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Effect of alternate maxillary expansion and contraction on protraction of the maxilla: a pilot study

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ABSTRACT

Objective. Patients with a skeletal Class III malocclusion and maxillary deficiency can be treated successfully using a combined protraction facemask and maxillary expansion appliance. Recent studies suggested that alternate rapid maxillary expansions and contractions (Alt-RAMEC) can open the circumaxillary sutures more extensively than conventional rapid maxillary expansion. The purpose of this pilot study was to evaluate clinically the difference in the extent of maxillary protraction when combined with either 7 weeks of Alt-RAMEC or 1 week of rapid maxillary expansion. **Methods.** Eighteen consecutive patients with such malocclusion treated between 2006 and 2008 with either Alt-RAMEC/protraction or rapid maxillary expansion/protraction were included in this study. Lateral cephalometric radiographs were used to evaluate skeletal and dental changes. Results were compared with a group of untreated Class III subjects who were matched for age, sex, and craniofacial morphology. Data were analyzed using analysis of variance and *t* tests. **Results.** Significant forward movement of the maxilla (SNA) was noted in the Alt-RAMEC (1.4 [±standard deviation, 2.0]º) and rapid maxillary expansion (2.1±0.7º) groups as compared to the controls (-0.6±1.9º). This, combined with downward and backward rotation of the mandible, contributed to the correction of the anterior crossbite and molar relationship. After taking the growth changes into account, significant differences between the two expansion protocols were only found with respect to the position of the lower molars. **Conclusions.** These preliminary data suggest that Alt-RAMEC alone does not increase the amount of forward movement of the maxilla. Other factors such as patient age, the duration the facemask is worn, and treatment duration need to be considered in future studies.

Key words: Cephalometry; Constriction; Maxilla; Orthodontic appliances; Palatal expansion technique

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Introduction

Patients having a Class III malocclusion may present with an anterior crossbite and/or a Class III molar relationship. Proclination of mandibular incisors and retroclination of maxillary incisors can result in posturing of the mandible in an anterior position due to incisal interference. This condition is known as pseudo-Class III malocclusion. Individuals

Table 1 Comparison of craniofacial morphology (starting form) in patients treated by the double-hinged expander (alternate rapid maxillary expansions and contractions [Alt-RAMEC]) and Hyrax expander (rapid maxillary expansion [RME]) *

Landmark	Alt-RAMEC group	RME group
SNA	79.0° (3.5°)	78.7° (3.7°)
SNB	79.2° (2.9°)	79.4° (2.7°)
ANB	-0.2° (2.4°)	-0.8° (2.2°)
Mandibular plane (SNL-ML)	34.9° (4.5°)	35.1° (4.0°)
Occlusal land (SNL-OLs)	20.9° (4.0°)	23.1° (3.9°)
Palatal plane (SNL-NL)	5.8° (3.6°)	6.8° (3.3°)
Lower face (ANS-Me)	67.3° (3.5°)	61.2° (3.1°)
Maxillary incisal angle (Is/SNL)	98.6° (10.5°)	102.5° (11.0°)
Mandibular incisal angle (Is-SNL)	84.9° (9.5°)	89.5° (9.2°)
Overjet	-1.7 (2.5) mm	-2.7 (2.1) mm
Overbite	2.1 (2.8) mm	3.4 (2.7) mm
Molar relationship	-3.8 (2.3) mm	-3.1 (2.8) mm

* Data are shown as mean (standard deviation); all were not statistically significant

with a true skeletal Class III malocclusion present with either a midface deficiency and/or mandibular prognathism [1]. It has been reported that a significant percentage of the skeletal Class III malocclusion cases are due to maxillary retrusion [2,3]. The incidence of Class III malocclusion among Chinese and other Asian populations can be as high as 14% [4,5].

