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Comparison of treatment effects of different maxillary protraction methods in skeletal class III patients

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Abstract

Objective: The aim of this study was to compare treatment outcomes with different maxillary protraction methods in patients with skeletal Class III malocclusion resulting from maxillary retrognathia.

Setting and Sample Population: A total of 55 individuals consisting of 29 females and 26 males with a mean age of 11.4 ± 1.06 years were included in this study.

Material and Methods: Fifty-five treated maxillary retrognathic patients who underwent different protraction facemask methods were evaluated. Eighteen patients treated with RME were in the first group, and 19 patients treated with a modified Alt-RAMEC protocol were in the second group; eighteen patients on whom face masks with miniplates were applied were included in the skeletal anchorage (SA) group. Thirty measurements were made on lateral cephalometric radiographs before and after treatment. Differences between the groups were assessed with the ANOVA test.

Results: The mean age was higher in the SA group (11.96 ± 0.92 years) compared with the other groups. The mean ANB angle increased by 2.96°, 4.91° and 3.86° in the RME, Alt-RAMEC and SA groups, respectively. The forward movement of the maxilla was similar between the groups. However, while the rate of protraction was higher in the modified Alt-RAMEC group, a greater skeletal effect was found in the SA group.

Conclusion: The most effective method in terms of skeletal effect is the application of the face mask with skeletal anchorage; the modified Alt-RAMEC protocol can be applied before face mask to obtain faster protraction.

KEYWORDS
Alt-RAMEC, face mask, RME, skeletal anchorage

1 | INTRODUCTION

Class III malocclusions are skeletal deformities caused by the effect of genetic and environmental factors on the regular development process of the jaws. These deformities occur when the development of the maxilla is affected negatively, or the mandible is overdeveloped, or when a combination of the two occurs.[1,2]

During patients' growth and development, this deformity can be corrected by the stimulation of maxillary growth. For this purpose, an acrylic appliance is bonded to the teeth, and a face mask is applied to this acrylic appliance. However, in these treatment techniques, the success rate of the orthopaedic effect is arguably relative. The most important reasons for this are the partial loss of force in tooth support during the use of tooth-supported appliances, relapses of dental movement, the unpredictability and lack of a precise estimation of mandibular growth, and the timing of skeletal growth complicating the treatment planning.[2-4]

To eliminate these disadvantages in patients with Class III deformities and to provide a more stable and predictable treatment, many solutions have been attempted from past to present.[5,6]

The first is the application of a face mask with the RME (Rapid Maxillary Expansion) appliance.[7,8] This method aims to solve the transversal problem in addition to the sagittal problem in Class III patients and to provide a more effective protraction by providing opening in the sutures. However, the researchers reported that a 12-15 mm expansion was required to ensure mobilization in the sutures, and this amount of expansion would cause both transversal incompatibility and irritation in the palatal tissues.[2,9] For this reason, new methods have been investigated.

In 2005, Liou[10] introduced the Alt-RAMEC (Alternate Rapid Maxillary Expansion and Constriction) protocol, applied by placing a double-hinged screw for a certain period of time and releasing resistant sutures to stimulate maxilla growth. Many researchers modified the Alt-RAMEC protocol by placing a hyrax screw on the acrylic device's palatal surface.[11,12] One advantage of bonded expansion appliances is that they control the vertical direction by reducing molar eruption from the splint effect during expansion.[13] By this means, the usage of the face mask, which was previously considered to be limited, is made possible during the permanent dentition by releasing the resistances. Studies indicated that the Alt-RAMEC protocol was more effective in maxillary development when compared to conventional facemask treatments.[11,14-22]

Another method developed to overcome disadvantages is the use of skeletal anchorage.[23,24] In this method, a face mask is applied with miniplates placed bilaterally on the apertura piriformis region of the lateral nasal walls to induce maxillary growth. This method aims to obtain more stable results by transmitting the orthopaedic forces directly to the maxilla. Studies indicated successful results, with reports of more favourable control of upper incisors and less dental relapse.[23,24]

This present study aims to compare the skeletal and dentoalveolar effects of facemask treatments used with RME, a modified Alt-RAMEC protocol, and skeletal anchorage and to provide the best treatment technique.

2 | MATERIAL AND METHODS

Ethical approval for this retrospective study was obtained from the local ethics committee (Clinical Research Ethics Committee, Suleyman Demirel University - 28.11.2019/296), and informed consent was obtained from the parents of the patients included in the study. The study consisted of patients who presented with skeletal Class III malocclusion with retrognathic maxilla, treated with either RME, modified Alt-RAMEC, or skeletal anchorage with facemask treatment.

The inclusion criteria were an absence of any craniofacial anomaly or systemic disorder and the presence of a negative overjet, a maxillary deficiency and a concave profile, and a decreased SNA angle and negative ANB angle identified in the cephalometric analysis.

Patients exhibiting a functional Class III anomaly, and patients treated with different RME appliances (banded hyrax appliance, full coverage appliance, fan-type expanders, etc) and different Alt-RAMEC protocols were excluded. Patients treated with facemask therapy with different protraction methods were evaluated and compared.

The sample size was calculated based on a significance level of 0.05 to detect a clinically meaningful difference of 1 mm (±0.98 mm)[25] for the distance from point A to the vertical reference plane between the groups by a power analysis using G*Power (Franz Faul, Universität Kiel, Germany). At least 17 patients per group were required to achieve 80% power. Finally, 55 patients (18 in the RME group, 19 in the modified Alt-RAMEC group and 18 in the SA group) whose pretreatment skeletal maturity stages were either CS2, CS3 or CS4 according to cervical vertebral maturation (Lamparski method) were included in this study.

Lateral cephalometric films obtained at the beginning of treatment (T0) and at the end of the facemask treatment (T1) were compared with determine the skeletal and dentoalveolar changes after maxillary protraction.

2.1 | Treatment protocols

In accordance with the information contained in the patients' treatment forms and records, patients in accordance with the treatment protocols below were selected.

