

Dentoskeletal and Soft Tissue Effects of Mini-Implants in Class II division 1 Patients

Madhur Upadhyay^a; Sumit Yadav^b; K. Nagaraj^c; Ravindra Nanda^d

ABSTRACT

Objective: To examine the skeletal, dental, and soft tissue treatment effects of retraction of maxillary anterior teeth with mini-implant anchorage in nongrowing Class II division 1 female patients.

Materials and Methods: Twenty-three patients (overjet ≥ 7 mm) were selected on the basis of predefined selection criteria. Treatment mechanics consisted of retraction of anterior teeth by placing mini-implants in the interdental bone between the roots of the maxillary first molar and second premolar. A force of 150 g was applied, bilaterally. Treatment effects were analyzed by taking lateral cephalograms and study casts at T1 (before initiation of retraction) and at T2 (after complete space closure).

Results: The upper anterior teeth showed significant retraction (5.18 ± 2.74 mm) and intrusion (1.32 ± 1.08 mm). The upper first molar also showed some distal movement and intrusion, but this was not significant ($P > .05$). The upper and lower lips were retracted by 2.41 mm and 2.73 mm, respectively, and the convexity angle reduced by over 2° ($P < .001$).

Conclusion: Mini-implants provided absolute anchorage to bring about significant dental and soft tissue changes in moderate to severe Class II division 1 patients and can be considered as possible alternatives to orthognathic surgery in select cases. (*Angle Orthod.* 2009;79;)

KEY WORDS: Class II; Maximum anchorage; Mini-implants

INTRODUCTION

Moderate to severe Class II malocclusions cannot only cause esthetic and functional problems but can also lead to psychological problems of varying intensity, depending on the amount of anterior-posterior discrepancy and its interaction with the related soft tissue structures.

Treatment for the correction of Class II malocclusions in nongrowing patients usually involves selective removal of permanent teeth, with subsequent dental camouflage to mask the skeletal discrepancy and provide a good facial balance. In moderate to severe malocclusions, orthognathic surgery can also be an option. Extractions can involve two maxillary premolars or two maxillary and two mandibular premolars. The extraction of only two maxillary premolars and anterior teeth retraction is generally indicated when there is no crowding or cephalometric discrepancy in the mandibular arch.^{1,2} While retracting anterior teeth in a full cusp Class II malocclusion, anchorage control assumes profound importance because maintaining the posterior segment in place becomes very critical. A loss in molar anchorage cannot only compromise correction of the anterior-posterior discrepancy, but can also affect the overall vertical dimension of the face.³

With the introduction of dental implants,⁴ miniplates,⁵ and microscrews^{6,7} as anchorage units, it has now become possible to obtain absolute anchorage for the posterior teeth and close the extraction spaces completely by anterior teeth retraction. However, there still seems to be a paucity of accurate scientific evidence pertaining to the treatment effects of skeletal anchorage in Class II malocclusions.

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Additionally, although the effects of four premolar extraction treatment on dentofacial structures has been reported, the pure effects of bilateral upper premolar extractions has not been widely investigated. The purpose of this prospective clinical-cephalometric study was to examine the dentoskeletal and soft tissue treatment effects of maxillary anterior teeth retraction with mini-implant anchorage in Class II division 1 patients undergoing extraction of only the maxillary first premolars.

MATERIALS AND METHODS

This prospective study was carried out only after a formal institutional approval was obtained for the use of humans from the ethical committee at the KLES' Institute of Dental Sciences. The original subject material consisted of first 35 female subjects (9.6–30.5 years) with a Class II division 1 malocclusion in the permanent dentition seeking orthodontic treatment at our postgraduate clinic. All patients had a full cusp Class II molar and canine relation with overjet ≥ 7 mm. Twenty-three patients were selected based on the following additional inclusion criteria:

- A minimum age at the beginning of treatment of 14 years.
- Maximum retraction of the upper anterior teeth.
- No history of thumb sucking, mouth breathing, or orthodontic treatment.
- Minimal lower arch crowding.

All patients and/or their parents were informed about the purpose of this study and signed a consent form. The patients and/or their parents or guardian signed a consent form. On the basis of the diagnosis of the presenting malocclusion, extraction of only the maxillary first premolars combined with maximum anchorage of the posterior teeth were indicated in all subjects. Maximum anchorage was predicated on the need to restrict mesial movement of posterior teeth so that the excessive overjet could be resolved through complete retraction of the upper anterior teeth en masse.

