Original Article

Effect of Varying the Force Direction on Maxillary Orthopedic Protraction

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Abstract: The aim of this study was to examine the effect of varying the force direction on maxillary protraction. A total of 20 patients with class III maxillary retrognathism were randomly divided into two groups. Group 1 was comprised of nine patients with a mean age of 8.58 years, and group 2 was composed of 11 patients with a mean age of 8.51 years. Both groups received a cap splint–type rapid palatal expander and the screw was activated twice a day for 10 days. After the expansion procedure the face mask protraction procedure was initiated. In group 1, we applied the force intraorally from the canine region with a forward and downward direction at a 30° angle to the occlusal plane. In group 2, the force was applied extraorally 20 mm above the maxillary occlusal plane. In both groups a unilateral 500 g force was applied and the patients were instructed to wear the face mask for 16 h/d for the first three months and 12 h/d for the next three months. The Wilcoxon sign rank test was used to evaluate the effect of the two different face masks, and a Mann-Whitney *U*-test was carried out to evaluate the differences between the two groups. The results showed that both force systems were equally effective to protract the maxilla; however, in group 1 we observed that the maxilla advanced forward with a counter-clockwise rotation. In group 2 we observed an anterior translation of maxilla without rotation. The dental effects of both methods were also different. The maxillary occlusal plane did not rotate in group 1, in contrast to the clockwise rotation in group 2. The maxillary incisors were proclined slightly in group 1, but in contrast they were retroclined and extruded in group 2. In conclusion, the force application from near the center of resistance of the maxilla was an effective method to prevent the unwanted side effects, such as counter-clockwise rotation of the maxilla, in group 1. The group 2 results suggest that this method can be used effectively on patients who present as class III combined with an anterior open bite. (*Angle Orthod* 2002;72:387–396.)

Key Words: Class III; Maxillary retrognathia; Face mask; Protraction headgear; Biomechanics

INTRODUCTION

The incidence of skeletal class III malocclusion is rather small in the population, but it is one of the most difficult malocclusions to treat. Class III malocclusions are often seen with maxillary retrognathia, mandibular prognathia, or a combination of both. According to Ellis and McNamara[1] and Sue et al,[2] maxillary retrognathism is present in 62% to 67% of all class III patients, making the face mask one of the main treatment modalities in class III maxillary retrognathic preadolescent and adolescent patients.

Many investigators have reported on the results of maxillary retrognathic patients treated with face masks.[3–32] The majority of these studies noted a counterclockwise rotation of the maxilla with the protraction headgear treatment.[14–17,27,32–41] Although this rotation was a benefit in the treatment of low-angle, deep-bite class III patients, it is not indicated in class III cases with high-angle skeletal patterns and anterior open bites. In order to eliminate these unwanted side effects,[20,42–44] some investigators have applied the protraction force at an angle of 30° downward from the occlusal plane. Other investigators have assessed the effects of force application using different points of force application for maxillary protraction. They experimented with applying the force from the buccal area of the molar, canine, and lateral incisor region while still applying the force close to the level of the occlusal plane.[14,20,36,37,42,44,45–48]

Some investigators tried to pinpoint the center of resistance of the maxilla in order to find better ways of con-