2.1.1 | RME group

The patients' parents were instructed to open the hyrax screw twice per day for 1 week. For those patients with a posterior crossbite, the activation of the screw was continued until the crossbite was overcorrected. Then, face masks, delivering a force of 400-500 g on each side, were applied via an acrylic bonded RME appliance that was cemented to the teeth (Figure 1).

2.1.2 | Modified Alt-RAMEC group

The patients' parents were instructed to open the hyrax screw twice per day for 1 week and to close it twice per day for the following week (0.25 mm per turn). This was the preferred daily expansion protocol, because it was applied to most of the patients in the archive twice a day (0.5 mm). The 7-9-week treatment protocols had similar effects to the 5-week protocol. The advantages of the 5-week protocol are that it reduces the treatment time and prevents complications (periodontal diseases, dental caries, etc) that may occur due to the duration of the device in the mouth.[11,18,21] This protocol was repeated for five consecutive weeks. Then, a Petit-type maxillary protraction appliance was used, with an approximately 500 g force

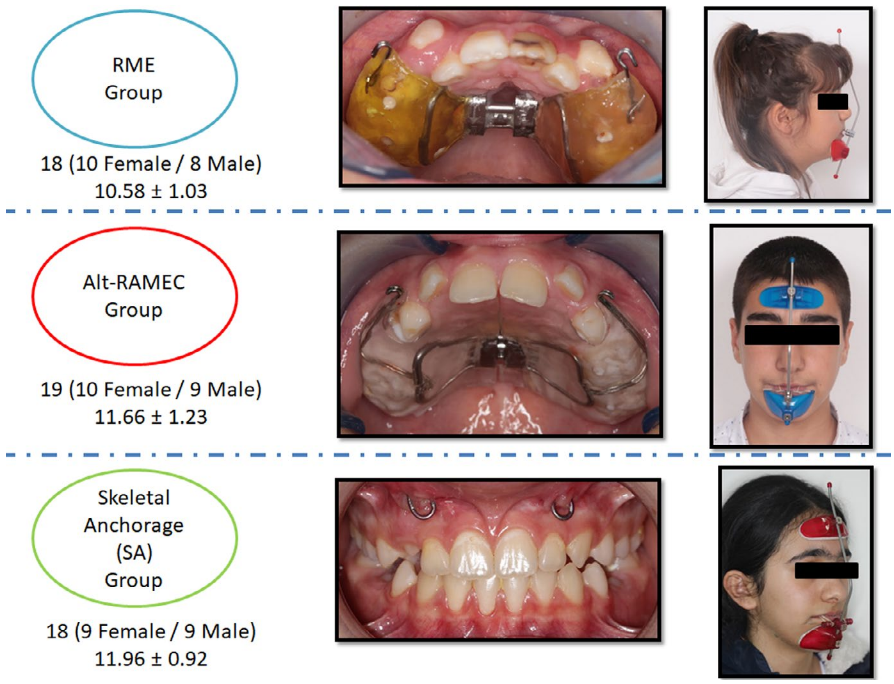


FIGURE 1 Intraoral appliances and face mask used in groups [Colour figure can be viewed at wileyonlinelibrary.com]

applied bilaterally from the hooks placed in the canine region on the buccal sides of the full coverage expander (Figure 1).

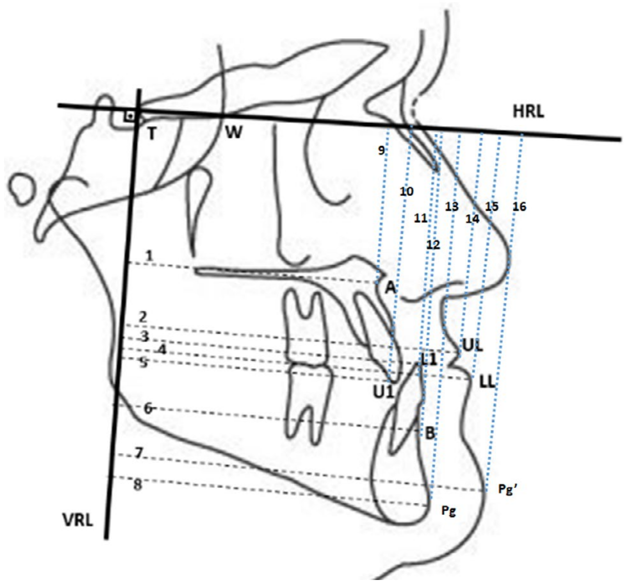
2.1.3 | SA group

In the SA group, titanium miniplates were surgically inserted bilaterally into the apertura piriformis region. Between the miniplates and face mask, 400-500 g of force was applied on both sides after a week of consolidation (Figure 1).

In facemask treatments in our clinic, patients are routinely checked at four-week intervals and are asked to wear the devices for at least 20 hours a day until at least a 2 mm positive overjet is obtained. All patients included in the study were treated by two clinicians in the same clinic between June 2018 and January 2020. The orthopaedic treatment length was 0.94 ± 0.42 years, 0.52 ± 0.16 years, and 0.7 ± 0.21 years in the RME, modified Alt-RAMEC, and SA groups, respectively.

2.2 | Cephalometric analysis

To minimize methodologic errors, all lateral cephalograms were digitized by one examiner. The Dolphin Imaging (Premium software, version 11.5.06.24, Dolphin Imaging and Management Solutions, Chatsworth, Calif) computerized cephalometric analysis program



No	Measurements
1	A – VRL
2	UL – VRL
3	L1 – VRL
4	LL – VRL
5	U1 – VRL
6	B – VRL
7	Pg' – VRL
8	Pg – VRL
9	A – HRL
10	U1 – HRL
11	L1 – HRL
12	B – HRL
13	Pg – HRL
14	UL – HRL
15	LL – HRL
16	Pg' - HRL

FIGURE 2 Reference plane measurements used in the study [Colour figure can be viewed at wileyonlinelibrary.com]

was applied, and 30 variables were selected from the customized analysis for each tracing. In addition to the cephalometric measurements routinely used in orthodontic studies, measurements were also made according to fixed reference planes. In each film, a horizontal reference line (HRL) was constructed passing through the tuberculum sella (T) and wing points (W), and a perpendicular line was constructed passing through the tuberculum sella as a vertical reference line (VRL). The reference lines and measurements used in our study are shown in Figure 2.

