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The effects of face mask therapy with and without rapid maxillary expansion in adolescent patients

İbrahim Yavuz, Koray Halıcıoğlu, İsmail Ceylan, İlhan Metin Dağsuyu and Abdulvahit Erdem
Department Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey

Objective: To examine the effects of face mask therapy with and without associated rapid maxillary expansion (RME) in adolescent patients presenting with skeletal Class III malocclusion characterised by maxillary retrognathism.
Methods: Case records consisting of lateral cephalograms and hand-wrist films of 43 patients with hypoplastic maxillary Class III malocclusions treated using a face mask with and without an RME were analysed. The patients were divided into two groups; Group A (N = 27) were treated with a face mask coupled with rapid maxillary expansion and patients in Group B (N = 16) were treated with a face mask appliance only. Ten cephalometric linear and 9 angular variables were measured to assess the dentofacial changes. Within group and between groups comparisons were determined by a paired *t*-test and Student's *t*-test, respectively.
Results: Forward displacement of the maxilla and a clockwise rotation of the mandible occurred in both groups. The maxillary-mandibular relationship improved and soft-tissue changes resulted in a more convex profile. The maxillary incisors moved forward only in Group B subjects but the mandibular incisors moved backward in both groups.
Conclusions: Face mask therapy with and without an associated RME improved skeletal Class III malocclusion by a combination of skeletal and dental changes. These results suggested that the use of an RME should be based on clinical criteria rather than assisting the Class III correction.
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Ibrahim Yavuz: iyavuz@erciyes.edu.tr; Koray Halıcıoglu: korayhalicioglu@hotmail.com; Ismail Ceylan: ismcyln@yahoo.com; iceylan@atauni.edu.tr; Ilhan Metin Dagsuyu: intraso@yahoo.com; Abdulvahit Erdem: aerdem@atauni.edu.tr

Introduction

A developing Class III malocclusion may be characterised by maxillary skeletal retrusion, mandibular skeletal protrusion, or a combination of both.[1] A posterior and/or anterior crossbite may also be present.[2,3] Ellis and McNamara[4] found that 65 to 67% of all Class III malocclusions were characterised by maxillary retrognathism. Common dental compensations often include maxillary dentoalveolar protrusion and mandibular dentoalveolar retrusion.[5] A midface deficiency is often apparent, as well as an increased lower incisor display and a prominent lower lip.[6]

In recent years, maxillary protraction treatment with and without rapid maxillary expansion has become a common technique for correcting maxillary retrusion. The popularity of face mask therapy has increased due to an awareness of maxillary deficiency as a component of the Class III structural aetiology.[5,7,8] Furthermore, maxillary expansion has been advocated as an important part of face mask protraction because it reportedly disrupts the circummaxillary sutural system and therefore facilitates the orthopaedic effect attempted by face mask therapy.[1,2,6,9,10] Additional benefits have been reported using rapid maxillary expansion in conjunction with maxillary protraction in treating hypoplastic maxillary Class III patients. These include transverse expansion to correct posterior crossbites, splinting of the maxillary dentition against forward movement and anterior constriction during protraction therapy, in addition to backward and downward rotation of the mandible which softens the Class III.[11] Disarticularion of the circummaxillary sutures is postulated to assist in the production of the orthopaedic effects. [6,7,12-15]

However, there is evidence that maxillary expansion alone may be beneficial in the treatment of certain types of Class III malocclusion, particularly in borderline Class III cases.[10,14] Haas[2,9] reported that maxillary expansion can produce a slight forward movement of the maxilla. It was also stated that, even though the patient had no transverse maxillary deficiency, expansion promoted maxillary protraction by disrupting the circummaxillary sutural system.[9] Furthermore, Jiang et al.[16] activated a rapid palatal expansion appliance 90 degrees twice a day for two weeks, after which the screw was reversed to its original position over a one-week period. It was considered that this procedure contributed substantially to maxillary protraction therapy.