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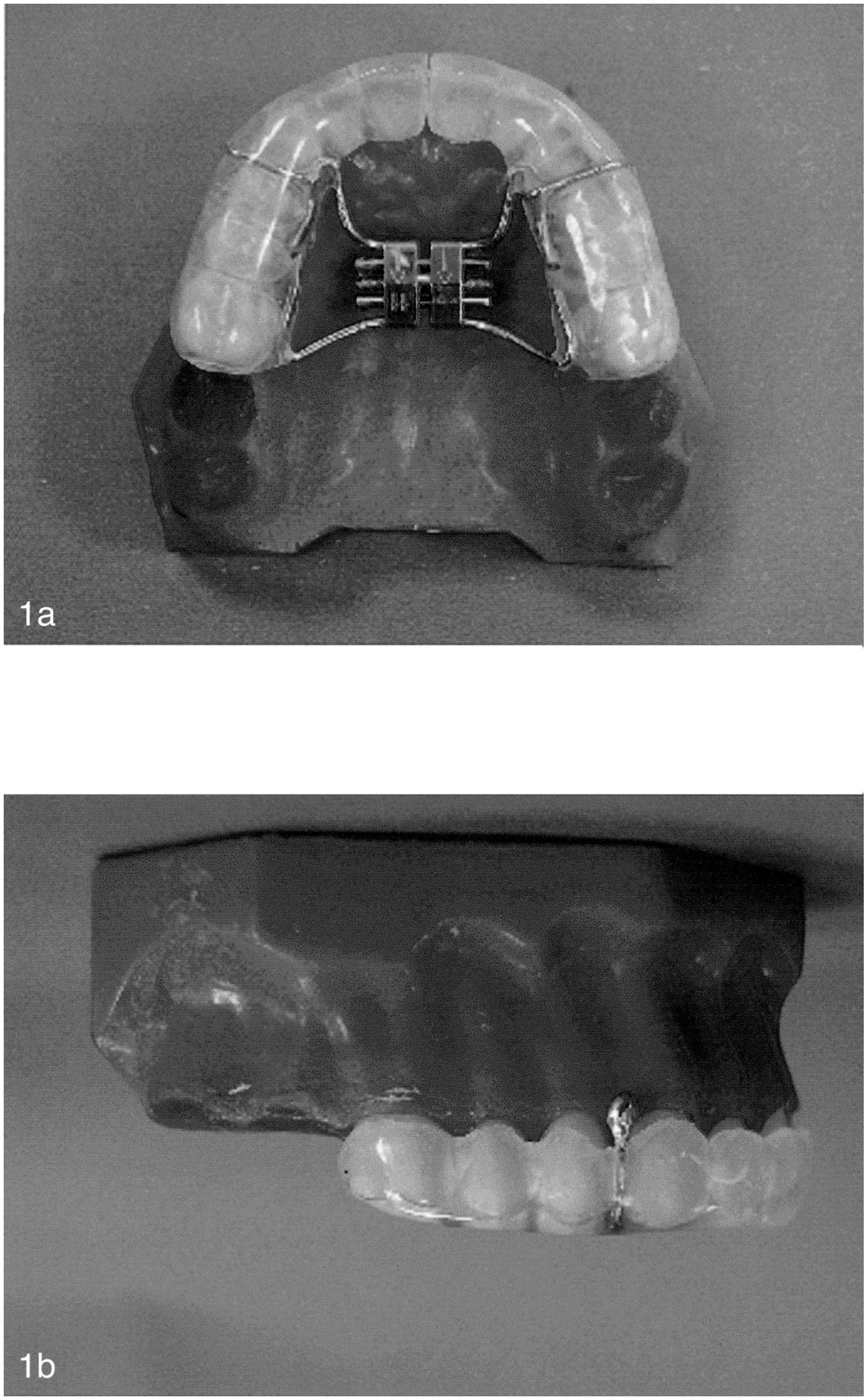


FIGURE 1. (a) Occlusal view of acrylic cap splint expander used for group 1. (b) Side view of the acrylic cap splint expander used for group 1 (note the hooks for elastic engagement).

trolling the maxillary rotations. According to Tanne and Hiroto,[49,50] the center of resistance of the maxilla is located between the root tips of the upper first and second premolars. Staggers et al[33] found it to be at the level of the zygomatic buttress, whereas Miki[51] found it to be between the first and second premolars in the postero-anterior direction and between the orbit and the distal root apex of first molars vertically. According to Hata et al,[52] the center of