Clinical Set Up

All patients received treatment with the 0.022-inch preadjusted edgewise appliance system, Roth prescription (GAC, International, Bohemia, NY). Once the initial leveling and aligning were complete, 0.017 \times 0.025-inch stainless steel arch wire, with crimpable hooks (TP Orthodontics, LaPorte, Ind) placed distal to lateral incisors, was inserted in the upper arch. To ensure that the wire was passive, it was left in place for at least 4 weeks before initiating retraction. Titanium mini-implants (1.3 mm in diameter and 8 mm in length) were inserted between the roots of the first molar and

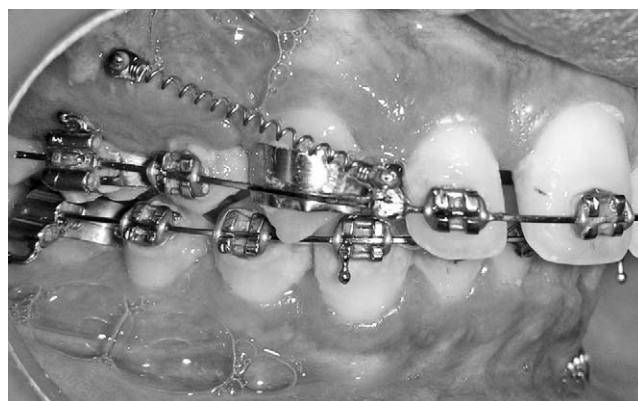


Figure 1. Clinical set-up for en masse retraction with mini-implant anchorage.

the second premolar in both upper quadrants. The surgical procedure for implant placement involved incision of the overlying mucosa, preparation of the insertion site with a pilot drill under constant irrigation with a coolant, and placement of the mini-implants with a screw driver. The mini-implants were checked for stability and were immediately loaded with precalibrated nickel-titanium closed coil from the implant head to the crimpable hooks. A force of 150 g was applied bilaterally for en masse retraction of the upper anterior teeth. Direction of the applied forces was upward and backward (Figure 1). Conventional mechanics were used for the lower arch.

Data Collection

The data were obtained by the analysis of paired lateral cephalograms for the 23 patients. In order to minimize the effects of any residual growth and to estimate treatment changes primarily due to retraction of anterior teeth, radiographs were taken just before initiation of retraction (T1) and immediately after complete space closure (T2). The length of time between two cephalograms was not more than 14 months for any of the subjects.

Data Interpretation

The tracings were done by one investigator with verification of anatomic outlines and landmarks by others. The suspicious structures and landmarks were re-traced to their mutual satisfaction. Landmarks, cephalometric planes, and linear and angular parameters used in this study have been elaborated in Figures 2 through 5. Horizontal and vertical changes of certain landmarks were measured in relation to a Cartesian coordinate system. A Frankfort horizontal plane was constructed by subtracting 7° from the sella-nasion line. This served as the x-axis, and a line perpendicular to it through sella served as the y-axis (Figure 2).