Most studies of maxillary protraction have reported skeletal, dental and soft-tissue treatment effects, however the effects of maxillary expansion on protraction therapy have not been investigated. Therefore, the purpose of this study was to cephalometrically examine the skeletal, dental and soft-tissue effects of face mask therapy, with and without maxillary expansion, in adolescent patients.

Materials and methods

Sample

The material consisted of the lateral cephalograms, orthodontic models and hand-wrist films of 43 patients (26 females and 17 males) with skeletal Class III malocclusions as a result of maxillary deficiency. The patients were treated using a face mask with and without an associated RME in the Department of Orthodontics, Faculty of Dentistry, Ataturk University. The mean age of the patients was 12.26 ± 1.34 years. The initial cephalometric radiographs (T1) were obtained before treatment and the second (T2) after achieving a positive overjet and/or a Class I occlusion. The skeletal maturation stages of patients were assessed with hand-wrist radiographs and the use of Fishman's[17] skeletal maturity indicators (SMI). Patient inclusion criteria were zero or negative overjet, a Class III molar relationship, an ANB angle of 0 degrees or less and a Wits appraisal of -1 mm or less. Exclusion criteria were the presence of a craniofacial anomaly, the report of previous orthodontic treatment or a severe skeletal anterior open bite of more than -7 millimetres.

Methods

The patients were divided into two groups representing those who were treated with a face mask and a rapid maxillary expansion appliance (Group A: N = 27; 17 females, 10 males) and those patients who were treated with a face mask and a passive palatal device (Group B: N = 16; 9 females, 7 males). Patients who had a maxillary arch deficiency in conjunction with a severe posterior cross bite were included in Group A and patients in Group B consisted of mild and moderate maxillary arch deficiency cases determined by a model analysis. If a posterior cross bite was observed when the maxillary model was advanced to establish Class I occlusion, a maxillary expansion procedure was indicated.

RME device and procedure

A Hyrax (Forestadent, St. Louis, MO, USA), maxillary expansion appliance was used for each patient in Group A (Figure 1). The maxillary first premolars and the first permanent molars were banded. The appliance was constructed and soldered hooks extending to the mesial of the canine were incorporated for the attachment of the face mask elastics. Upon insertion, the appliance was activated twice daily (0.5 mm/day) for a minimum of seven days. Continued expansion depended on the need for increased upper arch width.

Figure 1. Hyrax type banded maxillary expander appliance.

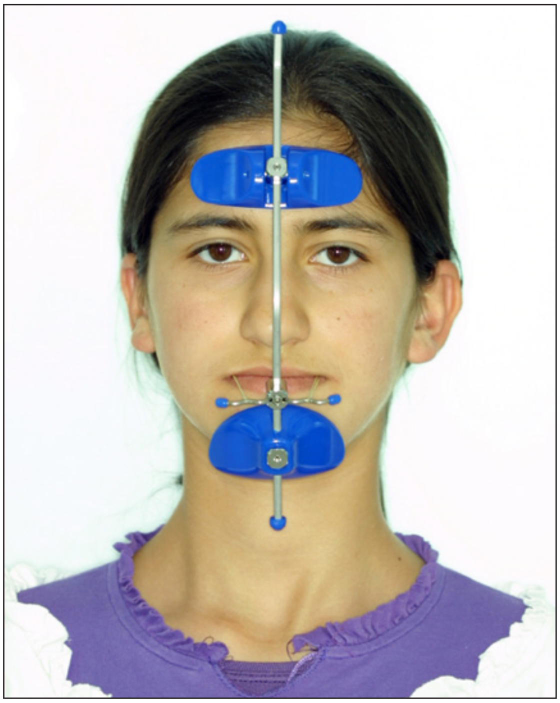

Figure 2. Petit type face mask appliance.