The protraction rates of the three different protraction methods in our study and the skeletal and dental effects of the treatment changes in these methods were calculated. The rate of protraction was found by calculating the amount of protraction by looking at the amount of sagittal movement of point A (A-VRL) and dividing it by the total protraction duration (Figure 3). The method used by Pancherz[26] in Class II malocclusions was modified to calculate skeletal and dental effects. The skeletal effect of the treatment changes in the three different methods was found by summing the sagittal movement of point A relative to the fixed reference plane (A-VRL) and adding the backward movement amounts of the Pg point (Pg-VRL). The dental effects were calculated by subtracting the skeletal effect in the total overjet correction (Figure 3).

2.3 | Statistical analysis

Descriptive statistics were calculated for all measurements at T0 and T1 for all treatment groups. All statistical analyses were performed using the SPSS software package program (SPSS Inc, version 21.0). Changes in treatment at T0 and T1 for all groups were assessed with repeated measurements and pairwise comparisons. The statistical significance of the comparisons was assessed with one-way ANOVA and Tukey's post hoc tests. Statistical significance was tested at $P < .05$, $P < .01$ and $P < .001$. Thirty lateral cephalometric radiographs were retraced to determine the method error. Correlation analysis was used to evaluate the intraobserver variability, which revealed no statistically significant error.

3 | RESULTS

No statistically significant differences were found between the groups in terms of chronological age, treatment duration and gender distribution (Table 1). The mean age at pretreatment was significantly highest in the SA group (11.96 ± 0.92 years) compared with all groups (RME group: 10.58 ± 1.03 years; modified Alt-RAMEC group: 11.66 ± 1.23 years) to allow for the eruption of the upper canines and the safe placement of the miniplates. The mean values of the parameters for the treatment periods and intragroup changes are shown in Table 2, and the comparisons of the changes in all groups are shown in Table 3.

Although there were statistically significant increases in all values except the A–HRL measurement (SNA°, Co-A, and A-VRL values) following maxillary protraction, there was a significant difference in the SNA° and A-VRL values between the groups associated with these variables. Following the facemask treatment, the amount of mean maxillary protraction (A-VRL) was 2.67 mm in the RME group, 3.65 mm in the modified Alt-RAMEC group and 4.01 mm in the SA group ($P < .01$). The amount and rate of maxillary protraction were significantly higher in the modified Alt-RAMEC and SA groups than in the RME group ($P < .01$). There was no significant difference between the modified Alt-RAMEC and SA groups ($P > .05$).

The cephalometric analysis results showing the maxilla-mandibular relationship showed that the mean ANB angle increased by 2.96°, 4.91°, and 3.86° in the RME, modified Alt-RAMEC, and SA groups, and the Wits value changed by 3.85 mm, 4.91 mm. and 4.78 mm, respectively ($P > .05$).

As a result of the analysis of the SN/GoGn angle, one of the vertical plane parameters, a significant difference was found between the groups. The mean SN/GoGn angle increased in all groups following maxillary protraction ($P < .001$). The lowest increase was determined in the SA group (1.35° ± 0.51). By the end of treatment, the vertical plane angle remained stable in the SA group, which made for a significant difference between the groups ($P < .05$). In addition, the vertical plane angle had increased minimally and mostly remained stable in the SA group and made a significant difference between these groups ($P < .05$). During the treatment, there was a

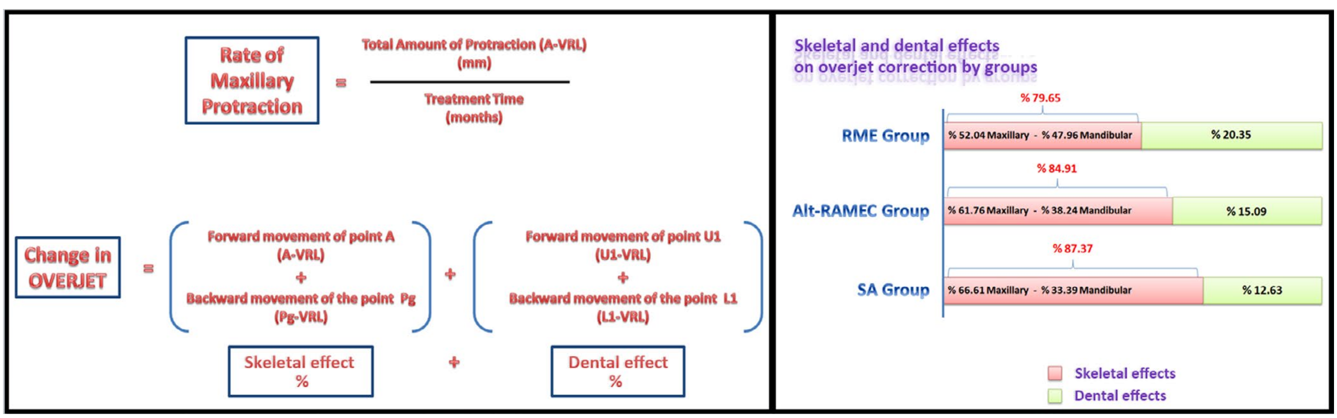


FIGURE 3 Calculation of skeletal and dental effects to overjet correction and calculation of rate of protraction [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Comparison of the chronological ages, gender distributions and treatment time between the groups

	Gender distribution (Male/female)	Chronological age (years) Mean ± SD	Treatment time (years) Mean ± SD
Group 1 RME group (N = 18)	8/10	10.58 ± 1.03	0.94 ± 0.42
Group 2 Alt-RAMEC group (N = 19)	9/10	11.66 ± 1.23	0.52 ± 0.16
Group 3 SA group (N = 18)	9/9	11.96 ± 0.92	0.57 ± 0.21
P	.852[a]	.922[b]	.716[b]

Abbreviations: N, Number; SD, Standard deviation.
[a]Results of Pearson's chi-square test.
[b]Results of ANOVA test.

slight decrease in the mean maxillary plane angle (SN/PP°) in both groups, and a minimal decrease in the SA group was statistically significant compared with other groups ($P < .05$). Although the ratio of the height of the back to the height of the anterior face (PFH/AFH) decreased in all three groups following the facemask treatment, it was not statistically significant ($P > .05$).

