DOI: 10.4274/TurkJOrthod.2023.2022.141

TURKISH JOURNAL of ORTHODONTICS

Original Article

# Comparison of Rapid Maxillary Expansion and Alternate Rapid Maxillary Expansion and Constriction Protocols with Face Mask Therapy

Göksu Emek Kayafoğlu, Elçin Esenlik

Akdeniz University Faculty of Dentistry, Department of Orthodontics, Antalya, Turkey

Cite this article as: Kayfaoğlu GE, Esenlik E. Comparison of Rapid Maxillary Expansion and Alternate Rapid Maxillary Expansion and Constriction Protocols with Face Mask Therapy. *Turk J Orthod.* 2023; 36(4): 231-238



Main Points

- Although Class III anomalies are an area known and researched by many orthodontists, we realized that the intraoral appliances used in their treatment were not investigated in the same way.
- The position of the incisors before and after the treatment is an important issue for the success and retention of the treatment; therefore, the intraoral appliances and the effect of these appliances on the skeletal and teeth are also important.
- Class III malocclusions/anomalies can be managed by improving facial profile and oral health with proper diagnosis and treatment methods.
- With the correct timing and appropriate treatment methods, anomalies can be eliminated in a shorter time period by avoiding unwanted tooth movements.

## ABSTRACT

**Objective:** This study compared dentoskeletal and soft tissue changes with face mask (FM) therapy. Rapid maxillary expansion (RME) and alternate rapid maxillary expansion and constriction (Alt-RAMEC) protocols were used with the two different types of expansion appliance, and their effects on the treatment outcome were investigated.

**Methods:** The study consisted of 79 (37 and 42 patients in the RME and Alt-RAMEC groups with FM, respectively) patients who had received FM treatment. The effects of the RME/FM (20 female, 17 male) and Alt-RAMEC/FM (14 female, 28 male) protocols were evaluated using lateral cephalometric films. The chronological ages of the RME/FM and Alt-RAMEC/FM groups were 11.58 and 11.99 years, respectively. In addition, both groups were divided into two subgroups based on the design of the expansion appliance (Spolyar or full coverage type). Differences in all parameters were analyzed using Student's t-tests.

**Results:** The maxilla significantly moved forward in both the RME/FM and Alt-RAMEC/FM groups ($p<0.001$). No significant skeletal differences were observed between the groups. Sagittal movement of the upper incisors significantly increased, and the lower incisors significantly retruded in both groups. While similar skeletal changes were found between the Spolyar and full-coverage appliance groups, the upper incisors protruded significantly more in the full-coverage type.

**Conclusion:** RME/FM and Alt-RAMEC/FM therapies were found to be efficient for maxillary protraction and resulted in similar skeletal changes. A full-coverage expansion appliance produced a more upper incisor protrusion than a spherical-type appliance.

**Keywords:** Alt-RAMEC, Face mask therapy, Full coverage appliance, RME, Spolyar-type appliance

## INTRODUCTION

Protracting (moving forward) the maxilla with rapid maxillary expansion (RME) and face mask (FM) therapy is a successful treatment method for correcting skeletal Class III anomalies with maxillary deficiency.[1-3] RME has been recommended before or during FM treatment as it stimulates maxillary movement by adjusting circummaxillary sutures. This eliminates transversal deficiency in the maxilla and prevents constriction of the anterior region

**Corresponding author:** Göksu Emek Kayafoğlu, e-mail: goksu.emek7@gmail.com



**Received:** September 20, 2022
**Accepted:** February 10, 2023
**Publication Date:** December 29, 2023

that may occur during protraction.[2] Various modifications of maxillary expansion appliances have been introduced for intraoral anchorage of the FM. Haas[4] proposed designing an appliance for maxillary expansion to increase orthopedic effects while reducing dental side effects. He introduced the acrylic Haas-type expansion appliance, covering both teeth and palatal tissue, providing support for transferring expansion forces to the maxillary skeletal base.[4] Modifications of tooth- and tissue-supported expansion appliances have been reported to prevent molar tipping and ensure vertical direction control have been reported in previous studies.[5,6] Spolyar[7] designed an expansion appliance covering the buccal segments with acrylic while leaving the palatal side open for better hygiene. The posterior acrylic part served as a bite block to control the vertical direction. In 2005, Liou and Tsai[8] introduced a novel maxillary expansion method known as the "alternate rapid maxillary expansions and constrictions" (Alt-RAMEC), a recurrent weekly expansion and constriction protocol lasting 9 weeks. This method enables better separation of circummaxillary sutures better than the RME procedure, stimulating maxillary forward movement. Despite these advancements, there is no consensus on the comparative effects of Alt-RAMEC and RME protocols with FM therapy on maxillary protraction rates. Therefore, the present study aimed to compare the effects of the two expansion protocols, both with FM therapy and using two different appliance designs, on maxillary protraction.



## METHODS

This retrospective study involved lateral cephalometric films of 79 patients with FM therapy for maxillary retrusion or a combination of maxillary retrusion and mandibular protrusion at the Akdeniz University, Department of Orthodontics. The study was approved by the University of Health Sciences Turkey, Antalya Training and Research Hospital Ethics Committee (approval no: 3/12, date: 08.02.2018). Using the G*Power 3.1 software,[9] determined a minimum of 16 patients per group were required with a power of 95% and a margin of error of 0.05 using the t-test. Lateral cephalometric films obtained before treatment (T0) and after maxillary protraction (T1) were evaluated. Inclusion criteria encompassed no syndrome or systemic disease, no history of of orthodontic treatment, Class III anomaly with maxillary retrusion or a combination of maxillary retrusion and mandibular protrusion, age between 7 and 14 years, maxillary protraction therapy with a Petit-type FM associated with RME or Alt-RAMEC, a bonded expansion appliance, and a minimum 3 mm overjet and a Class 1 relationship at the end of the facemask treatment.