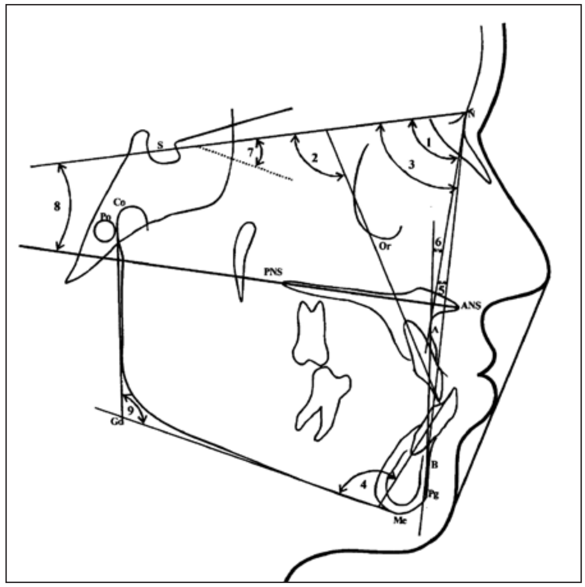

Figure 3. Angular measurements: (1) SNA; (2) maxillary incisor-SN; (3) SNB; (4) mandibular incisor-MP; (5) ANB; (6) convexity angle; (7) MPSN; (8) PP-SN; (9) gonial angle.

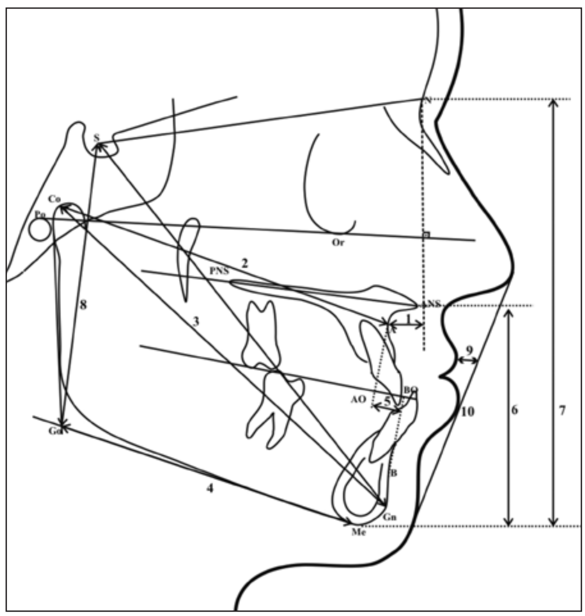

Figure 4. Linear measurements: (1) A-N perp; (2) Co-A; (3) Co-Gn; (4) Go-Me; (5) Wits; (6) LAFH; (7) TAFH; (8) TPFH; (9) UL-EL; (10) LL-EL

Protraction device and procedure

A Petit[18] type face mask (GAC Bohemia, NY, USA), employing 300 to 500 g of force per side was used for 16 hours a day (Figure 2). A force measurement gauge (Dentaurum, Ispringen, Germany) was used to adjust and maintain the magnitude of the applied force and patients were instructed to record the duration of wear per day. Maxillary protraction was instituted using forward and downward traction directed approximately 30 to 40 degrees to the maxillary occlusal plane. In Group B patients, intra-oral anchorage was provided via metal bands cemented to the maxillary first premolar and permanent molar teeth which were linked together by soldered 0.036 inch lingual and labial stainless steel wires. Hooks were placed in the maxillary canine region from which elastics extended to the face mask. All treatment was discontinued when the anterior crossbite was corrected.

Standardised lateral cephalometric radiographs were taken of the 43 patients before and after treatment with the same cephalometer and the same exposure specifications. Ten linear and nine angular variables were measured to assess the dentofacial changes (Figures 1 and 2). A cephalometric analysis was conducted using the Quick Ceph program (Quick Ceph Systems, San Diego, CA, USA) on a Macintosh PC.

Error of measurements

Twenty randomly selected radiographs were retraced and remeasured by the same investigator two weeks after the initial analysis. The method error was determined using the coefficient of reliability, calculated for each measurement: coefficient of reliability = $1\text{-}Se^2/St^2$ where Se^2 was the variance due to random error, and St^2 was the total variance of the measurements.[19]

Table I. Mean and standard deviations of chronological age and treatment period for each group, and the results of Student's *t*-test.