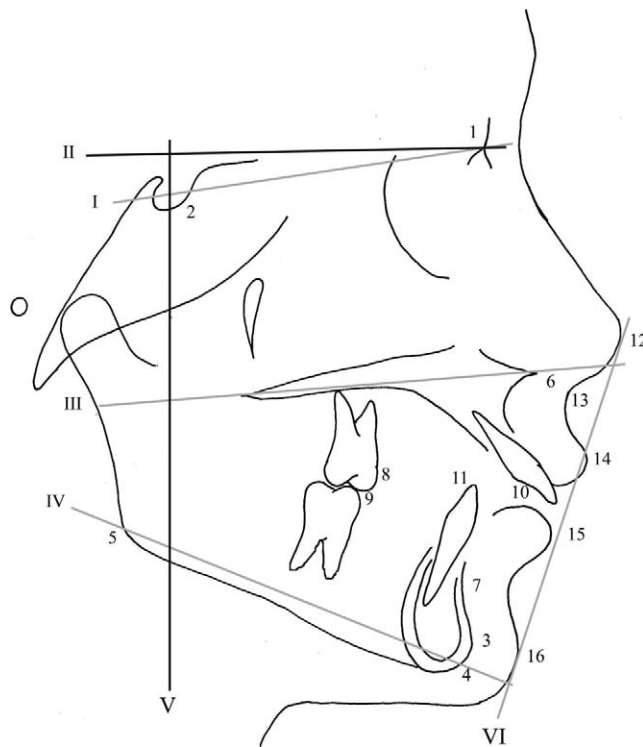


Figure 2. Cephalometrics landmarks and planes used. Cephalometric landmarks: Hard tissue: (1) Nasion (N). (2) Sella (S). (3) Pogonion (Pog). (4) Gnathion (Gn). (5) Gonion (Go). (6) Point A. (7) Point B. (8) Mesial cusp tip of maxillary first molar (U6). (9) Mesial cusp tip of mandibular first molar (L6). (10) Incisal tip of the maxillary incisor (U1). (11) Incisal tip of the mandibular incisor (L1). Soft tissue: (12) Anterior most point on the nose (Nt). (13) Subnasale (Sn). (14) Labrale superior (Ls). (15) Labrale inferior (Li). (16) Soft tissue pogonion (Pg). Cephalometric planes: (I) S-N plane. (II) Constructed FH plane (x-axis). (III) Palatal plane (ANS-PNS). (IV) Mandibular plane (Go-Gn). (V) Sella vertical (Sv or y-axis). (VI) Ricketts E-plane (Nt-Pg).

Linear and angular measurements were performed to the nearest 0.5 mm and 0.5°, respectively.

Study Model Analysis

Study casts were obtained at T1 and T2. Intermolar and intercanine width changes were measured to quantify the anterior and posterior arch width changes for the maxillary arch before and after retraction with mini-implants.

Statistical Analysis

All statistical analyses were performed using the SPSS software package (SPSS for windows 98, version 10.0, SPSS Inc, Chicago Ill). The interpretation of the treatment changes between T1 and T2 was obtained by applying the Wilcoxon signed rank test.

The method of error was calculated using Dahlberg's method error formula, $ME = \sqrt{(\sum d^2)/2n}$, with d being the difference between the two determinations

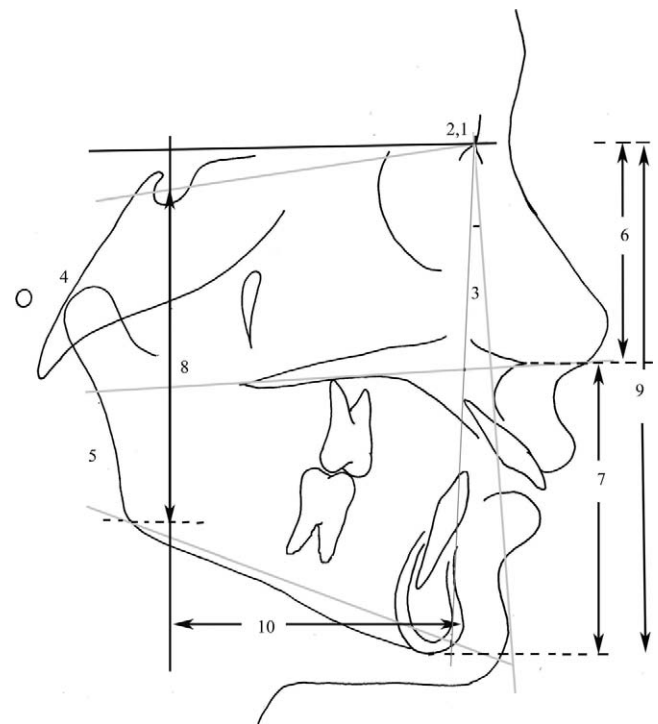


Figure 3. Skeletal Measurements. Angular measurements: (1) SNA. (2) SNB. (3) ANB. (4) SN-Go-Gn. (5) PP-MP. Linear measurements: (6) UFH (N-ANS). (7) LFH (ANS-Me). (8) PFH (S-Go). (9) AFH (N-Me). (10) Sv-Pog.

of the same variable, and n the number of double measurements (Table 1). The error varied between 0.346 and 0.934 and was within acceptable limits. Correlation analysis applied to the same measurement showed that the highest r value was 0.975 for Pog-Sv (chin position) with the lowest value 0.865 for the SNA angle.

RESULTS

The average time recorded for space closure was 9.4 months. All patients tolerated the implants well throughout the retraction phase. Two implants were lost (out of 46) during the initial stages of the study but were subsequently replaced. The overall success rate was 95.7%. In two patients the retraction was discontinued for 3 weeks because of inflammation around the implant site. Retraction was resumed once the inflammation was brought under control by stepping up the oral hygiene.

The post treatment changes for each measurement have been calculated by subtracting the pretreatment measurements from the post treatment. Linear measurements that show a negative sign are synonymous with distal or backward movement to a relevant reference line and a shortening of the vertical dimension, while a positive value indicates a forward or mesial movement and an increase in the vertical dimension.