All consecutively treated FM patients were evaluated, and those treated with a Petit-type FM and maxillary expansion were included. Exclusions were based on appliance type (Fan or banded types), FM type (Delaire or Nanda types), and the lack of radiographic records. The remaining 79 patients were divided into RME/FM (37 patients) or Alt-RAMEC/FM (42 patients) groups. (Table 1). A nine-week expansion and constriction protocol was used for the Alt-RAMEC group, as suggested by Liou and Tsai.[8] In the RME protocol, the screw was initially turned twice daily for 7 days to open the midpalatal suture and then once daily until, a 2-mm overcorrection transversely in maxillary and mandibular molars.

The effects of these two protocols were compared using cephalometric analysis. Subgroups were then divided based on the type of intraoral appliance: a full-coverage bonded expansion appliance or a spolyar-type bonded expansion appliance (Table 1). The effects of these appliances on skeletal, dental, and soft tissues were also compared using cephalometric analysis.

The bonded expansion appliance used in this study (Figure 1) resembled that designed by Dr. Spolyar.[7] In the Spolyar[7] appliance group, the buccal, palatinal, and occlusal sides of the premolar and molar teeth were covered with acrylic; leaving palatal tissue was acrylic-free. In the full coverage appliance group (Figure 2), all teeth and palatal tissue were covered with acrylic. Protraction elastics were facilitated with two hooks added between the lateral and canine in both appliance types.

**Figure 1.** Spolyar type expansion appliance; acrylic covers only the buccal, palatinal, and occlusal sides of the premolar and molar teeth

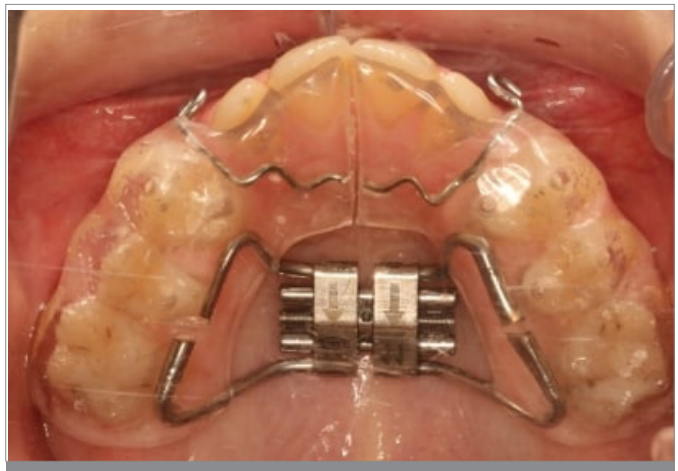

**Figure 2.** Full coverage type expansion appliance; acrylic covers the palatinal side of all the teeth and the buccal and occlusal sides of the premolar and molar teeth

Cephalometric analyses used in the study are shown in Figures 3 and 4.

The mean ages of the patients at the beginning and end of the orthopedic treatment, treatment duration, and gender distribution in the groups are shown in Table 1.

### Statistical Analysis

Cephalometric landmark identifications, tracings, and measurements were conducted on 40 randomly selected radiographs with a 2-week period after the first measurements by the same author (first author) to determine the method error. The reliability of the measurements was assessed using Cronbach's alpha reliability test, yielding coefficients of reliability of 0.90 for all measurements. Changes between periods (T0 and T1) were analyzed for both groups. Differences in all parameters by the therapies were examined using Student's t-tests. A paired t-test was used for intragroup comparisons between T0 and T1, whereas an independent t-test was used for intergroup comparisons (treatment changes). A statistically significant p-value was considered as <0.05. All statistical analyses were conducted using the Statistical Package for the Social Sciences version 22 (IBM; Armonk, NY).

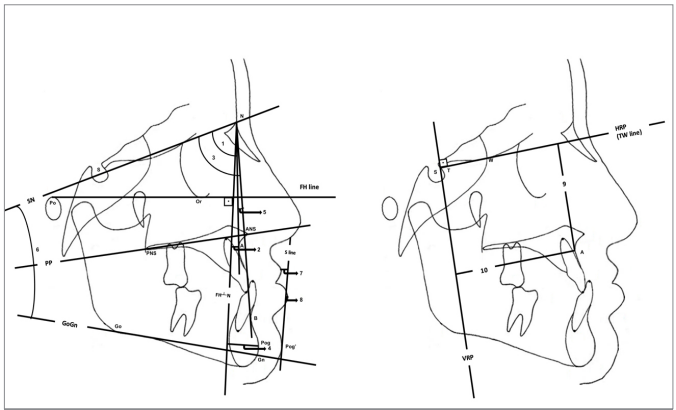


**Figure 3.** Skeletal and soft tissue cephalometric analyses. HRP indicates T-W line; VRP, perpendicular line to HRP; S line, line between the soft tissue S point and Pog'; SN, line between Sella and Nasion; PP (Palatal plane), line between ANS and PNS; GoGn, line between Gonion and Gnathion; FH, line between Porion and Orbitale; FH⊥N, perpendicular line from Nasion to FH line; 1, SNA°; 2, FH⊥N-A; 3, SNB°; 4, FH⊥N-Pg; 5, ANB; 6, SN/GoGn°; 7, upper lip-S; 8, lower lip-S; 9, A-HRP; 10, A-VRP.
HRP, horizontal reference plane; VRP, vertical reference plane.