	Face mask + RME (Group A)		Face mask (Group B)			
	Mean	SD	Mean	SD	*t*	*p* value
Chronological age (Years)	12.67	1.31	12.02	1.33	1.566	.125
Treatment period (Months)	8.00	1.67	7.83	1.75	.307	.760

Table II. Mean and standard deviation of pretreatment and post-treatment measurements and the results of the paired t-test in the face mask and RME group.

	Pretreatment		Post-treatment		*t*	Significance
Variables	Mean	SD	Mean	SD		
Maxillary skeletal						
SNA (degrees)	77.44	3.80	79.67	4.34	-5.957	.000
A-N Perp (mm)	-4.93	4.05	-1.98	4.66	-5.028	.000
Co-A (mm)	84.56	4.26	87.98	4.67	-7.259	.000
Maxillary dental						
Maxillary incisor-SN (degrees)	106.04	6.09	106.03	5.96	.007	.994
Mandibular skeletal						
SNB (degrees)	82.01	4.71	80.11	4.78	6.592	.000
Co-Gn (mm)	119.51	5.86	121.98	6.70	-5.047	.000
Go-Me (mm)	74.07	3.30	76.46	3.51	-5.690	.000
Mandibular dental						
Mandibular incisor-MP (degrees)	82.04	6.61	77.28	7.40	5.451	.000
Maxillary-mandibular relationship						
ANB (degrees)	-4.58	2.82	-0.53	2.09	-6.630	.000
Convexity angle	-7.99	4.94	-2.48	4.44	-15.546	.000
Wits (mm)	-10.54	4.11	-5.54	4.17	-5.440	.000
Vertical relationship						
MP-SN (degrees)	33.58	5.92	36.66	5.58	-8.183	.000
PP-SN (degrees)	8.07	2.89	6.48	3.31	4.245	.001
Gonial angle	131.54	6.41	132.06	6.49	-1.049	.311
LAFH (mm)	68.05	6.09	73.24	6.28	-9.059	.000
TAFH (mm	121.79	7.61	127.57	7.83	-8.962	.000
TPFH (mm)	78.99	6.85	81.29	7.05	-5.962	.000
Soft tissue						
UL-E line (mm)	-6.66	1.49	-5.69	2.15	-2.818	.013
LL-E line (mm)	-3.01	1.27	-4.41	2.11	3.281	.005

Statistical analysis

Data were analysed using SPSS for Windows, version 10.0 (SPSS, Chicago, IL, USA). The means and standard deviations were calculated for all variables in each group at the pretreatment and post-treatment periods. A Kolmogorov-Smirnov test was applied for normality. As the sample demonstrated normal distribution, parametric tests were used for statistical evaluations. A paired *t*-test was used to determine the differences within the groups. In addition, the Student's *t*-test was applied to investigate the differences between groups. The level of statistical significance was set at 5 per cent ($p \leq 0.05$).

Results

The value of the coefficient of reliability was above 0.90 (range 0.90 - 0.98) for all measurements. The mean chronological age was 12.67 ± 1.31 years, and the mean treatment period was 8.00 ± 1.67 months for Group A. The mean chronological age was 12.02 ± 1.33 years and the mean treatment duration was 7.83 ± 1.33 months for Group B (Table I). No statistically significant differences were found between groups in the chronological ages and treatment periods.

Fishman's[17] system of hand-wrist skeletal maturation assessment indicated that patients in both groups were entering an accelerated growth phase (SMI 1-3). According to the Student's *t*-test, no statistically significant differences were found in the majority of the measurements used between the genders. Therefore, data from males and females were pooled. Descriptive statistics including means and standard deviations of pretreatment and post-treatment measurements and the results of the paired *t*-test are presented in Tables II and III, respectively. The results of the Student's *t*-test are provided in Table IV.