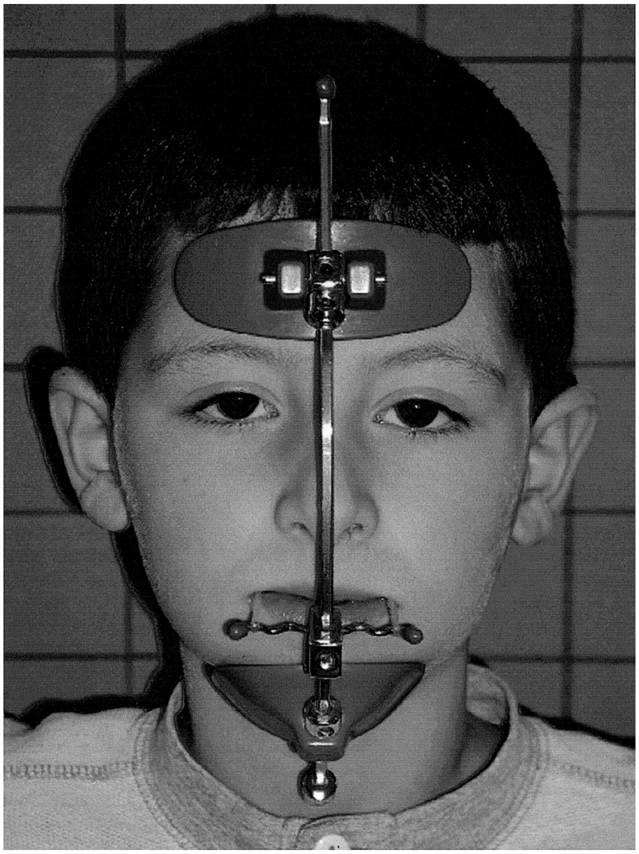


FIGURE 2. Extraoral frontal view of face mask application in group 1 (note intraoral force application).

resistance of the maxilla is located 5 mm above the nasal floor. They studied the effects of changing the level of force application on the maxilla in protraction procedures. Studies were done on dried skulls and face masks were used while applying the force from different levels ranging from 5 mm under the occlusal plane to 10 mm above the Frankfort horizontal plane. The researchers found that applying the force from a point 5 mm above the palatal plane and 15 mm above the occlusal plane resulted in elimination of the counterclockwise rotation effect on the maxilla. Some investigators experimented with several appliances, applying the force extraorally in order to carry the point of force application to a higher level and thus eliminating the unwanted counterclockwise rotation.[33,35,53] Nanda[35] introduced a modified protraction face bow design in order to deliver the protraction forces from a higher level and was able to eliminate the counterclockwise rotation of the maxilla. Staggers[33] also reported on the Nanda modified protraction headgear. Recently another design named the Modified Maxillary Protraction Headgear was introduced. The investigators applied the force above the eyes at the level of the frontal region with a specially designed face bow to prevent a counterclockwise rotation of the maxilla. Their results showed that the appliance is effective to protract the maxilla with significant clockwise rotation.[53]

The aim of this study was to assess the effects of varying force direction on maxillary orthopedic protraction. For group 1, the protraction force was applied intraorally from the canine region, and in group 2 the protraction force was applied with a modified face bow extraorally from a higher level.

MATERIALS AND METHODS

Case selection

Twenty patients who applied for orthodontic treatment at the Marmara University Department of Orthodontics were divided randomly into two groups. Group 1 consisted of nine patients (four boys and five girls) who were treated with the classical protraction face mask. The ages of the group 1 patients ranged from 7.3 to 10.8 years, with an average age of 8.58 years. Group 2 consisted of 11 patients (six boys and five girls) who were treated with the modified protraction headgear; the ages ranged from 7.8 years to 10.9 years, with an average age of 8.51 years. The skeletal maturation age was assessed with hand wrist radiographs. The sesamoid bone of the thumb was not present in any patient, and consequently all of the patients were classified as at a prepeak period of skeletal growth.