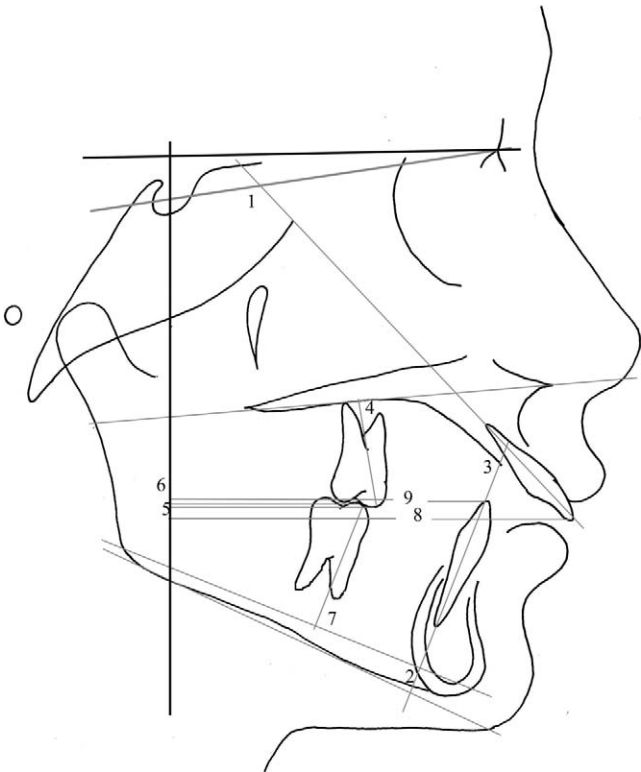


Figure 4. Dental measurements. Angular measurements: (1) U1-SN plane. (2) IMPA. (3) U1-L1 (interincisal angle). Linear measurements: (4) Vertical position of maxillary first molar (U6-PP). (5) Sagittal position of maxillary first molar (U6-Sv). (6) Sagittal position of mandibular first molar (L6-Sv). (7) Vertical position of mandibular first molar (L6-MP). (8) Sagittal position of upper incisal edge (U1-Sv). (9) Sagittal position of lower incisal edge (L1-Sv).

A positive value for change in an angular measurement indicates that the measurement became more obtuse during treatment. The descriptive statistics containing means and standard deviations have been highlighted in Tables 2 through 4.

Ratios of upper incisor movement and its effect on the overlying soft tissue were also calculated (Table 5). To produce a 1° decrease in the facial convexity angle and an equivalent increase in the nasolabial angle, the incisors were retracted by 2.36 mm and 0.63 mm, respectively. Similarly, to produce a 1-mm decrease in the upper and lower lip protrusion, the incisors were retracted by 2.23 mm and 1.67 mm, respectively.

DISCUSSION

Meticulous selection of patients led to a substantial reduction in many of the variables that might have affected the results. Unfortunately, this also reduced the size of the sample. In an attempt to reduce the effects of growth, selection was limited to only female patients more than 14 years of age (mean age 17.6 years). The

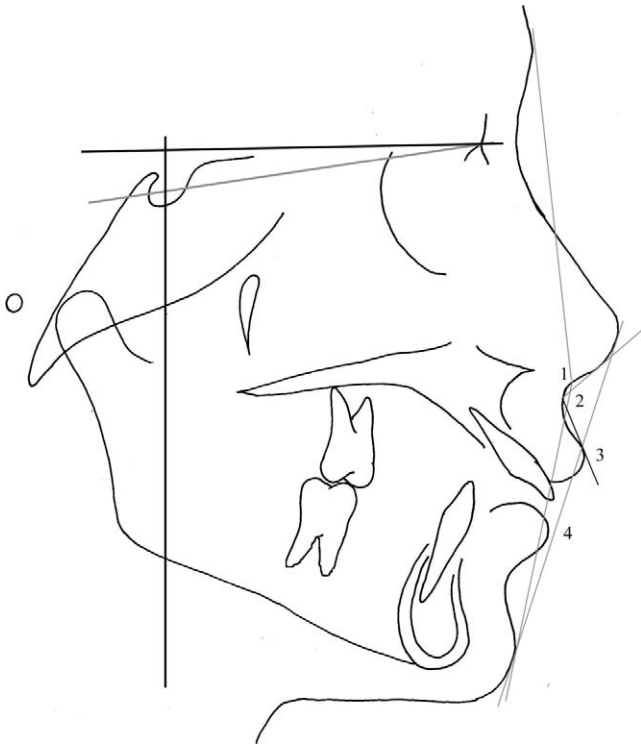


Figure 5. Soft tissue measurements. Angular measurements: (1) Facial convexity angle (G-SN-Pg). (2) Nasolabial angle. Linear measurements: (3) E line-Ls. (4) E line-Li.