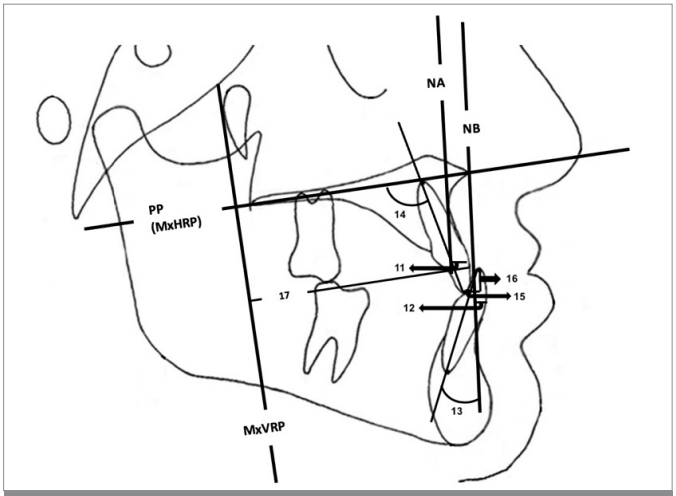


**Figure 4.** Dental cephalometric analyses. NA, indicates line between Nasion and A point; NB, line between Nasion and B point; Mx-VRP, perpendicular line to PP from distal point of the pterygomaxiller fissure; Mx-HRP (Palatal plane); 11, U1i-NA; 12, L1i-NB; 13, L1i/NB°; 14, U1/PP°; 15, overjet; 16, overbite; 17, U1-MxVRP.

## RESULTS

### Skeletal, Dentoalveolar, and Soft Tissue Changes in the RME/FM Therapy and Alt-RAMEC/FM Therapy Groups

The cephalometric changes between T0 and T1 for both groups are shown in Table 2. The maxilla significantly moved forward in both groups, and all maxilla-dependent measurements also significantly increased [p<0.001 for all measurements except A-horizontal reference plane (HRP) in RME/FM (p<0.01)]. Regarding mandibular parameters, the mandible displayed significant backward rotation in both groups. Similarly, there was a significant increase in the vertical plane angle (SN/GoGn°, p<0.001). Maxillomandibular measurement (ANB°) significantly increased in both groups (p<0.001).

In terms of dentoalveolar changes, both groups showed a statistically significant increase in overjet (p<0.001). Significant protrusions of upper incisors were observed only in the Alt-RAMEC/FM group [U1i-NA (mm), U1/PP°; p<0.05]. Both groups displayed significantly lower incisor retrusion [L1i-NB (mm), L1i/NB°]. Overbite was significantly reduced only in the Alt-RAMEC/FM group (p<0.01).

Soft tissue profile evaluation revealed increased facial convexity in both groups. The upper lip-S (mm) measurement significantly increased (p<0.001), and soft tissue facial angle (p<0.001) significantly decreased in both groups. The only significant differences between the groups following the treatment was in the upper lip-S (mm) measurement (p<0.05, Table 2).

### Comparison of Spolyar and Full-Coverage Appliance Types in the RME/FM Group

Intra-group treatment changes in the Spolyar and full-coverage expansion appliance groups with the RME/FM protocol and their comparisons are shown in Table 3. FM treatment significantly

**Table 1.** Mean treatment duration, age, and sex distribution

| Study groups | | RME/FM (n=37) | | Alt-RAMEC/FM (n=42) | |
|---|---|---|---|---|---|
| Appliance type | | Spolyar type | Full coverage type | Spolyar type | Full coverage type |
| n | | 20 | 17 | 19 | 23 |
| Gender | Female | 10 | 10 | 6 | 8 |
| | Male | 10 | 7 | 13 | 15 |
| Chronological age | | 11.85 | 11.27 | 11.93 | 12.04 |
| Treatment duration | | 8.95 | 6.88 | 8.74 | 7.35 |

RME/FM, Rapid maxillary expansion/face mask; Alt-RAMEC/FM, Alternate rapid maxillary expansions and constrictions

changed maxillary, mandibular, and maxillomandibular skeletal measurements. Vertical plane angle (SN/GoGn°) also changed in both appliance types.

A statistically significant difference in upper incisor dentoalveolar measurements was observed between the Spolyar and full coverage appliance groups. Upper incisors significantly protruded only in the full-coverage appliance group [U1i-NA (mm), U1/PP°, U1-MxVRP]. The only significant differences between the two appliance groups was in the U1/PP° parameter (p<0.05, Table 3).

### Comparison of Spolyar and Full-Coverage Appliance Types in the Alt-RAMEC/FM Group

Intra- and intergroup treatment changes between the Spolyar and full-coverage expansion appliance groups in the Alt-RAMEC/FM protocol are shown in Table 4. Similar to the RME/FM group, no significant changes between the Spolyar and full coverage appliance groups were found in maxillary, mandibular, maxillomandibular, and vertical measurement.



Similar to the RME/FM group, significant differences between the appliance types were mainly observed in the upper incisor parameters [U1/PP°, U1i-NA (mm), U1-MxVRP (mm)]. As an effect of the upper incisor changes, upper lip protrusion was more prominent in the full coverage appliance group than in the Spolyar group [upper lip-S (mm), p<0.001]. The lower lip protruded only in the full coverage group, and these changes were statistically significant [lower lip-S (mm), p<0.01]. These soft tissue changes [upper lip-S (mm), lower lip-S (mm)] were also statistically significant between the Spolyar and full coverage groups (p<0.01, Table 4).

## DISCUSSION

FM therapy with or without maxillary expansion is a common technique used in patients with skeletal Class III anomalies with maxillary retrognathia.[1-3,10,11] Although some studies have reported no significant difference in maxillary protraction rates[3,11] in FM therapy with or without RME, clinicians tend to combine it with RME.[1,2] As an alternative to this procedure, the Alt-RAMEC protocol has recently been utilized with FM therapy to enhance the effect of expansion on the maxilla, facilitate maxillary movement, and increase the rate of maxillary protraction.[8,12] In a prior study, Alt-RAMEC procedures demonstrated the ability to open both sagittal and coronal circummaxillary sutures more than conventional RME.[13] It was also claimed that Alt-RAMEC provided slight forward movement of the A point (mean, 0.89 mm) without an extra-oral force in a group of patients with Class III anomalies.[14] According to a randomized controlled trial conducted by Liu et al.,[15] the Alt-RAMEC protocol with FM therapy was compared with the RME protocol with FM therapy.