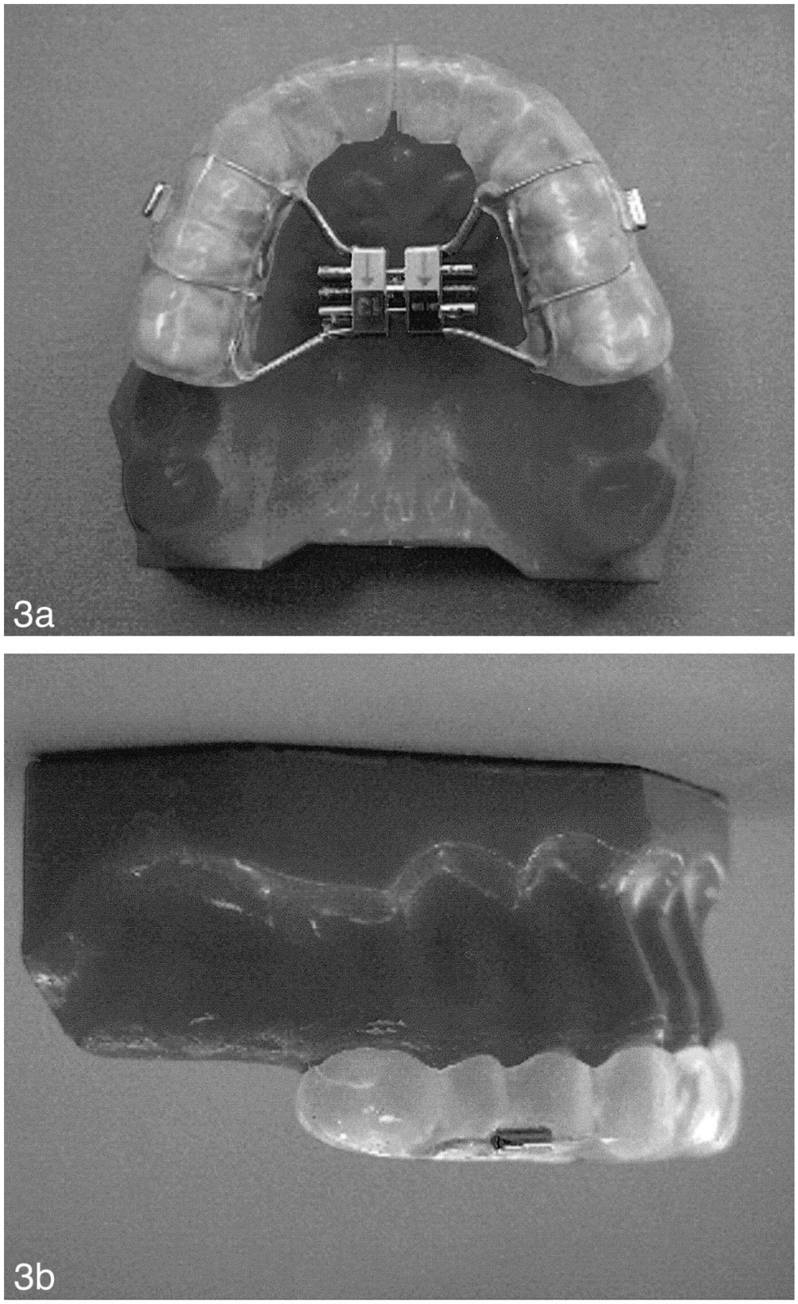
The patients in both groups were selected according to the following inclusion criteria:

1. Healthy patients without any hormonal or growth discrepancy;
2. Anterior cross bite with class III molar relationship;
3. True class III patients (pseudo or functional class III patients were excluded);
4. Class III patients with maxillary retrognathism were selected for treatment.

Appliance design

In group 1, a conventional face mask was applied. This consisted of a cap splint–type rapid palatal expander that was modified by adding two hooks in the canine area (Figure 1a,b). The purpose of these hooks was to hold the elastics in place for protraction. The protraction headgear was a Petit type (Ormco Corporation, Glendore, Calif), and a force of 500 g was applied to each hook at a 30° angle to the occlusal plane (Figure 2).