Treatment of mixed dentition using the protraction facemask in conjunction with rapid maxillary expansion (RME) was successful in correcting skeletal Class III malocclusions with maxillary deficiency [6-8]. In young patients, the circumaxillary sutures are patent, and opening of these sutures with orthopedic force can facilitate forward movement of the maxilla. Rapid maxillary expansion has been postulated as a means of disarticulating the maxilla from the surrounding bones connected by circumaxillary sutures [9,10]. The goal of combining RME with maxillary protraction was to facilitate the forward movement of the maxilla [11-13]. Studies have shown that the average extent of maxillary protraction with 1 week of RME was about 1.5 to 3.0 mm over a period of 8 to 12 months [14-18]. However, the circumaxillary sutures start to interlock or interdigitate during pubertal growth, making them difficult to protract in older patients [19]. It was suggested that alternate rapid maxillary expansions and contractions (Alt-RAMEC) can increase the amount of maxillary protraction and result in a shorter period of protraction [20-22]. An animal study suggested that 5 weeks of Alt-RAMEC opened both the sagittal and coronal circumaxillary sutures more extensively than 1 week of RME [23]. The purpose of this study was to clinically evaluate the difference in the degree of maxillary protraction when combined with 7 weeks of Alt-RAMEC or 1 week of RME.

Methods

Eighteen patients with Class III malocclusion and maxillary deficiency treated consecutively between 2006 and 2008 were included in the study. The inclusion criteria included patients with mixed dentition and maxillary deficiency and an ANB angle of <0°. Patients with craniofacial anomalies were excluded from the study. Nine patients were treated with Alt-RAMEC and protraction, and the other nine by RME and protraction.

The mean (±standard deviation) age of patients at the start of treatment was 8.6±1.2 years for the RME group, and 8.5±1.2 years for the Alt-RAMEC group. The mean (±standard deviation) cervical vertebrae maturation (CVM) stage at the start of treatment was 1.3±0.5 and 1.2±0.4 for the RME and Alt-RAMEC groups, respectively. There were no significant differences between the age when treatment was started and the CVM stage of the two experimental groups. The craniofacial morphology of the two groups at the start of treatment is shown in Table 1, and revealed no significant differences. The control group consisted of untreated Class III patients who were matched for sex, age, and craniofacial

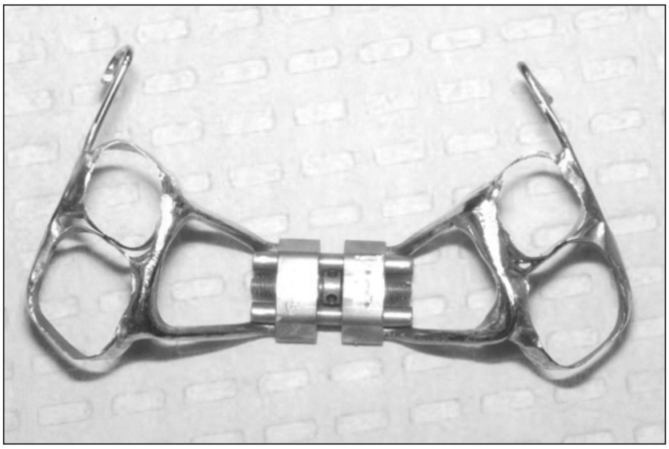

Figure 1 Hyrax expander with protraction hooks

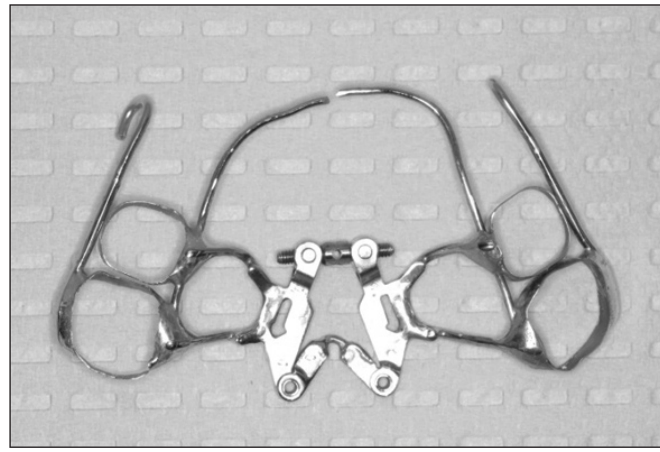

Figure 2 Double-hinged expander with protraction hooks

morphology.