**Table 2.** Intra-group changes (T0-T1) by the face mask therapy and comparisons between the RME/FM and Alt-RAMEC/FM groups

| | RME/FM n=37 | | | | Alt-RAMEC/FM n=42 | | | | p† |
|---|---|---|---|---|---|---|---|---|---|
| Variables | T0 | T1 | T1-T0 | p value | T0 | T1 | T1-T0 | p value | |
| | Mean ± SD | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | Mean ± SD | | |
| SNA° | 77.51±2.21 | 79.34±2.42 | 1.83±1.17 | **<0.001** | 77.73±1.92 | 80.04±2.38 | 2.3±1.6 | **<0.001** | 0.136 |
| (FH⊥N)-A (mm) | -1.78±2.33 | -0.38±2.53 | 1.4±1.22 | **<0.001** | -2.38±2.65 | -0.49±2.8 | 1.89±1.11 | **<0.001** | 0.061 |
| A-HRP | 50.11±5.9 | 51.15±6.38 | 1.04±1.79 | **0.001** | 51.04±5.67 | 52.33±5.94 | 1.3±1.84 | **<0.001** | 0.541 |
| A-VRP | 49.66±6.11 | 51.56±6.15 | 1.89±2.38 | **<0.001** | 49.9±6.16 | 51.98±6.57 | 2.09±2.22 | **<0.001** | 0.71 |
| SNB° | 79.1±2.95 | 78.2±2.99 | -0.9±1.3 | **<0.001** | 79.65±2.37 | 78.57±2.26 | -1.08±1.32 | **<0.001** | 0.546 |
| (FH⊥N)-Pg (mm) | 0.06±6.17 | -2.09±5.64 | -2.15±2.46 | **<0.001** | -1.18±5.04 | -3.36±4.56 | -2.18±2.07 | **<0.001** | 0.958 |
| ANB° | -1.59±1.63 | 1.14±1.86 | 2.73±1.58 | **<0.001** | -1.91±1.65 | 1.47±1.41 | 3.38±1.4 | **<0.001** | 0.056 |
| SN/GoGn° | 35.68±4.88 | 37.46±4.67 | 1.79±1.54 | **<0.001** | 34.47±4.69 | 36.44±4.41 | 1.97±1.63 | **<0.001** | 0.608 |
| U1i-NA (mm) | 3.58±1.7 | 3.84±1.88 | 0.26±1.1 | 0.156 | 4.05±2.49 | 4.61±2.73 | 0.56±1.4 | **0.013** | 0.303 |
| L1i-NB (mm) | 3.59±1.56 | 3.33±1.62 | -0.26±0.67 | **0.023** | 3.71±1.88 | 3.34±1.87 | -0.37±0.88 | **0.009** | 0.538 |
| L1i/NB° | 17.91±4.33 | 16.75±4.18 | -1.15±1.65 | **<0.001** | 19.69±5.57 | 18.16±5.91 | -1.53±2.71 | **0.001** | 0.455 |
| U1/PP° | 110.11±5.98 | 110.32±5.50 | 0.21±3.39 | 0.689 | 111.93±5.23 | 113.19±6.26 | 1.26±3.53 | **0.026** | 0.189 |
| Overjet (mm) | -1.07±1.43 | 3.18±0.85 | 4.25±1.36 | **<0.001** | -1.12±1.17 | 3.7±1.1 | 4.82±1.53 | **<0.001** | 0.086 |
| Overbite (mm) | 0.94±2.08 | 0.43±1.76 | -0.51±1.8 | 0.095 | 1.28±2.21 | 0.39±2.1 | -0.89±1.91 | **0.004** | 0.362 |
| U1-MxVRP | 45.68±4.03 | 47.31±3.63 | 1.64±2.4 | **<0.001** | 46.76±4.32 | 48.8±4.52 | 2.05±1.72 | **<0.001** | 0.381 |
| Upper lip-S (mm) | -1.82±2 | -0.52±2.04 | 1.3±0.96 | **<0.001** | -2.14±2.07 | -0.26±1.93 | 1.88±1.28 | **<0.001** | 0.025 |
| Lower lip-S (mm) | 0.36±2.27 | 0.5±2.24 | 0.14±1.55 | 0.592 | 0.39±2.07 | 0.61±2.35 | 0.22±1.61 | 0.379 | 0.816 |
| Soft tissue facial angle | 170.85±5.24 | 166.68±5.14 | -4.16±3.68 | **<0.001** | 171.51±3.67 | 166.76±3.51 | -4.75±2.58 | **<0.001** | 0.416 |

T0, Before treatment; T1, After maxillary protraction treatment; T1-T0, Treatment period; SD, Standard deviation; p, Intragroup comparison, paired t-test; p†: Intergroup comparison, independent t-test. Statistically significant differences are written in bold (p<0.05)

