no vertical change of the maxillary dentition between the two techniques was observed (Park *et al.*, 2008).

Control of mandibular rotation is important in orthodontic treatment (Jung and Kim, 2008). However, it is difficult to control this rotation by conventional techniques using intermaxillary elastics and headgear (Ellen *et al.*, 1998). Mandibular rotation following orthodontic treatment is influenced by changes in the vertical position of the maxillo-mandibular teeth and the cant of the occlusal plane (Bien, 1951; Kanter, 1956; Jung and Kim, 2008). The present results confirm that sliding mechanics using an edgewise appliance and implant anchorage can control the vertical position of the maxillary incisors and molars, and mandibular rotation. Therefore, this simple technique would be effective even without patient compliance or any extraoral appliance, especially in adult subjects with a high mandibular plane angle, in whom it is necessary to control mandibular rotation and anchorage.

Conclusions

1. Implant anchorage on sliding mechanics was more reliable than the conventional technique of straight-pull headgear and intermaxillary elastics.
2. Closing rotation of the mandible occurred during treatment with sliding mechanics using an edgewise appliance and implant anchorage, while opening rotation of the mandible was observed with straight-pull headgear and intermaxillary elastics.
3. Sliding mechanics with implant anchorage may provide absolute anchorage and could control mandibular rotation more than the conventional technique of straight-pull headgear and intermaxillary elastics.

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