Table 1. Error of the Method

	Measurement	Dahlberg's Calculation	Reliability Coefficient
1	SNA, degrees	0.661	.865
2	SNB, degrees	0.441	.898
3	ANB, degrees	0.45	.987
4	Go-Gn-SN, degrees	0.362	.923
5	PP-MP, degrees	0.39	.914
6	UFH (N-ANS) mm	0.854	.906
7	LFH (ANS-Me) mm	0.911	.987
8	UFH/LFH, %	0.776	.945
9	PFH (S-Go) mm	0.638	.932
10	AFH (N-Me) mm	0.55	.967
11	PFH/AFH, %	0.789	.897
12	Pog-Sv mm	0.346	.975
13	U1-SN, degrees	0.443	.907
14	IMPA, degrees	0.456	.969
15	U1-L1, degrees	0.6	.911
16	U6-PP mm	0.756	.975
17	U6-Sv mm	0.934	.941
18	L6-MP mm	0.65	.912
19	L6-Sv mm	0.432	.966
20	U1-Sv mm	0.346	.972
21	L1-Sv mm	0.384	.887
22	G-Sn-Pg, degrees	0.786	.948
23	Nasolabial angle, degrees	0.556	.971
24	E line-Ls mm	0.91	.963
25	E line-Li mm	0.812	.948

Table 2. Descriptive Statistics for the Skeletal Changes (T2–T1^a)

Skeletal Parameters	T1		T2		T2–T1		<i>P</i>	Sig ^b
	Mean	SD	Mean	SD	Mean	SD		
SNA, degrees	82.86	3.09	82.68	3.36	–0.18	1.23	.641	NS
SNB, degrees	76.55	3.53	77	3.38	0.45	1.19	.195	NS
ANB, degrees	6.32	1.65	5.68	1.91	–0.64	0.98	.055	NS
Go–Gn–SN, degrees	29.91	6.26	29.41	5.87	–0.5	1.26	.250	NS
PP–MP, degrees	26.77	6.25	26.36	5.97	–0.41	1.26	.375	NS
UFH (N–ANS) mm	51.41	2.62	51.27	2.11	–0.14	0.84	.844	NS
LFH (ANS–Me) mm	65.09	4.91	65.45	4.92	0.36	0.95	.203	NS
UFH/LFH, %	79.37	6.19	74.96	7.81	–4.41	5.73	.014	*
PFH (S–Go) mm	76.95	7.1	78.55	7.05	1.59	0.94	.002	**
AFH (N–Me) mm	116.32	6.25	116.5	6.13	0.18	1.17	.820	NS
PFH/AFH, %	66.16	4.84	67.39	4.51	1.23	0.92	.004	**
Pog–Sv mm	60.36	9.59	61.32	8.93	1.41	1.41	.114	NS

^a T1 indicates before initiation of retraction; T2, after complete space closure.

^b Sig indicates significance. NS, not significant; * $P < .05$; ** $P < .01$.

Table 3. Descriptive Statistics for the Dental and Soft Tissue Changes (T2–T1^a)

	T1		T2		T2–T1		<i>P</i>	Sig ^b
	Mean	SD	Mean	SD	Mean	SD		
Dental parameters								
U1–SN, degrees	108.55	6.83	96.14	5.07	–12.41	5.76	.000	***
IMPA, degrees	97.91	4.95	93.09	6.63	–4.82	5.36	.016	*
U1–L1, degrees	119.59	7.22	136.18	5.6	16.59	6.67	.000	***
U6–PP mm	21.91	2.12	21.27	1.78	–0.64	0.78	.063	
U6–Sv mm	49.82	6.54	49.36	6.25	–0.45	0.79	.109	
L6–MP mm	27.45	2.62	28.27	2.45	0.52	0.75	.216	
L6–Sv mm	47.82	7.61	48.45	7.51	0.64	1.1	.074	
U1–Sv mm	76.91	8.35	71.73	6.97	–5.18	2.74	.000	***
L1–Sv mm	68.5	10.55	66.73	10.12	–1.77	2.16	.019	*
Soft tissue parameters								
G–SN–Pg, degrees	19.64	4.86	17.45	4.41	–2.18	1.33	.002	**
Nasolabial angle, degrees	92.18	17.33	103.73	14.42	11.55	6.4	.000	***
E line–Ls mm	0.55	1.72	–1.86	1.32	–2.41	1.22	.000	***
E line–Li mm	2.55	4.24	–0.18	2.72	–2.73	2.4	.01	**

^a T1 indicates before initiation of retraction; T2, after complete space closure.