When the dentoalveolar measurements were examined, an increase was observed in the values showing the average upper incisor position in all groups after the facemask treatment, while the minimum increase in the SA group was not statistically significant ($P > .05$). In addition, when the three groups were evaluated, the protrusion of the upper incisor in the SA group was found to be significantly lower than in both the RME and the modified Alt-RAMEC groups ($P < .001$). In addition, the mandibular incisor inclination (IMPA) and sagittal position decreased in all groups, but there was no statistically significant difference ($P > .05$).

In all three groups, while the upper lip moved forward, the nasolabial angle also decreased significantly ($P < .001$). No statistically significant difference was found between the modified Alt-RAMEC and SA groups ($P > .05$). The change in lower lip position remained minimal, and no statistically significant difference was found ($P > .05$).

4 | DISCUSSION

Researchers have used the face mask in various combinations over the years.[3,27,28] Temporary anchorage devices and maxillary protraction applications with direct bone support are recently popular to reduce dentoalveolar effects and increase the skeletal effect.[23,24] There are also applications that perform maxillary protraction with the use of direct miniscrews and inter-miniplates with Class III elastics, as well as successful studies that can be constructed from direct skeletal anchorage using a face mask.[29-32] In the literature, Class III elastics between miniplates are stated to be more advantageous in terms of patient cooperation, and their popularity is increasing since they do not require the use of extraoral appliances. However, the face mask is still seen as the ideal option for shorter and effective maxillary protraction.[33] It has a superiority in terms of maxillary protraction and vertical direction control (from the apertura piriformis) compared with other skeletal anchorage methods.[34]

When the literature is reviewed regarding the maxillary protraction methods and treatment activities, facemask treatments with and without RME,[35] after RME and Alt-RAMEC protocols,[14-18] and with and without skeletal anchorage were compared,[23,24] conventional facemask treatments were compared with Class III elastics from miniplates[29-32] and, finally, two different skeletal anchorage methods were compared.[34] The selection criteria of the different methods in our study are that they have a sufficient sample size. It was also noted that some methods in the literature have not been compared before. Apart from these methods, maxillary protraction methods are the most frequently used and studied methods in the literature. However, there was no study that examined and compared the treatment results of three different methods in a single study. Our study will be the first in this respect, and by determining which method is more effective, it aims to be a guide to clinicians.

There is a need for patient cooperation in both the facemask application and in the protraction with the use of intraoral elastics. The patients in our study were told to use their face masks all day, except for during their daily activities. When most of the patient records were examined, it was seen that they used the face mask for at least 19 hours daily (mean 19.1 ± 2.11 hours/day). Since it is retrospective, it is not possible to reach the usage times of all patients. However, when the total treatment times of the patients in all three groups are examined, it is seen that a successful protraction has occurred in a short time, and they used their appliances well.

As a result of the protraction with face mask, an increase in the maxillary skeletal parameters was observed in all three methods. As a result of the forward movement of the maxilla, point A is different in the three different methods, though it was not statistically significant. In studies comparing the effects of the face mask after RME with Alt-RAMEC, it has been reported that with the application of Alt-RAMEC (average of 3.04-5.82 mm) is approximately two

TABLE 2 Mean values at different maxillary protraction methods and intragroup changes