**Table 3.** Mean changes in the RME/FM group by appliance type and their comparisons

| RME/FM | Spolyar type appliance (n=20) | | | | Full coverage type appliance (n=17) | | | | p† |
|---|---|---|---|---|---|---|---|---|---|
| Variables | T0 | T1 | T1-T0 | p value | T0 | T1 | T1-T0 | p value | |
| | Mean ± SD | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | Mean ± SD | | |
| SNA° | 77.61±2.19 | 79.47±2.3 | 1.86±1.31 | **<0.001** | 77.39±2.29 | 79.19±2.63 | 1.81±1.02 | **<0.001** | 0.901 |
| (FH⊥N)-A (mm) | -1.07±1.78 | 0.51±2.22 | 1.58±1.36 | **<0.001** | -2.61±2.66 | -1.42±2.53 | 1.19±1.02 | **<0.001** | 0.342 |
| A-HRP | 52.27±6.48 | 53.7±6.91 | 1.43±1.72 | **0.002** | 47.57±3.96 | 48.16±4.18 | 0.59±1.82 | 0.197 | 0.163 |
| A-VRP | 49.15±7.04 | 51.08±7.5 | 1.93±2.24 | **0.001** | 50.27±4.95 | 52.12±4.2 | 1.85±2.61 | **0.01** | 0.924 |
| SNB° | 79.29±2.7 | 78.13±2.51 | -1.16±1.36 | **0.001** | 78.88±3.29 | 78.29±3.55 | -0.59±1.19 | 0.056 | 0.19 |
| (FH⊥N)-Pg (mm) | 0.89±5.96 | -1.11±5.43 | -2±2.61 | **0.003** | -0.92±6.45 | -3.25±5.82 | -2.34±2.34 | **0.001** | 0.686 |
| ANB° | -1.68±1.86 | 1.34±2 | 3.02±1.73 | **<0.001** | -1.49±1.37 | 0.91±1.72 | 2.4±1.36 | **<0.001** | 0.243 |
| SN/GoGn° | 34.5±5.16 | 36.17±4.89 | 1.67±1.14 | **<0.001** | 37.06±4.28 | 38.98±4.03 | 1.92±1.94 | **0.001** | 0.964‡ |
| U1i-NA (mm) | 3.41±1.86 | 3.36±2.19 | -0.05±1.08 | 0.838 | 3.78±1.53 | 4.41±1.28 | 0.63±1.03 | **0.023** | 0.06 |
| L1i-NB (mm) | 3.34±1.65 | 3.17±1.7 | -0.17±0.65 | 0.258 | 3.89±1.45 | 3.52±1.56 | -0.36±0.69 | **0.044** | 0.209‡ |
| L1i/NB° | 17.86±4.49 | 16.94±4.53 | -0.92±1.04 | **0.001** | 17.96±4.28 | 16.53±3.86 | -1.44±2.16 | **0.015** | 0.821‡ |
| U1/PP° | 111.58±6.82 | 110.66±6.38 | -0.92±3.52 | 0.26 | 108.35±4.41 | 109.91±4.41 | 1.56±2.77 | **0.031** | 0.024 |
| Overjet (mm) | -0.73±1.41 | 3.37±0.97 | 4.1±1.39 | **<0.001** | -1.48±1.4 | 2.95±0.65 | 4.43±1.33 | <0.001 | 0.462 |
| Overbite (mm) | 0.74±2.05 | 0.32±1.91 | -0.42±2.08 | 0.378 | 1.18±2.16 | 0.56±1.62 | -0.61±1.47 | 0.105 | 0.752 |
| U1-MxVRP | 47.16±2.99 | 48.36±2.86 | 1.2±2.63 | 0.055 | 43.94±4.47 | 46.08±4.11 | 2.15±2.05 | **0.001** | 0.236 |
| Upper lip-S (mm) | -2.1±1.94 | -0.71±1.89 | 1.39±0.93 | **<0.001** | -1.5±2.09 | -0.31±2.24 | 1.19±1.02 | **<0.001** | 0.546 |
| Lower lip-S (mm) | -0.13±2.07 | -0.12±1.66 | 0.01±1.22 | 0.986 | 0.94±2.42 | 1.24±2.64 | 0.29±1.89 | 0.531 | 0.579 |
| Soft tissue facial angle | 169.54±5.6 | 164.86±5 | -4.68±3.76 | **<0.001** | 172.39±4.45 | 168.83±4.56 | -3.56±3.59 | **0.001** | 0.365 |

T0, Before treatment; T1, After maxillary protraction treatment; T1-T0, Treatment period; SD, Standard deviation; p, Intragroup comparison; paired t-test; p†: Intergroup comparison, independent t-test; ‡: Mann-Whitney U test. Statistically significant differences are written in bold (p<0.05)