The group 2 appliance was composed of three parts: a modified full-cover acrylic cap splint expansion appliance, a specially designed face bow, and a Petit type protraction headgear. The cap splint expansion appliance was modified by adding two tubes (3M Unitek, USA, item no. 325–303) on the buccal side of the acrylic in the premolar area (Figure 3a,b).[54] The tubes were soldered to the RME screw (Leone, item A620-09) and the acrylic was constructed. The purpose of these tubes was to accommodate the inner bows of the specially designed face bow. The face bow was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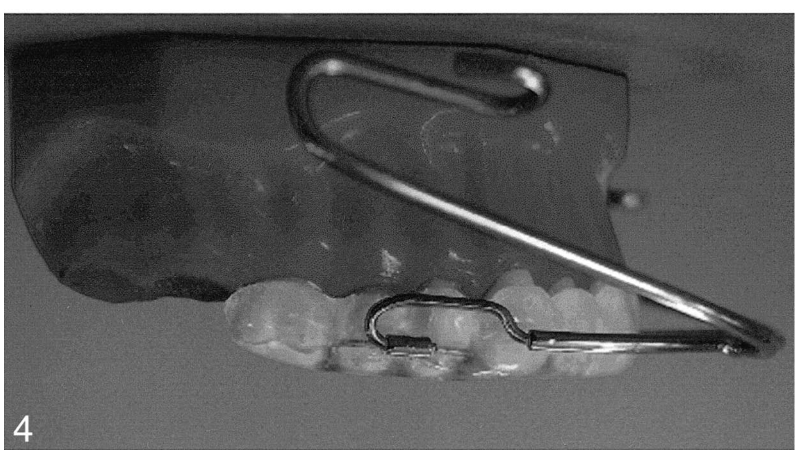
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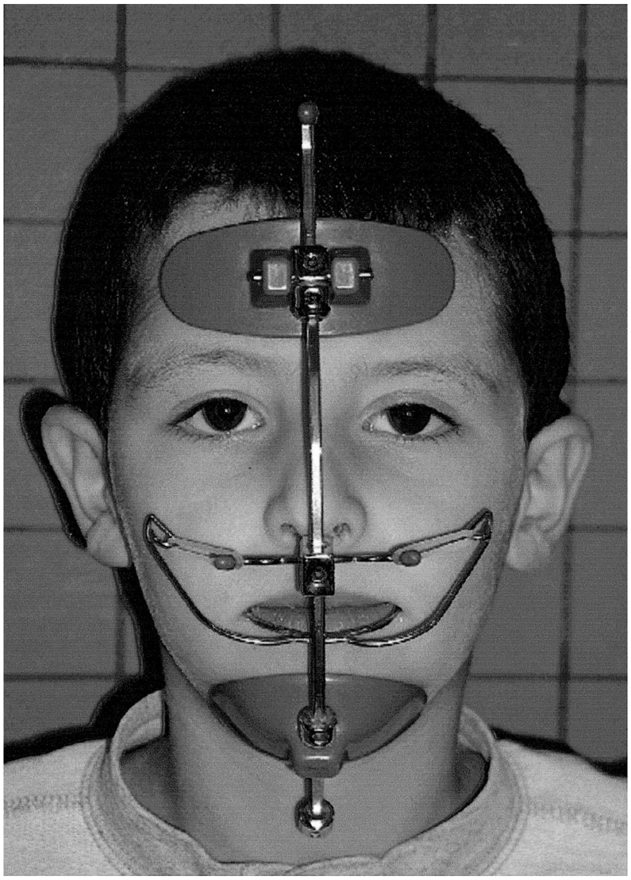

FIGURE 5. Extraoral frontal view of face mask application in group 2 (note the extraoral force application at a higher level).

constructed from an adjustable face bow (Ormco, item 200-0227 Glendora, CA, USA). The inner bows of the face bow ended in the mouth with a special *U*-shape bend in order to enter the buccal tubes from the distal, and thus be able to retain itself when an anterior pull was applied. In order to carry the level of force application above the occlusal plane, the outer bows of the face bow were bent in a 30° upward direction and ended with two hook bends in order to hold the elastics used for the face mask (Figure 4). These hooks were positioned around the root tips of the first and second premolars and 500 g of force was applied parallel to the Frankfort plane in an anterior direction. The same Petit-type face mask was used and the direction of the force was adjusted by moving the wire piece upward on the face mask for elastic engagement (Figure 5).

Treatment protocol

In both groups treatment was started with 10 days of rapid maxillary expansion. Following the expansion, a face mask was applied to the patients of both groups and the appliance was used for six months after the onset of treatment. Patients were advised to wear the face mask for a minimum of 16 h/d in the first three months and 12 hours in the second three months. In both groups a 500 g force was used. In group 1 it was angled downward 30° to the occlusal plane, whereas in the Nanda group 2 patients it was applied parallel to the Frankfort horizontal plane.

Cephalometric and statistical method

Lateral cephalometric films were taken both at the beginning and the end of treatment. Eighteen linear and angular cephalometric measurements were made for all patients. The measurements were statistically analyzed using the Wilcoxon signed rank test, and the results of both groups were cross-analyzed using a Mann-Whitney *U*-test. The Number Cruncher Statistical System (NCSS) computer software package was used.

RESULTS

At the end of the treatment the maxilla had moved anteriorly in both groups. SNA increased 3.11° ($P < .01$) in group 1 and 3.09° ($P < .01$) in group 2. ANS-TVr (true vertical) increased 1.44 mm ($P < .05$) in group 1 and 1.9 mm ($P < .05$) in group 2. The A-TVr distance increased 3 mm ($P < .01$) in group 1 and 2.45 mm ($P < .01$) in group 2.