The changes in Group A (Face Mask with RME) were statistically significant except for the maxillary incisor-SN and gonial angle variables. The changes in Group B (Face Mask without RME) were statistically significant except for the gonial angle measurement. In both groups, the measurements of SNB, mandibular incisor-MP, PP-SN, and LL-E exhibited a significant decrease, whereas the other measurements showed a significant increase. Forward displacement of the maxilla and clockwise rotation of the mandible occurred in both groups. The upper lip moved forward in Group A patients while the lower lip moved backward in both groups. The maxillary incisors moved forward only in Group B while the mandibular incisors uprighted in both groups. The skeletal sagittal relationship showed improvement, and the soft-tissue changes resulted in a more convex profile. According to the Student's *t*-test, no statistically significant differences were found between Group A and Group B except for the measurements involving the maxillary incisor-SN and MP-SN.

Discussion

In recent years, face mask therapy with and without associated palatal expansion has become a common technique used to correct a developing hypoplastic maxillary Class III malocclusion.[20] Maxillary expansion has been advocated as a routine part of Class III treatment caused by maxillary deficiency,[1,6,21] however, a critical evaluation of expansion in conjunction with maxillary protraction has been limited. Therefore, the aim of the present study was to examine the skeletal, dental and soft-tissue effects of face mask therapy with and without associated maxillary expansion. The results of the present study indicated that face mask therapy with and without RME induced significant skeletal and dentoalveolar changes in adolescent Class III patients. The changes included a significant amount of maxillary forward movement supported by an increase in the SNA angle, A-N perpendicular and Co-A distances in both treatment groups. These findings have been previously reported as a result of maxillary protraction via face mask therapy.[11,22-28] There was a statistically significant correction in the maxillary-mandibular relationship and soft-tissue profile in both treatment groups. This correction was a result of an increase in the ANB angle and Wits appraisal and a decrease in the SNB angle. The downward and forward movement of the maxilla and the downward and backward rotation of the mandible improved the maxillomandibular skeletal relationship and the convexity of the profile. Clinical studies focusing on maxillary protraction described forward and downward movement of the maxilla and a clockwise rotation of the mandible.[1,6,20,26,29-31] Mandibular rotation may be due to vertical maxillary movement or a retractive force on the chin. The mandibular rotation resulted in an increase in lower anterior facial height. In the present study, statistically significant increases were found in the lower and total anterior facial heights for both groups.

Table III. Mean and Standard Deviation of pretreatment and post-treatment measurements and the results of the paired *t*-test in the face mask group.

	Pretreatment		Post-treatment		*t*	Significance
Variables	Mean	SD	Mean	SD		
Maxillary skeletal						
SNA (degrees)	77.06	2.86	78.91	2.77	-6.819	.000
A-N Perp (mm)	-5.72	3.42	-3.78	3.58	-6.617	.000
Co-A (mm)	84.15	4.17	87.48	4.72	-4.928	.000
Maxillary dental						
Maxillary incisor-SN (degrees)	101.06	6.52	105.88	5.80	-6.823	.000
Mandibular skeletal						
SNB (degrees)	79.55	2.99	78.20	3.04	4.866	.000
Co-Gn (mm)	115.53	5.11	118.73	5.81	-3.527	.002
Go-Me (mm)	73.76	3.53	76.72	4.43	-3.966	.001
Mandibular dental						
Mandibular incisor-MP (degrees)	84.16	6.81	79.70	4.80	7.013	.000
Maxillary-mandibular relationship						
ANB (degrees)	-2.46	1.85	0.71	1.45	-11.740	.000
Convexity angle	-5.69	4.71	-0.31	4.09	-7.608	.000
Wits (mm)	-8.53	3.79	-4.62	3.41	-6.702	.000
Vertical relationship						
MP-SN (degrees)	36.66	4.30	38.37	4.89	-5.473	.000
PP-SN (degrees)	8.86	4.08	7.21	4.47	5.342	.000
Gonial angle	125.30	20.82	125.45	20.51	-.333	.742
LAFH (mm)	68.03	4.71	72.70	4.79	-10.130	.000
TAFH (mm	121.49	6.18	126.46	6.04	-8.415	.000
TPFH (mm)	76.06	5.97	78.19	5.77	-6.673	.000
Soft tissue						
UL-E line (mm)	-6.68	1.89	-5.09	2.54	-6.246	.000
LL-E line (mm)	-1.93	2.67	-2.61	2.35	2.320	.028