**Table 4.** Mean changes in the Alt-RAMEC/FM group by appliance type and their comparisons

| Alt-RAMEC/FM | Spolyar type appliance (n=19) | | | | Full coverage type appliance (n=23) | | | | p† |
|---|---|---|---|---|---|---|---|---|---|
| Variables | T0 | T1 | T1-T0 | p value | T0 | T1 | T1-T0 | p value | |
| | Mean ± SD | Mean ± SD | Mean ± SD | | Mean ± SD | Mean ± SD | Mean ± SD | | |
| SNA° | 78.24±1.56 | 80.3±2.23 | 2.06±1.57 | **<0.001** | 77.32±2.12 | 79.82±2.52 | 2.5±1.63 | **<0.001** | 0.38 |
| (FH⊥N)-A (mm) | -1.6±2.61 | 0.44±2.83 | 2.04±1.29 | **<0.001** | -3.03±2.56 | -1.25±2.59 | 1.77±0.94 | **<0.001** | 0.45 |
| A-HRP | 53.69±4.5 | 55.44±5.02 | 1.74±2.21 | **0.003** | 48.84±5.68 | 49.77±5.48 | 0.93±1.42 | **0.005** | 0.175 |
| A-VRP | 48.19±6.77 | 50.16±7.38 | 1.97±2.47 | **0.003** | 51.3±5.35 | 53.49±5.53 | 2.19±2.04 | **<0.001** | 0.755 |
| SNB° | 79.42±2.2 | 78.45±2.07 | -0.97±1.02 | **0.001** | 79.83±2.54 | 78.67±2.44 | -1.17±1.54 | **0.001** | 0.389‡ |
| (FH⊥N)-Pg (mm) | -0.85±4.62 | -2.48±4.39 | -1.63±1.94 | **0.002** | -1.46±5.45 | -4.1±4.66 | -2.63±2.11 | **<0.001** | 0.12 |
| ANB° | -1.18±1.15 | 1.85±1.33 | 3.04±1.08 | **<0.001** | -2.51±1.77 | 1.16±1.42 | 3.67±1.58 | **<0.001** | 0.146 |
| SN/GoGn° | 35.92±4.72 | 37.49±4.47 | 1.58±1.76 | **0.001** | 33.28±4.42 | 35.57±4.26 | 2.3±1.49 | **<0.001** | 0.16 |
| U1i-NA (mm) | 3.26±2.17 | 3.25±2.39 | -0.01±1.75 | 0.979 | 4.7±2.59 | 5.73±2.51 | 1.03±0.82 | **<0.001** | **0.025** |
| L1i-NB (mm) | 3.6±1.83 | 3.02±1.8 | -0.58±1.15 | **0.039** | 3.8±1.96 | 3.61±1.93 | -0.19±0.54 | 0.104 | 0.713‡ |
| L1i/NB° | 18.96±5.24 | 16.89±5.22 | -2.07±3.34 | **0.014** | 20.28±5.88 | 19.2±6.34 | -1.08±2.02 | **0.018** | 0.264 |
| U1/PP° | 112±5.39 | 111.95±6.93 | -0.05±3.99 | 0.955 | 111.87±5.21 | 114.21±5.6 | 2.34±2.74 | **<0.001** | **0.027** |
| Overjet (mm) | -0.81±1.11 | 3.57±1.14 | 4.37±1.58 | **<0.001** | -1.37±1.18 | 3.81±1.08 | 5.18±1.42 | **<0.001** | 0.088 |
| Overbite (mm) | 1.18±1.95 | 0.67±1.97 | -0.51±1.7 | 0.212 | 1.37±2.44 | 0.16±2.21 | -1.21±2.05 | **0.009** | 0.236 |
| U1-MxVRP | 47.91±4.52 | 49.31±4.91 | 1.4±1.82 | **0.004** | 45.81±4.01 | 48.39±4.24 | 2.58±1.47 | **<0.001** | **0.025** |
| Upper lip-S (mm) | -2.08±1.97 | -0.76±1.89 | 1.32±1.07 | **<0.001** | -2.19±2.19 | 0.15±1.9 | 2.34±1.26 | **<0.001** | **0.008** |
| Lower lip-S (mm) | 0.17±2.15 | -0.5±2.31 | -0.67±1.66 | 0.097 | 0.58±2.03 | 1.53±1.98 | 0.96±1.16 | **0.001** | **0.001** |
| Soft tissue facial angle | 171.05±3.9 | 166.55±2.64 | -4.51±2.72 | **<0.001** | 171.9±3.51 | 166.93±4.14 | -4.96±2.5 | **<0.001** | 0.982 |

T0: Before treatment; T1: After maxillary protraction treatment; T1-T0: Treatment period; SD: Standard deviation; p: Intragroup comparison, paired t-test; p†: Intergroup comparison, independent t-test; ‡: Kruskal-Wallis test. Statistically significant differences are written in bold (p<0.05)

They found that the average maxillary forward movements were 3.04 mm and 2.11 mm in the Alt-RAMEC and RME groups, respectively. Although this difference was statistically significant, they stated that it might not be clinically relevant.[15] Some systematic reviews have suggested that Alt-RAMEC results in a small, but significantly greater increase in maxillary protraction.[16,17] However, there are some inconsistencies regarding its effects in the literature.[8,11-19] Therefore, the main purpose of the present study was to compare the effectiveness of RME/FM and Alt-RAMEC/FM procedures.

In this study, the maxilla exhibited significant protraction in both treatment protocols. Consistent with previous studies, there were notable increases in the maxilla-dependent variables [SNA°, (FH⊥N)-A (mm), A-HRP, and A-VRP].[15,18,19] When assessing the amount of forward movement of the maxilla (A-VRP), it was observed that the A-point increased by 2.09 mm and 1.89 mm in the Alt-RAMEC/FM and RME/FM groups, respectively, a difference that is neither statistically significant nor clinically relevant. These protraction rates fell within the range of A-point (1.8-3.4 mm) movement reported in previous studies using the RME and Alt-RAMEC procedure with FM therapy.[15,18-21] However, it seems that our Alt-RAMEC/FM group had lower maxillary protraction rates than those reported in previous studies using the Alt-RAMEC procedure with FM therapy.[8,15,17,19] For instance, Liou and Tsai[8] found that the A point moved forward in the Alt-RAMEC group almost two times more than that in the RME group, indicating a significant increase in the protraction rate. However, Liou and Tsai[8] used a double-hinged expander in their study, whereas a Hyrax expander with acrylic coverage was used in this study. Their original design might have provided better maxillary protraction, as the double hinge could create torque movement on the maxillary sutures by facilitating a more stimulated adjustment response.[8] Overall, however, both RME/FM and Alt-RAMEC/FM protocols resulted in successful maxillary protraction and improvement of the maxillomandibular sagittal relationship; neither procedure demonstrated superiority over the other in the present study.



Skeletal modifications induced by FM therapy have been reported to included forward displacement of the maxilla, backward movement of the mandible, counterclockwise rotation of the maxilla, and clockwise rotation of the mandible.[11] Therefore, the vertical movement of the maxilla (A-HRP) was evaluated in the present study, and vertical displacements of 1.3 and 1.04 mm were determined in the Alt-RAMEC/FM and RME/FM groups, respectively.

The mandibular response to FM therapy is well known. Some clinicians have claimed that the mandibular effective length can be restricted due to the chincap of the FM.[1,2] Others have reported that the effective mandibular length increases because of growth and development during treatment in the pre-peak and peak growth periods.[10,22] The role of mandibular modification in maxillomandibular sagittal improvement results in part from mandibular restriction and in part from mandibular posterior rotation by the chincap. Maxillary protraction therapy and expansion results in extruded maxillary molar teeth that are tipped buccally, slight counterclockwise rotation of the maxilla, and clockwise rotation of the mandible.[3,11,15] Gallagher et al.[23] suggested that the backward rotation of the mandible is caused by the rotation effect of the maxillary protraction forces and the tipping and extrusion of the maxillary molar teeth created by maxillary expansion. In the present study, the SNB° and Pogonion protrusion [(FH⊥N)-Pg] decreased, indicating a clockwise rotation of the mandible by the chincap of the FM, consistent with the results of previous studies.[1,11] These mandibular changes also contributed to the improvement of maxillomandibular discrepancy. Consistent with the results of previous studies, both the RME/FM and Alt-RAMEC/FM groups showed significant improvements in the maxillomandibular relationship.[15,19] The ANB° angle increased by 2.73° in the FM/RME group and 3.38° in the Alt-RAMEC/FM group; there was no significant difference between the two groups.