In group 1, a counterclockwise rotation of the maxilla was observed, whereas in group 2 no rotation occurred. SN-PP decreased by 2.44° ($P < .05$) in group 1, but the SN-PP did not show any significant change in group 2. There were no significant changes in SN to the occlusal plane or palatal plane to the occlusal plane in group 1; however, these angles increased 8.91° and 11.09°, respectively, in group 2.

Due to the clockwise rotation of maxillary dentition, the maxillary incisors were retroclined in group 2, with the SN-U1 angle decreasing an average of 8° ($P < .01$). The upper incisors extruded 1.56 mm ($P < .05$) in group 1 and 6 mm ($P < .01$) in group 2. The cephalometric changes on each group and the evaluation of the differences between the two groups are presented in Tables 1–3. Cephalometric composite superimpositions of each group are presented in Figures 6 and 7.

DISCUSSION

Many investigators have stated that face masks were contraindicated in class III cases characterized by maxillary

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FIGURE 3. (a) Occlusal view of acrylic cap splint expander used for group 2. (b) Side view of the acrylic cap splint expander used for group 2 (note the tubes for face bow engagement).

FIGURE 4. Special design custom-made face bow engaged to the tubes on the cap splint in group 2.

TABLE 1. Changes That Occurred Between the Initial and the End of the Sixth Month in Group 1 (n = 9)[a]

	Initial		Sixth Month		Difference		Wilcoxon	
	X	S	X	S	D	S	*P*-Value	Significance
Angular								
SNA	79.22	2.54	82.33	2.18	3.11	1.05	0.0077	**
SNB	79.67	3.5	78.89	3.95	−0.78	1.48	0.138	
ANB	−0.44	2.4	3.44	2.35	3.89	1.17	0.0077	**
SN-PP	8	3.35	5.56	4.36	−2.44	2.35	0.018	*
SN-OP	19.44	3.43	18.44	4.39	−1	2.12	0.1834	
PP-OP	11.44	3.5	12.22	3.73	0.78	4.06	0.398	
Linear								
N per PA	−3.44	2.92	1.67	2.18	5.11	2.15	0.0077	**
ANS-Thr	40.33	2.4	40.78	2.54	0.44	1.94	0.3454	
PNS-Thr	39.33	2.4	41.78	1.56	2.44	1.24	0.0077	**
A-Thr	45.67	2	46.56	2.24	0.89	1.54	0.1282	
ANS-Tvr	67.44	3.43	68.89	4.57	1.44	2.07	0.0429	*
A-Tvr	59.44	4.33	62.44	4.25	3	0.87	0.0077	**
U1-SN	101.11	5.49	104.67	5.52	3.56	4.59	0.0663	
U1-PP	25	3.2	26.78	2.44	1.78	2.27	0.0587	
U1-Thr	65.22	3.19	66.78	4.12	1.56	1.67	0.0423	*
U6-PP	19.33	1.5	20.11	2.09	1	0.71	0.063	
U6-Thr	59.67	3.39	61.33	4.58	2.56	1.24	0.197	
U6-Tvr	33	3.84	37.89	4.54	4.89	1.69	0.0077	**

[a] Thr indicates true horizontal (7° correction of SN plane); Tvr, true vertical (90° line drawn to true horizontal); X, the mean value of the initial and the sixth month measurement; S, standard deviation; D, the mean value of the difference between the initial and sixth month measurements.
* $P < .05$.
** $P < .01$.

TABLE 2. Changes That Occurred Between the Initial Record and and the End of the Sixth Month in Group 2 (n = 11)[a]