	RME group			Alt-RAMEC group			Skeletal Anchorage (SA) Group		
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	*P*	Mean ± SD	Mean ± SD	*P*
Maxillary skeletal measurements									
SNA (°)	76.82 ± 3.05	78.82 ± 3.52	***	76.83 ± 2.51	80.51 ± 2.79	***	76.62 ± 2.79	80.01 ± 0.59	***
Co-A (mm)	74.64 ± 3.99	77.93 ± 4.21	***	72.05 ± 3.35	76.56 ± 4.31	***	74.33 ± 4.79	77.85 ± 4.46	***
A-HRL (mm)	54.13 ± 0.97	52.85 ± 3.65	NS	52.14 ± 0.85	53.96 ± 3.64	NS	51.31 ± 0.59	52.33 ± 3.63	NS
A-VRL (mm)	49.78 ± 5.11	52.45 ± 0.51	***	50.95 ± 3.75	54.61 ± 0.51	***	49.88 ± 1.99	53.89 ± 0.55	***
Mandibular skeletal measurements									
SNB (°)	79.44 ± 2.97	76.45 ± 3.13	***	80.05 ± 2.83	77.24 ± 2.37	***	78.81 ± 2.77	76.15 ± 0.87	***
Co-Gn (mm)	102.42 ± 4.69	103.41 ± 5.84	NS	101.91 ± 4.69	102.53 ± 5.17	NS	103.81 ± 6.76	104.36 ± 6.81	NS
Pg-HRL (mm)	94.15 ± 6.71	97.53 ± 6.02	***	97.66 ± 5.05	100.69 ± 4.73	***	96.45 ± 4.92	99.18 ± 3.13	***
Pg-VRL (mm)	48.11 ± 7.68	45.65 ± 7.81	***	47.66 ± 5.05	45.41 ± 12.16	***	49.47 ± 3.12	47.46 ± 2.89	***
Maxillo-mandibular measurements									
ANB (°)	−2.61 ± 1.69	2.37 ± 1.75	***	−3.22 ± 1.41	3.29 ± 1.56	***	−2.07 ± 0.66	3.99 ± 0.81	***
Wits (mm)	−6.93 ± 2.96	−3.08 ± 3.23	***	−7.35 ± 2.64	−2.45 ± 2.51	***	−6.21 ± 1.42	−1.43 ± 0.84	***
Konveksite (mm)	−3.59 ± 1.72	5.22 ± 1.82	***	−5.36 ± 2.05	3.97 ± 4.25	***	−3.29 ± 2.73	7.12 ± 3.86	***
Dentoalveolar measurements									
U1/PP (°)	110.34 ± 4.68	115.52 ± 5.71	***	111.57 ± 3.88	115.61 ± 5.67	***	113.72 ± 3.61	115.7 ± 4.14	NS
IMPA (°)	84.84 ± 6.11	82.34 ± 7.54	***	85.37 ± 6.62	83.09 ± 7.61	***	87.41 ± 6.54	85.04 ± 6.54	***
Overjet (mm)	−2.06 ± 1.71	4.38 ± 1.57	***	−1.75 ± 1.57	5.21 ± 1.42	***	−1.51 ± 0.96	5.38 ± 1.01	***
Overbite (mm)	3.04 ± 2.78	1.09 ± 2.53	***	2.32 ± 1.11	0.96 ± 1.91	***	1.55 ± 0.89	1.17 ± 1.45	*
U1-HRL (mm)	54.18 ± 2.78	53.41 ± 2.99	NS	53.53 ± 2.06	52.96 ± 2.16	NS	54.24 ± 2.95	54.03 ± 2.46	NS
U1-VRL (mm)	52.13 ± 7.91	55.61 ± 7.33	***	54.15 ± 7.08	58.04 ± 7.15	***	55.55 ± 7.35	59.61 ± 7.33	***
L1-HRL (mm)	69.11 ± 2.89	71.78 ± 2.75	***	68.71 ± 4.63	70.79 ± 9.81	***	68.11 ± 3.47	70.41 ± 4.03	***
L1-VRL (mm)	66.85 ± 3.71	63.87 ± 3.99	***	69.91 ± 4.31	66.84 ± 4.85	***	70.39 ± 1.12	67.55 ± 1.18	***
Vertical plane measurements									
SN/Go-GN (°)	32.25 ± 4.38	34.65 ± 5.08	***	32.61 ± 4.66	34.56 ± 4.66	***	34.61 ± 2.96	35.96 ± 1.98	***
SN/OP (°)	17.59 ± 5.03	16.63 ± 5.32	***	17.57 ± 4.93	17.36 ± 4.48	*	20.16 ± 2.84	20.06 ± 2.66	*
SN/PP (°)	10.71 ± 2.97	9.76 ± 3.61	***	10.52 ± 4.46	9.84 ± 3.96	***	10.95 ± 1.25	10.64 ± 1.25	*
PYY/AYY	65.03 ± 4.23	64.36 ± 4.53	*	65.77 ± 7.47	65.11 ± 6.22	*	67.97 ± 3.51	67.28 ± 3.71	*

(Continues)

TABLE 2 (Continued)

	RME group			Alt-RAMEC group			Skeletal Anchorage (SA) Group		
	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment		Pre-treatment	Post-treatment	
	Mean ± SD	Mean ± SD	P	Mean ± SD	Mean ± SD	P	Mean ± SD	Mean ± SD	P
Soft tissue measurements									
Nasolabial Angle (°)	112.54 ± 3.09	108.82 ± 3.98	*	115.48 ± 7.34	111.53 ± 7.88	***	111.91 ± 3.29	107.08 ± 4.67	***
UL-HRL (mm)	62.92 ± 5.13	63.21 ± 5.41	NS	63.49 ± 3.07	66.35 ± 3.71	***	61.41 ± 4.03	64.23 ± 3.63	***
UL-VRL (mm)	64.67 ± 6.91	67.74 ± 6.56	***	65.48 ± 4.06	69.05 ± 5.46	***	63.91 ± 3.51	67.74 ± 3.37	***
LL-HRL (mm)	66.72 ± 4.72	67.45 ± 5.66	NS	66.46 ± 6.29	65.73 ± 6.31	NS	64.02 ± 4.56	63.43 ± 4.58	NS
LL-VRL (mm)	65.03 ± 7.41	65.26 ± 7.42	NS	67.39 ± 3.97	67.54 ± 3.74	NS	63.17 ± 4.55	63.26 ± 4.35	NS
Pg(s)-HRL (mm)	94.22 ± 6.61	94.59 ± 6.05	NS	96.71 ± 4.42	97.38 ± 5.67	NS	91.42 ± 4.77	91.83 ± 4.06	NS
Pg(s)-VRL (mm)	59.24 ± 7.74	57.21 ± 8.89	***	59.95 ± 7.99	57.99 ± 7.74	***	59.81 ± 7.03	57.97 ± 7.04	***

Abbreviations: NS, Not significant; P, Results of paired *t*-test; SD, Standard Deviation.

*$P < .05$.

**$P < .01$.

***$P < .001$.

times more effective than RME (average 1.92-2.74 mm).[2] In skeletal anchorage–supported maxillary protraction applications in the literature, the amount of protraction varies between 2.83 mm and 4 mm.[23,24,36] In our study, at least (2.67 mm) in the RME and modified Alt-RAMEC groups, a forward movement with a maximum of 4.01 mm was observed in the maxilla. Although our findings are consistent with the literature, in the previous studies, in the modified Alt-RAMEC group, more forward movement was observed in RME, while in skeletal anchorage applications, more forward motion was observed than in RME. However, it is difficult to compare the facemask treatment with Alt-RAMEC, as there is no study comparing skeletal anchorage with face mask use. Nevertheless, in our study, the reason we found the amount of protraction in the modified Alt-RAMEC group may be due to the fact that the maxillary protraction becomes easier after the mobilization in the sutures, and accordingly, the maxilla comes forward.

When we examine the rotational movements of the maxilla, it is reported in the literature that there is a counterclockwise rotation in the maxilla and a decrease in the SN/PP angle. Sar et al reported a 1.63° counterclockwise rotation in the maxilla with a conventional face mask and a 0.92° rotation from the miniplates in the facemask group.[23] Lee et al reported a 0.54° counterclockwise rotation in the maxilla with a conventional face mask, and a 0.73° rotation from the miniplates in the facemask group.[36] While the most rotation among the three groups in our study was in the RME group (−2.69°), the least rotation was found in the skeletal anchorage group (−0.31°). The reason for this is that the force direction from the skeletal anchorage devices creates less rotational movement where the maxilla is located above the resistance centre. In other groups, the force direction is below the resistance centre.