Rotation of the mandible is associated with increases in vertical dimensions.[24] Kwak et al.[24] reported that these vertical skeletal changes were related to the initial mandibular plane angle, severity of skeletal malocclusion, and the amount of growth during treatment. In the present study, SN/GoGn° increased in both groups (1.79° and 1.97° in the RME/FM and Alt-RAMEC/FM groups, respectively), and the difference between the groups was not significant. Although these increases were statistically significant, they may not be clinically relevant because the posterior acrylic blocks created a temporary interocclusal space. Similar to our study, Isci et al.[19] found a clockwise rotation in the mandibular plane angle resulting from the Alt-RAMEC and RME/FM procedures, and no significant differences between the groups were observed.

The second aim of this study was to compare two different types of intraoral appliances for FM anchorage. Both the RME/FM and Alt-RAMEC/FM groups included two different bonded intraoral appliances. Although these two appliances were designed similarly regarding the covering of the occlusal surfaces with acrylic, the coverage of the palatal surface and incisors differed. Maxillary protraction rates were similar between the two appliance groups. Studies on maxillary expansion have shown that A point moves forward and downward with the use of different kinds of RME appliances.[4,6,25] Regardless of these findings, Sarver and Johnston26 claimed that forward movement of the A point would be limited by Spolyar-type appliance. On the contrary to this we found the forward and downward movement of A point which resulted similar for each appliance that we combined with.

In the Spolyar appliance group, the upper incisors were covered by the appliance and were slightly retruded following treatment. The retrusion of the upper incisors in the Spolyar appliance group likely resulted from changes in the balance of pressure between the cheeks and upper lip following maxillary expansion and protraction. Some have claimed that the tongue

is positioned more inferiorly than normal because of the acrylic blocks in the bonded expansion appliances, and the incisors are retruded by the muscles around the stretched mouth.[25] Sarver and Johnston[26] and Habeeb et al.[27] observed palatal tipping when using the Spolyar expansion appliance. They stated that these changes were due to the pulling forces of the transseptal periodontal fibers between the teeth; to mitigate this, they recommended extending the acrylic to the palatinal side of the incisors where retrusion was undesirable.[27] Similarly, Uzuner et al.[28] found upper incisor retrusion resulting from a Spolyar expansion appliance and FM therapy, whereas Ngan et al.[21] found protrusion with the same treatment protocol. In the second type of appliance group in the present study, the anterior teeth were covered by acrylic; therefore, the upper incisors protruded during expansion by opening the acrylic halves and by the protraction forces. Similarly, Arman et al.[20] reported a 2.6° increase in the angulation of the upper incisors when using a full-coverage expansion appliance with FM therapy. These anteroposterior movements of the incisor teeth were considered to be related to lip positions.[29]

In this study, the distance from the upper lip to the reference line (S line) increased significantly in all groups. The movement of the upper lip in the sagittal direction was associated with the forward movement of the maxilla and the protrusion of the upper incisors, consistent with the results of previous studies.[1,30] However, in the full-coverage appliance group (Alt-RAMEC/FM), the upper lip moved forward significantly more than in the Spolyar appliance group, probably resulting from increased upper incisor protrusion in the full-coverage appliance group. The lower lip to the S line significantly increased in the full-coverage appliance group when using the Alt-RAMEC/FM procedure. Kilicoglu and Kirlic[29] emphasized that the lower lip contacts both the lower and upper incisors following the elimination of the anterior crossbite. Therefore, the lower lip may not only be affected by the retraction of the lower incisors but also by the protracted upper incisors.[29] Therefore, in this study, for patients who underwent the Alt-RAMEC/FM procedure, changes in the upper and lower lip to S-line measurements were significantly different between the Spolyar and full coverage appliance groups. The findings of this study included only short-term results, which was one of the limitations of the study. Long-term studies regarding the stability of these two main protocols should be conducted.

## CONCLUSION

RME and Alt-RAMEC combined with FM therapy resulted in similar maxillary protraction rates and mandibular skeletal changes. Spolyar and full-coverage expansion appliances did not lead to any differences in maxillary protraction. However, the upper incisors retruded and protruded in the Spolyar and full coverage appliance group. Therefore, the choice between these two types of appliances should be based on the pretreatment upper incisor positions.

## Ethics

**Ethics Committee Approval:** The study was approved by the University of Health Sciences Turkey, Antalya Training and Research Hospital Ethics Committee (approval no: 3/12, date: 08.02.2018).

**Informed Consent:** Retrospective study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - E.E.; Design - E.E.; Supervision - E.E.; Materials - G.E.K.; Data Collection and/or Processing - G.E.K.; Analysis and/or Interpretation - E.E., G.E.K.; Literature Review - E.E., G.E.K.; Writing - E.E., G.E.K.; Critical Review - E.E., G.E.K.