Soft-tissue changes combined to improve the Class III profile. The upper lip showed forward movement, whereas the lower lip demonstrated backward movement in both groups. The observed soft-tissue effects appeared to result from the induced skeletal changes. The maxillary incisors proclined during treatment in the face mask group, whereas these teeth showed no significant changes in the face mask with the RME group. This finding may be due to the expansive effect of the RME in the maxillary anterior segment. However, the mandibular incisors retroclined, despite the fact that no mechanical treatment was applied. This effect may be due to soft-tissue pressure from the chin-cup component of the face mask appliance. The present findings are consistent with the observation by Kapust et al.[26] who reported, in addition to skeletal changes in the maxilla and mandible, that dental effects included forward movement of the maxillary incisors and retroclination of the lower incisors.

Clinicians have advocated maxillary expansion a week before starting face mask use, even in the absence of maxillary constriction or crowding. However, the effects of the palatal expansion on maxillary protraction have been disputed. Baik[29] and Sung and

Table IV. The results of Student's *t*-test regarding the differences between treatment groups.

Variables	Face mask and RME Mean	Face mask and RME SD	Face mask Mean	Face mask SD	*t*	Significance
Maxillary skeletal						
SNA (degrees)	-2.23	1.50	-1.85	1.41	-.833	.410
A-N Perp (mm)	-2.94	2.34	-1.94	1.53	-1.697	.097
Co-A (mm)	-3.43	1.89	-3.33	3.51	-.100	.921
Maxillary dental						
Maxillary incisor-SN (degrees)	0.06	3.35	-4.82	3.67	4.302	.000
Mandibular skeletal						
SNB (degrees)	1.91	1.16	1.35	1.44	1.317	.195
Co-Gn (mm)	-2.47	1.96	-3.21	4.73	.594	.556
Go-Me (mm)	-2.39	1.68	-2.96	3.88	.561	.578
Mandibular dental						
Mandibular incisor-MP (degrees)	4.42	3.89	4.46	3.30	-.036	.971
Maxillary-mandibular relationship						
ANB (degrees)	-4.05	2.44	-3.17	1.40	-1.498	.142
Convexity angle	-4.76	1.63	-5.38	3.67	.638	.527
Wits (mm)	-5.01	3.68	-3.91	3.03	-1.057	.297
Vertical relationship						
MP-SN (degrees)	-3.08	1.51	-1.71	1.62	-2.745	.009
PP-SN (degrees)	1.59	1.50	1.65	1.60	-.123	.903
Gonial angle	-0.51	1.95	-0.14	2.26	-.542	.590
LAFH (mm)	-5.19	2.29	-4.68	2.40	-.685	.497
TAFH (mm	-5.78	2.58	-6.44	5.44	.459	.649
TPFH (mm)	-2.30	1.54	-2.13	1.66	-.342	.734
Soft tissue						
UL-E line (mm)	-0.97	1.37	-1.59	1.32	1.459	.152
LL-E line (mm)	1.39	1.70	0.68	1.53	1.418	.164

Baik[32] analysed face mask therapy using a passive, rigid labio-lingual appliance and an active rapid palatal expander. Statistically significant differences were evident between the two groups as greater forward and downward movement occurred in the expansion group at A- point. However, the present results showed no statistically significant differences between Groups A and B in any measured variable except for the measurements of maxillary incisor-SN and MP-SN. No statistically significant differences in overall treatment time or in the correction time of the anterior crossbite were found.