^b Sig indicates significance. * $P < .05$; ** $P < .01$; *** $P < .001$.

Table 4. Changes in Maxillary Intermolar and Inter canine Arch Widths (T2–T1^a)

Measurements, mm	T1		T2		T2–T1		<i>P</i>	Sig ^b
	Mean	SD	Mean	SD	Mean	SD		
Intermolar width	52.86	2.16	50.11	2.53	–1.76	1.32	.023	*
Inter canine width	36.21	1.91	36.13	1.78	–0.19	1.45	.456	NS

^a T1 indicates before initiation of retraction; T2, after complete space closure.

^b Sig indicates significance; NS, not significant; * $P \leq .05$.

assumption was that by the onset of menstruation, the majority of the growth is complete.⁸ Therefore, only preretracted and postretraction cephalograms (as opposed to pretreatment (T1) and posttreatment (T2) cephalograms) were included for the study so as to have a minimum time difference between the two set of records.

Dentoskeletal Effects

In the present study, a surgical approach to treatment was not desired by the patients or their families, and although the underlying sagittal jaw discrepancies in some cases were severe, the selective extraction of permanent teeth was considered acceptable. The

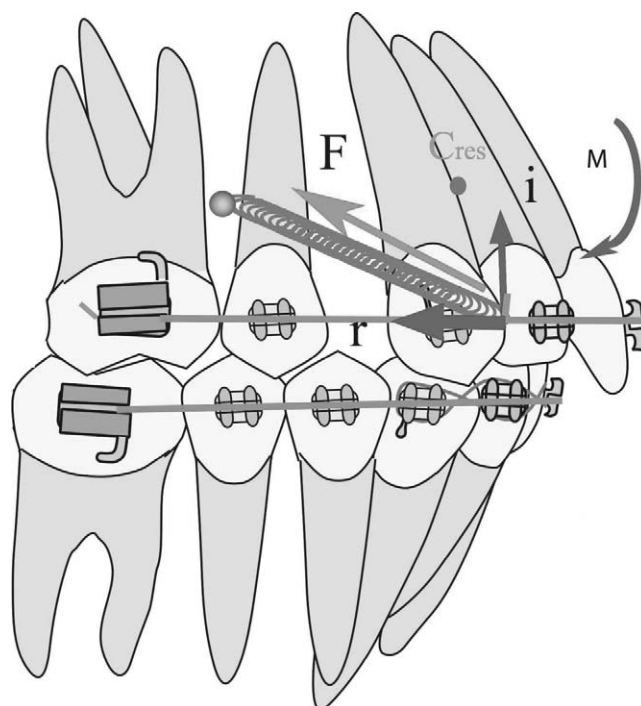
Table 5. Ratio of Maxillary Incisor Retraction to Soft Tissue Retraction

Ratio	Mean	SD	<i>r</i>
U1-Sv/G-SN-Pg	2.36	0.97	.32
U1-Sv/Nasolabial angle	0.63	0.38	-.6
U1-Sv/Ls	2.23	0.95	.8
U1-Sv/Li	1.67	0.83	.49

mini-implants maintained absolute anchorage and enabled simultaneous retraction of all six anterior teeth, into the extraction spaces to correct overjet ≥ 7 mm (range: 6–13.4 mm). Previously, with traditional mechanics, 1.6 mm to 4 mm of mesial movement of the molars has been noted.^{9,10} With the use of adjuncts for anchor preservation, up to 2.4 mm of anchor loss has been observed.^{11,12} In sharp contrast, our study showed a net distal and intrusive movement of the maxillary molar, although not significant ($P > .05$; Table 3). After space closure, the contact between the canine and second premolar was established. At this point any further continuation of the retraction force resulted in its transmission to the posterior segments through the interdental contacts.

The coil springs in the majority of cases were left in place for at least a couple of months after space closure to obtain a tight overjet or close some residual spaces. This might have caused some distal movement and intrusion of the molars as observed in the cephalometric radiograph. Also, the vertical vector of the total force can cause some binding (or increase the friction) of the archwire to the brackets or tubes, preventing sliding and causing the total force to be transmitted through the archwire to the entire dentition. Similar results have also been reported in recently published case reports.^{6,7}

Controlling the vertical plane during orthodontic treatment is often a difficult and unpredictable task. Although in our sample the UFH/LFH ratio decreased while PFH/AFH increased ($P < .05$; Table 2), indicative of a counter-clockwise rotation of the mandible, no significant change in the mandibular plane angle (SN-Go-Gn, PP-MP) or chin projection (Pog-Sv) was noted. This can perhaps be explained by the compensating eruption of the mandibular molars (0.52 ± 0.75 mm) in the lower arch. By focusing Class II correction on methods that control eruption and intrude teeth in both arches, greater amounts of true mandibular rotation and greater improvements in the chin projection might be expected, especially in high angle patients. It has been shown that posterior bite blocks and vertical chin cups, with or without headgear, can redirect condylar growth, increase posterior facial height, and reduce mandibular plane angles.^{13,14} However, with

**Figure 6.** Schematic representation of the force system involved: F = total force; i = intrusive force; r = retractive force; M = moment of force.

such techniques patient compliance is always an issue.