	Initial		Sixth Mouth		Difference		Wilcoxon	
	X	S	X	S	D	S	*P*-Value	Significance
Angular								
SNA	77.18	3.12	80.27	4.15	3.09	1.7	0.0033	**
SNB	78.73	3	76.64	2.91	−2.1	1.58	0.008	**
ANB	−1.55	1.13	3.64	1.8	5.18	1.4	0.0033	**
SN-PP	7	3.87	7.27	4	0.27	0.65	0.1797	
SN-OP	22.18	4.73	31.09	4.13	8.91	4.59	0.0033	**
PP-OP	14.27	2.97	25.36	4.99	11.09	5.49	0.0033	**
U1-SN	100.27	6.92	92.27	4.17	−8	3.77	0.0033	**
Linear								
N per-PA	−3.09	2.84	2.27	2.53	5.36	1.75	0.0033	**
ANS-Thr	39.73	4.29	41.18	3.06	1.45	2.11	0.0425	*
PNS-Thr	40.36	3.44	42.45	3.53	2.09	0.7	0.0033	**
A-Thr	46.82	3.99	49.09	3.3	2.27	2.37	0.0152	*
ANS-Tvr	63.82	5.29	65.73	4.54	1.91	2.55	0.0469	*
A-Tvr	57.27	3.66	59.72	4.69	2.45	1.92	0.0077	**
U1-PP	25.91	1.87	30.55	2.11	4.64	2.06	0.0033	**
U1-Thr	65.91	4.53	71.91	3.78	6	2.49	0.0033	**
U6-PP	18.45	2.46	18.64	2.8	0.36	1.43	0.6726	
U6-Thr	59	4.84	60.83	4.94	1.82	1.08	0.05	
U6-Tvr	30.59	4.34	34.18	5.43	3.59	2.31	0.051	*

[a] Thr indicates true horizontal (7° correction of SN plane); Tvr, true vertical (90° line drawn to true horizontal); X, the mean value of the initial and the sixth month measurements; S, standard deviation; D, the mean value of the difference between the initial and sixth month measurements.
* $P < .05$.
** $P < .01$.

TABLE 3. Evaluation of the Differences Between the Two Groups[a]

	Group 1			Group 2				
	D	Significance	S	D	Significance	S	*P*-Value	Significance
Angular								
SNA	3.11	**	1.05	3.09	**	1.7	0.9697	
SNB	−0.78		1.48	−2.1	**	1.58	0.0742	
ANB	3.89	**	1.17	5.18	**	1.4	0.0527	
SN-PP	−2.44	*	2.35	0.27		0.65	0.0021	**
SN-OP	−1		2.12	8.91	**	4.59	0.0002	***
PP-OP	0.78		4.06	11.09	**	5.49	0.0005	***
U1-SN	2.11		4.85	−8	**	5.8	0.0003	***
Linear								
N per PA	5.11	**	2.15	5.36	**	1.75	0.6214	
ANS-Thr	0.44		1.94	1.45	*	2.11	0.5433	
PNS-Thr	2.44	**	1.24	2.09	**	0.7	0.5688	
A-Thr	0.89		1.54	2.27	*	2.37	0.1837	
ANS-Tvr	1.44	*	2.07	1.91	*	2.55	0.0682	
A-Tvr	3	**	0.87	2.45	**	1.92	0.1715	
U1-PP	1.78		2.22	4.64	**	2.06	0.0109	*
U1-Thr	1.56	*	1.71	6	**	2.49	0.0014	**
U6-PP	1		0.97	0.36		1.43	0.5688	
U6-Thr	2.56		1.24	1.82		1.08	0.2909	
U6-Tvr	4.89	**	1.69	3.59	**	2.31	0.1024	

[a] Thr indicates true horizontal (7° correction of SN plane); Tvr, true vertical (90° line drawn to true horizontal); D, the mean value of the difference between the initial and sixth month measurements; S, standard deviation.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

retrognathism and an open-bite tendency.[25–28,38,43] The reason for this was the counterclockwise rotation of the maxilla that occurred in patients treated with face mask therapy. To prevent this counterclockwise rotation effect, several variations on the point and level of force application have been described. In this study two groups of patients were treated using two different face mask designs. The effects of each system were analyzed and a comparison of the effects of each group was made.

Treatment was started with 10 days of RME in both groups to release the surrounding sutures. This was intended to ease the protraction as well as contribute to the protraction by moving the maxilla forward.[18,35,38,40,41,53–58]

During the protraction procedure, rigid appliances are needed to withstand the heavy forces. For this purpose some investigators have used rigid wires,[18,27,29,59] whereas others used an acrylic cap splint.[30,54] Some investigators noted that increasing the number of teeth in the anchorage unit would increase the skeletal effect.[18,42,53,59,60] In this study a full-coverage acrylic cap splint–type RME appliance was used in order to increase the rigidity of the appliance, to prevent the occlusal interferences, and to maximize the skeletal effect of the protraction headgear.