The study results suggested that, in the absence of objective reasons for expansion such as width or space deficiencies, maxillary expansion did not assist in the face mask correction of Class III malocclusions caused by maxillary deficiency. In the present study, no control group was used to differentiate treatment effects from normal growth. Class I subjects have been previously used as controls, however dentoalveolar and skeletal growth trends in subjects with Class III malocclusions differ from those of normal subjects and therefore Class I control groups are not suitable for comparison with Class III treatment groups.[25,33,34] In addition, Shanker et al.[34] reported that A point advanced 0.2 mm in 6 months in an untreated Class III control sample. In the present study, the total treatment period was 8 months for Group A (face mask with RME) and 7.83 months for Group B (face mask without RME) and so growth effects over the duration of treatment were considered negligible. However, the results demonstrated a significant response to face mask therapy, with or without rapid maxillary expansion. In agreement with previous reports, skeletal changes were a combination of anterior and vertical movement of the maxilla, with corresponding downward and backward rotation of the mandible.[15,31,35] However, different results have been reported,[23,29,33] which may be attributed to differences in study design, appliance design, treatment duration and treatment goals.

Conclusions

1. The correction of a skeletal Class III malocclusion characterised by maxillary deficiency using face mask therapy (with or without RME) appears to result from a combination of skeletal and dental changes in adolescent patients.
2. Skeletal change was a combination of anterior and vertical movement of the maxilla, and posterior and downward rotation of the mandible. Dental changes also contributed to the correction, while soft-tissue changes produced a more convex profile.
3. It is concluded that expansion does not specifically aid face mask therapy in the correction of Class III malocclusions.
4. These findings confirm that the indication for RME should be based on clinical criteria other than assisting the Class III correction.

Corresponding author

Professor Dr İsmail Ceylan
Department of Orthodontics
Atatürk University
25240, Erzurum
Turkey

Email: iceylan@atauni.edu.tr

References

1. McNamara JA Jr. An orthopaedic approach to the treatment of Class III malocclusion in young patients. J Clin Orthod 1987;21:598-608.
2. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. Am J Orthod 1970;57:219-55.
3. Haas AJ. Rapid palatal expansion: A recommended prerequisite to Class III treatment. Trans Eur Orthod Soc 1973:311-18.
4. Ellis EE, McNamara JA Jr. Components of adult Class III openbite malocclusion. Am J Orthod 1984;86:277-90.
5. Williams S, Andersen CE. The morphology of the potential Class III skeletal pattern in the growing child. Am J Orthod 1986;89:302-11.
6. Turley PK. Orthopedic correction of Class III malocclusion with palatal expansion and custom protraction headgear. J Clin Orthod 1988;22:314-25.
7. Guyer EC, Ellis EE, McNamara JA Jr, Behrents RG. Components of Class III malocclusion in juveniles and adolescents. Angle Orthod 1986;56:7-30.
8. Sue G, Chaconas SJ, Turley PK, Itoh J. Indicators of skeletal Class III growth. J Dent Res 1987;66 (special issue):348.
9. Haas AJ. Treatment of maxillary deficiency by opening the midpalatal suture. Angle Orthod 1965;65:200-17.
10. McNamara JA Jr, Brudon WL. Orthodontic and orthopedic treatment in the mixed dentition. Ann Arbor, Michigan. Needham Press 1993, pp:67-177.
11. Ngan P, Hagg U, Yiu C, Merwin D, Wei SH. Soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment. Am J Orthod Dentofacial Orthop 1996;109:38-49.
12. Turley PK. Orthopedic correction of Class III malocclusion: retention and phase II therapy. J Clin Orthod 1996;30:313-24.
13. Da Silva Filho OG, Magro AC, Filho L. Early treatment of the Class III malocclusion with rapid maxillary expansion and maxillary protraction. Am J Orthod Dentofacial Orthop 1998;113:196-203.
14. Baccetti T, McGill JS, Franchi L, McNamara JA Jr, Tollaro I. Skeletal effects of early treatment of Class III malocclusion with maxillary expansion and face mask therapy. Am J Orthod Dentofacial Orthop 1998;113:333-43.
15. Baccetti T, Franchi L, McNamara JA Jr. Treatment and post-treatment craniofacial changes after rapid maxillary expansion and face mask therapy. Am J Orthod Dentofacial Orthop 2000;118:404-13.
16. Jiang J, Lin J, Ji C. Two-stage treatment of skeletal Class III malocclusion during the early permanent dentition. Am J Orthod Dentofacial Orthop 2005;128:520-7.
17. Fishman LS. Radiographic evaluation of skeletal maturation: a clinically oriented method based on hand-wrist films. Angle Orthod 1982;52:88-112.
18. Petit HP. Adaptation following accelerated facial mask therapy. In: McNamara JA Jr, Ribbens KA, Howe RP, eds. Clinical alteration of the growing face. Monograph 14, Craniofacial growth series. Ann Arbor, Michigan. Center for human growth and development, University of Michigan 1983;81-105.
19. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
20. Cha KS. Skeletal changes of maxillary protraction in patients exhibiting skeletal Class III malocclusion: a comparison of three skeletal maturation groups. Angle Orthod 2003;73:26-35.
21. Vaughn GA, Mason B, Moon H-B, Turley PK. The effects of maxillary protraction therapy with or without rapid palatal expansion: A prospective, randomized clinical trial. Am J Orthod Dentofacial Orthop 2005;128:299-309.
22. Nanda R. Biomechanical and clinical considerations of a modified protraction headgear. Am J Orthod 1980;78:125-39.
23. Mermigos J, Full CA, Andreasen G. Protraction of the maxillofacial complex. Am J Orthod Dentofacial Orthop 1990;98:47-55.