**Declaration of Interests:** The authors have no conflicts of interest to declare.

**Funding:** The authors declared that this study has received no financial support.

## REFERENCES



1. Ngan P, Hägg 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(1):38-49. [CrossRef]
2. Ngan PW, Hagg U, Yiu C, Wei SH. Treatment response and long-term dentofacial adaptations to maxillary expansion and protraction. *Semin Orthod.* 1997;3(4):255-264. [CrossRef]
3. Foersch M, Jacobs C, Wriedt S, Hechtner M, Wehrbein H. Effectiveness of maxillary protraction using facemask with or without maxillary expansion: a systematic review and meta-analysis. *Clin Oral Investig.* 2015;19(6):1181-1192. [CrossRef]
4. Haas AJ. Palatal expansion: just the beginning of dentofacial orthopedics. *Am J Orthod.* 1970;57(3):219-255. [CrossRef]
5. Brudvik JS, Nelson DR. Adult palatal expansion prostheses. *J Prosthet Dent.* 1981;45(3):315-320. [CrossRef]
6. Basciftci FA, Karaman AI. Effects of a modified acrylic bonded rapid maxillary expansion appliance and vertical chin cap on dentofacial structures. *Angle Orthod.* 2002;72(1):61-71. [CrossRef]
7. Spolyar JL. The design, fabrication, and use of a full-coverage bonded rapid maxillary expansion appliance. *Am J Orthod.* 1984;86(2):136-145. [CrossRef]
8. Liou EJ, Tsai WC. A new protocol for maxillary protraction in cleft patients: repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. *Cleft Palate Craniofac J.* 2005;42(2):121-127. [CrossRef]
9. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods.* 2007;39(2):175-191. [CrossRef]
10. Yüksel S, Uçem TT, Keykubat A. Early and late facemask therapy. *Eur J Orthod.* 2001;23(5):559-568. [CrossRef]
11. Cordasco G, Matarese G, Rustico L, et al. Efficacy of orthopedic treatment with protraction facemask on skeletal Class III malocclusion: a systematic review and meta-analysis. *Orthod Craniofac Res.* 2014;17(3):133-143. [CrossRef]
12. Wilmes B, Ngan P, Liou EJ, Franchi L, Drescher D. Early class III facemask treatment with the hybrid hyrax and Alt-RAMEC protocol. *J Clin Orthod.* 2014;48(2):84-93. [CrossRef]
13. Wang YC, Chang PM, Liou EJ. Opening of circumaxillary sutures by alternate rapid maxillary expansions and constrictions. *Angle Orthod.* 2009;79(2):230-234. [CrossRef]

14. Yilmaz BS, Kucukkeles N. Skeletal, soft tissue, and airway changes following the alternate maxillary expansions and constrictions protocol. *Angle Orthod.* 2014;84(5):868-877. [CrossRef]
15. Liu W, Zhou Y, Wang X, Liu D, Zhou S. Effect of maxillary protraction with alternating rapid palatal expansion and constriction vs expansion alone in maxillary retrusive patients: a single-center, randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2015;148(4):641-651. [CrossRef]
16. Pithon MM, Santos NL, Santos CR, et al. Is alternate rapid maxillary expansion and constriction an effective protocol in the treatment of Class III malocclusion? A systematic review. *Dental Press J Orthod.* 2016;21(6):34-42. [CrossRef]
17. Almuzian M, McConnell E, Darendeliler MA, Alharbi F, Mohammed H. The effectiveness of alternating rapid maxillary expansion and constriction combined with maxillary protraction in the treatment of patients with a class III malocclusion: a systematic review and meta-analysis. *J Orthod.* 2018;45(4):250-259. [CrossRef]
18. Do-deLatour TB, Ngan P, Martin CA, Razmus T, Gunel E. Effect of alternate maxillary expansion and contraction on protraction of the maxilla: a pilot study. *Hong Kong Dent J.* 2009;6:72-82. [CrossRef]
19. Isci D, Turk T, Elekdag-Turk S. Activation-deactivation rapid palatal expansion and reverse headgear in Class III cases. *Eur J Orthod.* 2010;32(6):706-715.
20. Arman A, Ufuk Toygar T, Abuhijleh E. Evaluation of maxillary protraction and fixed appliance therapy in Class III patients. *Eur J Orthod.* 2006;28(4):383-392. [CrossRef]
21. Ngan P, Cheung E, Wei SH. Comparison of protraction facemask response using banded and bonded expansion appliances as anchorage. *Semin Orthod.* 2007;13:175-185. [CrossRef]
22. Mermigos J, Full CA, Andreasen G. Protraction of the maxillofacial complex. *Am J Orthod Dentofacial Orthop.* 1990;98(1):47-55. [CrossRef]
23. Gallagher RW, Miranda F, Buschang PH. Maxillary protraction: treatment and posttreatment effects. *Am J Orthod Dentofacial Orthop.* 1998;113(6):612-619. [CrossRef]
24. Kwak HJ, Park HJ, Kim YJ, Lee DY. Factors associated with long-term vertical skeletal changes induced by facemask therapy in patients with Class III malocclusion. *Angle Orthod.* 2018;88(2):157-162. [CrossRef]
25. Akkaya S, Lorenzon S, Uçem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. *Eur J Orthod.* 1999;21(2):175-180. [CrossRef]
26. Sarver DM, Johnston MW. Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances. *Am J Orthod Dentofacial Orthop.* 1989;95(6):462-466. [CrossRef]
27. Habeeb M, Boucher N, Chung CH. Effects of rapid palatal expansion on the sagittal and vertical dimensions of the maxilla: a study on cephalograms derived from cone-beam computed tomography. *Am J Orthod Dentofacial Orthop.* 2013;144(3):398-403. [CrossRef]
28. Uzuner FD, Öztürk D, Varlık SK. Effects of Combined Bonded Maxillary Expansion and Face Mask on Dental Arch Length in Patients with Skeletal Class III Malocclusions. *J Clin Pediatr Dent.* 2017;41(1):75-81. [CrossRef]
29. Kiliçoglu H, Kirliç Y. Profile changes in patients with class III malocclusions after Delaire mask therapy. *Am J Orthod Dentofacial Orthop.* 1998;113(4):453-462. [CrossRef]
30. Chang HF, Chen KC, Nanda R. Two-stage treatment of a severe skeletal Class III, deep bite malocclusion. *Am J Orthod Dentofacial Orthop.* 1997;111(5):481-486. [CrossRef]