A small, but statistically significant level of intrusion was observed for the maxillary incisors (-1.32 ± 1.08 mm). The force (F) exerted by the nickel-titanium coil springs (bilaterally) had two distinct components to it: a larger and predominantly retractive force (r) and a smaller intrusive force (i), causing en masse retraction and some intrusion of the anterior teeth (Figure 6). Despite extensive retraction of maxillary anterior teeth, there was no change in the SNA angle ($-0.18 \pm 1.23^\circ$). Insufficient torque control over the incisors during retraction might have been the cause. As the retraction force was below the estimated center of resistance¹⁵ (Cres), a clockwise moment (M) on the anterior segment was produced. Besides, a 0.017×0.025 -inch SS archwire was used for retraction, which shows about 15° of play¹⁶ in a 0.022-inch slot, making torque control over the retracting incisors difficult. We could have supplemented the retraction unit with a torquing auxiliary for augmenting translatory mechanics, but that would have created additional forces on the maxillary arch, thereby compromising the true effects of skeletal anchorage.

In the transverse dimension, the maxillary arch did not show any significant changes when measured at the intercanine width. However, a statistically significant decrease in the intermolar width was noted (Table

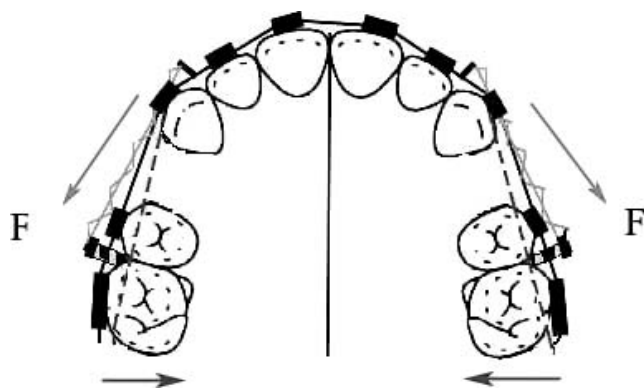


Figure 7. Schematic description of the force system, which might have caused a reduction in the intermolar width (T2-T1).

5). This can be attributed to the deformation that took place in the rectangular archwire because of the distal pull exerted by the coil springs (Figure 7). As the force was buccal to the Cres of the posterior segments, it caused the posterior teeth to move inward, resulting in a decrease in the overall intermolar width. This effect can be counterbalanced by using a transpalatal arch or by applying a buccal crown torque on the molar.

Soft Tissue Effects

Significant changes were observed in all measured soft tissue parameters. A mean increase of 11.5° was observed for the nasolabial angle, while the upper and lower lips were retracted by 2.41 mm and 2.73 mm, respectively (Table 3). In a study by Luecke and Johnston,³ the upper and lower lips were retracted by 2.2 mm and 1.4 mm, respectively, relative to the E plane in upper premolar extraction cases. Paquette et al¹⁷ found only 0.7 mm retraction of the upper lip relative to the E plane. Demir et al¹⁸ reported mean retraction of 1.31 mm and 0.52 mm for the upper and lower lips, respectively. The increased retraction of the lips in the current sample was primarily due to the strict retraction requirements of the patient sample and larger mean maxillary incisor retraction.

It has been suggested that the way anchorage is managed, not the mere extraction of teeth, determines the magnitude of anterior dental retraction and the resulting change in lip position.¹⁹ Additionally, the upper incisors tipped lingually more than they were bodily retracted, causing increased lip retraction. It would be interesting to mention that despite extensive retraction, the mean scores for the upper and lower lips were well within Ricketts' esthetic ideal.²⁰ Taking into account the flexible and mobile lip texture, a rather large variability in lip position can be expected on the lateral cephalogram, even when patients are instructed to keep their lips relaxed and their teeth in occlusion.²¹ An inability to quantify this variable remains a draw-

back of this study. Also, lip response as a proportion of incisor retraction decreases as the amount of incisor retraction increases, indicating that lips have some inherent support.²² The more regional effect of incisor retraction should be expected because even with orthognathic surgery, soft tissue changes decrease as the distance from the surgical site increases.