In order to minimize the counterclockwise rotation produced by the protraction forces, investigators have changed the point of force application and the direction of the protraction forces. Some investigators applied the force from the canine region.[20,43,44] Spoiler[47] applied the force at the premolar or deciduous molar region. Others[45,46] moved the point of force application distal to the laterals, whereas some investigators[36,43] changed the direction of force at an angle of 15°–30° from the occlusal plane. All of these attempts showed that the counterclockwise rotation of the maxilla during protraction was unavoidable. Others noted that this was due to the fact that all of these attempts applied the force intraorally, and so they experimented with modified designs and appliances that enabled them to apply the force from a level higher than the palatal plane.

According to Tanne[49] and Hirato,[50] the center of resistance of the maxillary dentoalveolar complex is located between the root tips of maxillary first and second premolars. According to Staggers,[33] the center of resistance of the maxillary bone is at the level of the zygomatic buttress. According to Hata,[34] the center of resistance of the maxilla is located 5 mm above the nasal floor. In the literature variation has existed between the studies locating the center of resistance of the maxilla.

In our study, 500 g of force was applied for 16 h/d for the first three months and 12 h/d for the second three months. Haas[57] noted that in order to obtain orthopedic forces, the amount of force had to exceed one pound (454 g). Some investigators[20,31,39,40,61] have applied forces that varied between 300 and 800 g.

In this study the sagittal measurements showed that both methods were equally effective to protract the maxilla. In group 1, a counterclockwise forward and upward rotation

FIGURE 6. Cephalometric composite superimposition of the cases treated in group 1 (black line represents pretreatment, red line represents at the end of the sixth month).

FIGURE 7. Cephalometric composite superimposition of the cases treated in group 2 (black line represents pretreatment, red line represents at the end of the sixth month).

of the maxilla was observed during protraction. However, in group 2 the SN-PP angle did not change and the maxilla did not rotate while coming forward. When we compare the two groups, the differences become more significant ($P < .01$). This could be related to the level of point of force application. In group 1, the point of force application was located at the level of occlusal plane, which was below the center of resistance of the maxilla (Figure 2). In group 2, the point of force application was applied at a higher level that was 20 mm above the maxillary occlusal plane, and the line of force might pass through the center of resistance of the maxillary bone (Figures 4 and 5). If the force is applied such that the line of action passes through the center of resistance of an object, bodily movement of the object occurs.

The cant of the maxillary occlusal planes differed significantly between the two groups. In group 1, the cant of the maxillary occlusal plane did not change; however, in group 2 the maxillary occlusal plane rotated in a clockwise manner. This could be related again to the location of the point of force application. In group 1 the force was applied at the canine region with an angle of 30° downward. Thirty degrees of downward angulation might allow the force to pass between the root tips of first and second premolars.

As mentioned earlier, the center of resistance of the maxillary dento-alveolar complex is located between the root tips of the upper first and second premolars. In group 1, the line of force might pass through or near the center of resistance of the maxillary dento-alveolar complex because of the 30° downward angulation of the force vector. However, in group 2 the line of action passed above the center of resistance of the maxillary dento-alveolar complex.

There was a slight increase in the maxillary incisor inclination in group 1; however, the incisor retroclination was greater in group 2. If the two groups are compared, the differences became more significant. Again the retroclination of incisors in group 2 is related to the clockwise rotation of the maxillary dentition.

Our results suggest that the maxilla and the maxillary dentition are two separate units and their centers of resistance are not at the some location. Since the maxillary bone is connected to the other facial bones with sutures and the maxillary dentition is connected to the maxillary bone with periodontal attachments, they cannot be considered as one unit and they may behave differently with the application of two different protraction forces.

CONCLUSION

In summary:

1. An anterior advancement of the maxilla was achieved in both groups.
2. A counterclockwise rotation of the maxilla was observed in group 1.
3. An anterior translation of maxilla without rotation occurred in group 2.
4. The maxillary occlusal plane did not rotate in group 1; however, it rotated in a clockwise direction in group 2.
5. In group 2, the maxillary incisors extruded and retroclined because of the clockwise rotation of maxillary dentition.

In this study the effects of varying force direction on maxillary orthopedic protraction was assessed for six months and the results obtained are short-term outcomes. Further studies at the end of second-stage orthodontic treatment and the postretention period are required to examine the longer-term effects of the treatment.

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