Finally, when we evaluate the monthly maxillary protraction rate, it is as follows: 0.19 mm per month for an average of 11 months in the RME group, 0.61 mm per month for an average of 6 months in the modified Alt-RAMEC group, and 0.43 mm per month for an average of 7 months in the skeletal anchorage group. Correspondingly, we can say that it is possible to obtain faster and a greater amount of protraction by applying Alt-RAMEC with the facemask treatment. Most studies are lacking information on the rate of protraction. Sar et al reported that with a conventional face mask, the rate of protraction in the maxilla was 0.24 mm per month and 0.45 mm per month from the miniplates in the facemask group[23]; in another study, the researchers reported a 0.43 mm monthly protraction rate from miniplates and a 0.53 mm monthly rate from an intraoral appliance with Class III elastic.[24]

In the literature, an increase of approximately 2-3° in the SN/GoGn angle in facemask applications with RME and Alt-RAMEC has been reported,[16,17,22] while a less than 1-2° increase in facemask applications with skeletal anchorage has been reported.[23,24] With the application of interplates Class III elastics, there are fewer increases and even decreases in some studies.[34] Since part of the face mask receives support from the chin, the applied protraction force is also transmitted to the mandible. Accordingly, posterior rotation is seen in the mandible, and an increase in vertical direction parameters and a decrease in overbite are

TABLE 3 Comparison of changes in the groups

	RME group	Alt-RAMEC group	SA group	Post hoc tests *P′*			
	Mean ± SD	Mean ± SD	Mean ± SD	1-2	1-3	2-3	*P*
Maxillary skeletal measurements							
SNA (°)	2.01 ± 1.22	3.67 ± 1.59	3.38 ± 0.48	**	**	NS	***
Co-A (mm)	3.28 ± 1.88	4.51 ± 2.78	3.51 ± 1.12	NS	NS	NS	NS
A-HRL (mm)	−1.29 ± 2.09	−1.82 ± 2.14	−1.02 ± 2.04	NS	NS	NS	NS
A-VRL (mm) (Protraction Amount)	2.67 ± 1.01	3.65 ± 1.07	4.01 ± 1.47	**	**	NS	**
Protraction Rate (mm/ months)	0.24 ± 0.09	0.61 ± 0.17	0.57 ± 0.21	**	**	NS	**
Mandibular skeletal measurements							
SNB (°)	−2.99 ± 1.61	−2.81 ± 1.28	−2.65 ± 0.31	NS	NS	NS	NS
Co-Gn (mm)	0.98 ± 0.47	0.62 ± 0.42	0.55 ± 0.22	NS	NS	NS	NS
Pg-HRL (mm)	3.38 ± 1.92	3.03 ± 1.54	2.73 ± 1.06	NS	NS	NS	NS
Pg-VRL (mm)	−2.46 ± 1.86	−2.26 ± 1.26	−2.01 ± 1.68	NS	NS	NS	NS
Maxillo-mandibular measurements							
ANB (°)	4.98 ± 1.33	6.51 ± 1.71	6.06 ± 0.44	NS	NS	NS	NS
Wits (mm)	3.85 ± 2.46	4.91 ± 3.49	4.78 ± 0.71	NS	NS	NS	NS
Konveksite (mm)	8.81 ± 4.49	9.33 ± 4.34	10.41 ± 3.98	NS	NS	NS	NS
Dentoalveoler measurements							
U1/PP (°)	5.18 ± 4.26	4.04 ± 1.98	2.08 ± 0.46	NS	***	***	***
IMPA (°)	−2.51 ± 1.39	−2.28 ± 1.25	−2.37 ± 1.07	NS	NS	NS	NS
Overjet (mm)	6.44 ± 1.85	6.96 ± 1.49	6.89 ± 0.98	NS	NS	NS	NS
Overbite (mm)	−1.95 ± 2.59	−1.36 ± 2.22	−0.38 ± 0.63	NS	NS	NS	NS
U1-HRL (mm)	−0.77 ± 1.03	−0.57 ± 1.27	−0.21 ± 1.05	NS	NS	NS	NS
U1-VRL (mm)	3.47 ± 2.25	3.89 ± 2.22	4.05 ± 2.17	NS	NS	NS	NS
L1-HRL (mm)	2.67 ± 2.23	2.08 ± 1.63	2.31 ± 1.76	NS	NS	NS	NS
L1-VRL (mm)	−2.97 ± 1.68	−3.07 ± 1.85	−2.84 ± 1.79	NS	NS	NS	NS
Vertical plane measurements							
SN/Go-GN (°)	2.39 ± 2.11	1.95 ± 1.44	1.35 ± 0.51	*	**	*	*
SN/OP (°)	−0.94 ± 2.71	−0.21 ± 3.95	−0.11 ± 0.91	**	**	NS	*
SN/PP (°)	−0.95 ± 2.65	−0.68 ± 1.66	−0.31 ± 0.13	NS	*	*	*
PYY/AYY	−0.67 ± 0.06	−0.65 ± 0.27	−0.69 ± 0.74	NS	NS	NS	NS
Soft tissue measurements							
Nasolabial Angle (°)	−3.72 ± 1.05	−3.95 ± 1.25	−4.83 ± 1.78	NS	NS	NS	NS
UL-HRL (mm)	0.29 ± 2.92	2.86 ± 5.57	2.82 ± 0.91	***	***	NS	**
UL-VRL (mm)	3.07 ± 1.07	3.57 ± 0.86	3.83 ± 0.31	NS	NS	NS	NS
LL-HRL (mm)	0.73 ± 3.64	−0.72 ± 6.35	−0.58 ± 0.24	NS	NS	NS	NS
LL-VRL (mm)	0.23 ± 2.25	0.15 ± 2.38	0.09 ± 2.84	NS	NS	NS	NS
Pg(s)-HRL (mm)	0.37 ± 1.21	0.67 ± 1.34	0.41 ± 1.07	NS	NS	NS	NS
Pg(s)-VRL (mm)	−2.06 ± 2.28	−1.96 ± 2.09	−1.84 ± 2.27	NS	NS	NS	NS

Abbreviations: NS, Not significant; P, Results of One-way ANOVA test (*P*': Post Hoc (Tukey) test); SD, Standard Deviation.