24. Ngan P, Wei SH, Hagg U, Yiu C, Merwin D, Stickel B. Effect of protraction headgear on Class III malocclusion. Quintessence Int 1992;23:197-207.
25. Takada K, Petdachai S, Sakuda M. Changes in dentofacial morphology in skeletal Class III children treated by a modified maxillary protraction headgear and a chin cup: a longitudinal cephalometric appraisal. Eur J Orthod 1993;15:211-21.
26. Kapust AJ, Sinclair PM, Turley PK. Cephalometric effects of face mask/expansion therapy in Class III children: a comparison of three age groups. Am J Orthod Dentofacial Orthop 1998;113:204-12.
27. Dellinger EL. A preliminary study of anterior maxillary displacement. Am J Orthod 1973;63:509-16.
28. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. Am J Orthod 1978;74:121-41.
29. Baik HS. Clinical results of the maxillary protraction in Korean children. Am J Orthod Dentofacial Orthop 1995;108:583-92.
30. Chong YH, Ive JC, Artun J. Changes following the use of protraction headgear for early correction of Class III malocclusion. Angle Orthod 1996; 66:351-62.
31. Nartallo-Turley PE, Turley PK. Cephalometric effects of combined palatal expansion and face mask therapy on Class III malocclusion. Angle Orthod 1998;68:217-24.
32. Sung SJ, Baik HS. Assessment of skeletal and dental changes by maxillary protraction. Am J Orthod Dentofacial Orthop 1998;114:492-502.
33. Gallagher RW, Miranda F, Buschang PH. Maxillary protraction: treatment and posttreatment effects. Am J Orthod Dentofacial Orthop 1998;113:612-19.
34. Shanker S, Ngan P, Wade D, Beck M, Yiu C, Hägg U, et al. Cephalometric A point changes during and after maxillary protraction and expansion. Am J Orthod Dentofacial Orthop 1996;110:423-30.
35. Macdonald KE, Kapust AJ, Turley PK. Cephalometric changes after the correction of Class III malocclusion with maxillary expansion/facemask therapy. Am J Orthod Dentofacial Orthop 1999;116:13-24.