On a broader perspective, the final outcome of this study further widens the application of mini-implant anchorage, especially in patients showing moderate to severe Class II malocclusions. The possibility of using mini-implants as an alternative to orthognathic surgery in borderline cases should be further explored in the near future.

CONCLUSION

- Mini-implants placed in the maxillary interraderic bone provided absolute intraoral skeletal anchorage and helped to bring about greater levels of skeletal, dental, and soft tissue changes.

REFERENCES

1. Bishara SE, Cummins DM, Jakobsen JR, Zaher AR. Dentofacial and soft tissue changes in Class II division 1 cases treated with and without extractions. *Am J Orthod Dentofacial Orthop.* 1995;107:28–37.
2. Rock WP. Treatment of Class II malocclusions with removable appliances. Part 4. Class II division 2 treatment. *Br Dent J.* 1990;168:298–302.
3. Luecke PE, Johnston LE. The effect of maxillary first premolar extraction and incisor retraction on mandibular position: testing the central dogma of "functional orthodontics". *Am J Orthod Dentofacial Orthop.* 1992;101:4–12.
4. Roberts WE, Nelson CL, Goodacre CJ. Rigid implant anchorage to close a mandibular first molar extraction site. *J Clin Orthod.* 1994;28:693–704.
5. Choi BH, Zhu SJ, Kim YH. A clinical evaluation of titanium miniplates as anchors for orthodontic treatment. *Am J Orthod Dentofacial Orthop.* 2005;128:382–384.
6. Park HS, Kwon TG. Sliding mechanics with microcrew implant anchorage. *Angle Orthod.* 2004;74:703–710.
7. Park HS, Bae SM, Kyung HM, Sung JH. Micro-implant anchorage for treatment of skeletal Class I bialveolar protrusion. *J Clin Orthod.* 2001;35:417–422.
8. Proffit WR, Fields HW. *Contemporary Orthodontics*. 3rd ed. St Louis, Mo: Mosby Inc; 2000:94–112.
9. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. *Am J Orthod Dentofacial Orthop.* 1989;95:99–106.
10. Thiruvengkatachari B, Pavithranand A, Rajasigamani K, Kyung HM. Comparison and measurement of the amount of anchorage loss of the molars with and without the use of implant anchorage during canine retraction. *Am J Orthod Dentofacial Orthop.* 2006;129:551–554.
11. Baker RW, Guay AH, Peterson HW Jr. Current concepts of anchorage management. *Angle Orthod.* 1972;42:129–138.
12. Gjessing P. Biomechanical design and clinical evaluation of new canine-retraction spring. *Am J Orthod.* 1985;87:353–362.
13. Melsen B, McNamara JA Jr, Hoenie DC. The effect of bite-

- blocks with and without repelling magnets studied histomorphologically in the rhesus monkey (*Macaca mulatta*). *Am J Orthod Dentofacial Orthop*. 1995;108:500–509.
14. Majourau A, Nanda R. Biomechanical basis of vertical dimension control during rapid palatal expansion therapy. *Am J Orthod Dentofacial Orthop*. 1996;106:322–328.
 15. Melsen B, Fotis V, Burstone CJ. Vertical force considerations in differential space closure. *J Clin Orthod*. 1990;24:678–683.
 16. Sebanc J, Brantley WA, Pinesak JJ, Conover JP. Variability of effective root torque as a function of edge bevel on orthodontic archwires. *Am J Orthod*. 1984;86:43–51.
 17. Paquette DE, Beathie JR, Johnston LE. A long-term comparison of non extraction and premolar extraction edgewise therapy in borderline Class II patients. *Am J Orthod Dentofacial Orthop*. 1992;102:1–14.
 18. Demir A, Uysal T, Sari Z, Basciftci FA. Effects of camouflage treatment on dentofacial structures in Class II division 1 mandibular retrognathic patients. *Eur J Orthod*. 2005;27:524–531.
 19. Burstone CJ. The segmented arch approach to space closure. *Am J Orthod*. 1982;82:361–363.
 20. Ricketts RM. Esthetics, environment and the law of lip relation. *Am J Orthod*. 1968;54:272–289.
 21. Hillesund E, Fjeld D, Zacchrisson BU. Reliability of soft-tissue profile in cephalometrics. *Am J Orthod*. 1978;74:537–550.
 22. Wisth PJ. Soft tissue response to upper incisor retraction in boys. *Br J Orthod*. 1974;1:199–204.