*$P < .05$.

**$P < .01$.

***$P < .001$

observed. In the groups in the study, an increase in the vertical skeletal parameters was observed with the posterior rotation of the mandible. While the greatest vertical skeletal parameter increase is seen in the RME group, an increase was less common in the skeletal anchorage and modified Alt-RAMEC groups. In the RME group, the vertical skeletal parameters may have increased due to the posterior rotation caused by the face mask and the primer occlusal contacts in the posterior teeth due to the expansion of the maxilla. In the modified Alt-RAMEC group, the vertical skeletal parameters did not increase as much as in the RME group. This may be due to the lower resistance of the maxilla to the protraction force due to the mobilization of circummaxillary sutures in the Alt-RAMEC protocol, and that the reactive force has less effect on the mandible, resulting in less posterior rotation. In addition, since the amount of expansion in the modified Alt-RAMEC protocol is less than that of RME, the vertical skeletal parameters have increased less. In the skeletal anchorage group, although there is a very minimal increase in the vertical skeletal parameters due to the effect of the face mask, the force direction causes less rotation in the maxilla and therefore less posterior rotation in the mandible, since it is located above the resistance centre of the maxilla.

In parallel with the findings of the literature,[2,33-39] an increase in dentoalveolar parameters, protrusion in the upper incisors, retrusion in the lower incisors and, accordingly, an increase in overjet was observed in all three groups. Although there was no direct support from the upper incisors in all the groups, protrusion occurred in the upper incisors as a result of mesialization of the upper teeth from the protraction force in the RME and modified Alt-RAMEC groups, which received support from the posterior teeth. Less protrusion of the upper incisors in the modified Alt-RAMEC group compared with the RME group may be due to mobilization in the sutures. Because it can be connected to the forward movement of the skeletal base rather than the dental so that the protraction force is transmitted more to the maxilla. Although no tooth support was received in the skeletal anchorage group, protrusion was observed in the upper incisors, although clinically insignificant. In accordance with the literature, in the mandibular incisors, retrusion was observed from the pressure applied by the part of the face mask receiving support from the chin. In the RME and modified Alt-RAMEC groups, although the lingual arch was made to prevent the retrusion of the lower incisors, retrusion was not completely inhibited. In the skeletal anchorage group, even when a mandibular Hawley appliance was applied to prevent the movement of the maxillary in the lower incisors and to prevent the retrusion of the lower incisors, retrusion was not completely prevented in this group. A mandibular Hawley appliance was used to eliminate occlusal contacts and allow bite jumping and to prevent the retrusion of the lower incisors for skeletal anchorage group. However, retrusion of the lower incisors was not completely prevented in this group.

In our study, unlike those in the literature, the skeletal and dental effects of the treatment changes in three different methods were calculated. The skeletal effect was found by summing the sagittal movement of the A point relative to the fixed reference plane and the backward movement amounts of the Pg point. The dental effects were calculated by subtracting the skeletal effect from the total overjet change. While the greatest skeletal effect was found in the skeletal anchorage group (87.37%), the highest dental effect was found in the RME group (20.35%) (Figure 3). In light of our findings, we can say that the face mask applied with skeletal anchorage is the most ideal option to gain greater skeletal effects and to decrease relapse after treatment in Class III patients with maxillary retrognathia.

Since our study included short-term results of maxillary protraction, the failure to examine long-term results can be considered a limitation. In addition, future prospective studies using CBCT (Cone beam computed tomography) images with larger study samples could provide accurate findings and provide an opportunity for clinicians to compare their findings with ours because those images were reported to have several advantages when compared with the lateral cephalometric films. Thus, the findings of the present prospective clinical study should be assessed within the limitations of the two-dimensional radiography design.

5 | CONCLUSION

- Maxillary protraction was achieved in all groups.
- The most effective method in terms of skeletal effect is the application of the face mask with skeletal anchorage (87.37%); the modified Alt-RAMEC protocol can be applied before the face mask to obtain faster protraction (0.61 mm per month).
- An increase of the vertical plane angle encountered with FM therapy was minimized by skeletal anchorage units.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper. (Written consent is obtained from patients who apply to our clinic for treatment purposes, indicating that their radiographs or materials can be used scientific articles).

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REFERENCES

1. Litton SF, Ackerman LV, Isaacson J, Shapiro BL. A genetic study of Class III malocclusion. *Am J Orthod*. 1970;58:565-577.
2. Buyukcavus MH. Alternate rapid maxillary expansion and constriction (Alt-RAMEC) protocol: a comprehensive literature review. *Turk J Orthod*. 2019;32(1):47-51.
3. Ngan PW, Deguchi T, Roberts EW. Orthodontic treatment of class III malocclusion. 2014.
4. Sung SJ, Baik HS. Assessment of skeletal and dental changes by maxillary protraction. *Am J Orthod Dentofacial Orthop*. 1998;114:492-502.
5. Nanda R. Protraction of maxilla in rhesus monkeys by controlled extraoral forces. *Am J Orthod Dentofacial Orthop*. 1978;74:121-141.
6. Jackson GW, Kokich VG, Shapiro PA. Experimental and post-experimental response to anteriorly directed extraoral force

in young Macaca nemestrina. *Am J Orthod Dentofacial Orthop*. 1979;75:318-333.
7. Baccetti T, Franchi L, McNamara JA. Treatment and posttreatment craniofacial changes after rapid maxillary expansion and facemask therapy. *Am J Orthod Dentofacial Orthop*. 2000;118:404-413.
8. Yu HS, Baik HS, Sung SJ, Kim KD, Cho YS. Three-dimensional finite element analysis of maxillary protraction with and without rapid palatal expansion. *Eur J Orthod*. 2007;29:118-125.
9. Haas AJ. Long-term posttreatment evaluation of rapid palatal expansion. *Angle Orthod*. 1980;50:189-217.
10. Liou EJ. Effective maxillary orthopedic protraction for growing Class III patients: a clinical application simulates distraction osteogenesis. *Prog Orthod*. 2005;6:154-171.
11. Masucci C, Franchi L, Giuntini V, Defraia E. Short-term effects of a modified Alt-RAMEC protocol for early treatment of Class III malocclusion: a controlled study. *Orthod Craniofac Res*. 2014;17(4):259-269.
12. Rota E, Ferrari M, Maddalone M. Dentofacial effects of modified Alt-RAMEC protocol combined with the facial mask for treatment of preadolescent caucasian class III patients. *Int J Clin Pediatr Dent*. 2019;12(3) :222-228.
13. Sarver DM, Johnston MW. Skeletal changes in vertical and anterior displacement of the maxilla with bonded rapid palatal expansion appliances. *Am J Orthod Dentofac Orthop*. 1989;95(6):462-466.
14. 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.
15. 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;42:21-27.
16. da Luz VG, de Menezes LM, de Lima EM, Rizzatto S. Dentoskeletal effects of maxillary protraction in cleft patients with repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. *Cleft Palate Craniofac J*. 2009;46(4):391-398.
17. Do-de Latour 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.
18. Isci D, Turk T, Elekdag-Turk S. Activation-deactivation rapid palatal expansion and reverse headgear in Class III cases. *Eur J Orthod*. 2010;32:706-715.
19. 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.
20. Canturk BH, Celikoglu M. Comparison of the effects of face mask treatment started simultaneously and after the completion of the alternate rapid maxillary expansion and constriction procedure. *Angle Orthod*. 2015;85(2):284-291.
21. Wang YC, Chang PM, Liou EJ. Opening of circumaxillary sutures by alternate rapid maxillary expansions and constrictions. *Angle Orthod*. 2009;79(2):230-234.
22. 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.
23. Sar C, Arman-Ozcirpici A, Uckan S, Yazici AC. Comparative evaluation of maxillary protraction with or without skeletal anchorage. *Am J Orthod Dentofacial Orthop*. 2011;139:636-649.
24. Sar C, Sahinoglu Z, Ozcirpici AA, Uckan S. Dentofacial effects of skeletal anchored treatment modalities for the correction of maxillary retrognathia. *Am J Orthod Dentofacial Orthop*. 2014;145(1):41-54.
25. Celikoglu M, Oktay H. Effects of maxillary protraction for early correction of Class III malocclusion. *Eur J Orthod*. 2014;36:86-92.
26. Pancherz H. The mechanism of Class II correction in Herbst appliance treatment. A cephalometric investigation. *Am J Orthod Dentofacial Orthop*. 1982;82:104-113.
27. Celikoglu M, Buyukcavus MH. Evaluation of the effects of two different Alt-RAMEC procedures: Five weeks versus nine weeks. *Aust Orthod J*. 2017;33(2):249-257.
28. Celikoglu M, Buyukcavus MH. Changes in pharyngeal airway dimensions and hyoid bone position after maxillary protraction with different alternate rapid maxillary expansion and construction protocols: a prospective clinical study. *Angle Orthod*. 2017;87(4):519-525.
29. Cevidanes L, Baccetti T, Franchi L, McNamara JA, De Clerck H. Comparison of two protocols for maxillary protraction: bone anchors versus face mask with rapid maxillary expansion. *Angle Orthod*. 2010;80:799-806.
30. Heymann GC, Cevidanes L, Cornelis M, De Clerck HJ, Tulloch JF. Three-dimensional analysis of maxillary protraction with intermaxillary elastics to miniplates. *Am J Orthod Dentofacial Orthop*. 2010;137:274-284.
31. Nguyen T, Cevidanes L, Cornelis MA, Heymann G, de Paula LK, De Clerck H. Three-dimensional assessment of maxillary changes associated with bone anchored maxillaryprotraction. *Am J Orthod Dentofacial Orthop*. 2011;140(6):790-798.
32. Hino C, Cevidanes L, Nguyen T, De Clerck H, Franchi L, McNamara JA Jr. Three-dimensional analysis of maxillary changes associated with facemask and rapid maxillary expansion compared with bone anchored maxillary protraction. *Am J Orthod Dentofacial Orthop*. 2013;144:705-714.
33. de Souza RA, Neto JR, de Paiva JB. Maxillary protraction with rapid maxillary expansion and facemask versus skeletal anchorage with mini-implants in class III patients: a non-randomized clinical trial. *Prog Orthod*. 2019;20(1):35.
34. Elnagar MH, Elshourbagy E, Ghobashy S, Khedr M, Evans CA. Comparative evaluation of 2 skeletally anchored maxillary protraction protocols. *Am J Orthod Dentofacial Orthop*. 2016;150(5):751-762.
35. Yavuz I, Halicioglu K, Ceylan I, Dagsuyu IM, Erdem A. The effects of face mask therapy with and without rapid maxillary expansion in adolescent patients. *Aust Orthod J*. 2012;28:63-71.
36. Lee SH, Koh SD, Chung DH, Lee JW, Lee SM. Comparison of skeletal anchorage and tooth-borne maxillary protraction followed by fixed appliance in Class III malocclusion. *Eur J Orthod*. 2020;42(2):193-199.
37. Tortop T, Keykubat A, Yuksel S. Facemask therapy with and without expansion. *Am J Orthod Dentofacial Orthop*. 2007;132:467-474.
38. Clemente R, Contardo L, Greco C, Di Lenarda R, Perinetti G. Class III treatment with skeletal and dental anchorage: a review of comparative effects. *BioMed Res Int*. 2018;2018:7946019.
39. de Guzman-Barrera JR, Martinez CS, Boronat-Catal M, et al. Effectiveness of interceptive treatment of class III malocclusions with skeletal anchorage: a systematic review and meta-analysis. *PLoS One*. 2017;12(3):e0173875.

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