Hyrax expansion appliance

The Hyrax rapid palatal expansion appliance was constructed by using bands on the posterior teeth (Figure 1). Bands were fitted on the upper second deciduous molars and on the upper permanent first molars. The bands were soldered to heavy wires (0.045 inch) which were connected to a jackscrew that centered along the midline of the maxillary palate. Bilaterally, a 0.045-inch wire was soldered to the buccal aspects of the molar bands, and extended anteriorly to the canine area. This buccal wire had a curve at the canine area so that elastics could be used to connect the appliance to a protraction facemask. Over a 1-week period, the patients activated the appliance twice daily (one turn in the morning and one in the evening; with each turn the jackscrew was widened 0.25 mm).

Double-hinged expansion appliance

The double-hinged expander (Figure 2) was used in the Alt-RAMEC protocol for greater anterior displacement of maxilla. The expansion appliance consisted of two rotational hinges posteriorly, a jackscrew in the center, and 0.051-inch wires attached to the appliance [22]. When activated, the double-hinged expander rotated each half of the maxilla outward via the two hinges. This allowed for expansion that entailed forward rotation of the maxilla with a reduced likelihood of bone resorption behind the maxillary tuberosities [20-22]. Bands were fitted on the primary second molars and permanent first molars and soldered to the jackscrew, which was positioned perpendicular to the intermaxillary suture. Bilaterally, a 0.045-inch wire was soldered to the buccal aspects of the molar bands, and extended anteriorly to the canine area. This buccal wire had a curve at the canine area so that elastics could be used to connect the appliance to a protraction facemask. In some cases, a lingual wire (0.045 inch) was soldered to the molar bands and extended to the cingulum of the maxillary incisors (to increase anchorage control).

Alternate rapid maxillary expansions and contractions protocol

The Alt-RAMEC protocol was designed to loosen the sutures that connect the maxilla to the surrounding bones via rapid expansion and contraction on an alternating weekly basis [20,21]. For this study, a 7-week protocol was used. The maxilla was expanded or contracted 1 mm per day (two turns in the morning and two turns in the evening). The amount of expansion was checked after the first, second, and fifth week. The mobility of the maxilla was checked before proceeding to maxillary protraction. The maxilla could be clinically examined for mobility by holding patients' head with one hand and rocking the anterior segment of the maxilla up and down with the other hand.

Protraction facemask

The Petit protraction facemask (Ormco Corporation, Glendora [CA], USA) is a one-piece construction with adjustable forehead padding, adjustable chin cup, and an adjustable anterior bar. The adjustable components of the protraction facemask and appropriate positioning of the anterior bar (to which elastics were attached to both right and left sides) allowed for proper positioning of the chin cup for comfort upon both opening and closing of the mandible. To avoid an opening of the bite as the maxilla was protracted, the elastics were attached near the maxillary canines with a downward and forward pull of 30 degrees to the occlusal plane. A Correx gauge (Haag-Streit, Bern, Switzerland) was used to measure the elastic force on both the Alt-RAMEC and the RME patients, to ensure that approximately 380 grams of force was generated on each side. Patients were instructed to wear the protraction facemask for 10 to 12 hours per day, which included night-time wear.

Cephalometric analysis

To evaluate treatment changes, lateral cephalograms were obtained before treatment (T1) and 6 months after protraction facemask therapy (T2). The mean (±standard deviation) treatment interval for the RME and Alt-RAMEC groups was 8±2 months and 9±3 months, respectively. A Class III removable functional appliance was used as a retainer to maintain the Class III correction after protraction facemask treatment. For the control group, serial lateral cephalometric radiographs of untreated Class III subjects were taken 6 months apart for growth evaluation (t1 and t2).

The cephalometric system used was described by Bjork [24] and Pancherz [25]. The landmarks used are defined in Figure 3. All radiographs were traced on acetate paper. Analysis of the sagittal and dental changes was recorded along the occlusal plane and to the occlusal plane perpendicular (OLp) from the first cephalogram, which formed the reference grid of all the sagittal and vertical measurements. The grid was then transferred to the second cephalogram by superimposing the tracing on the midsagittal cranial structure. All sagittal measurements were assessed and recorded twice with electronic calipers. The extent of dental changes that occurred within the maxilla and mandible were calculated to determine the skeletal and dental contributions to the overjet and molar relationship corrections.

Statistical methods

The arithmetic mean and SD were calculated for each cephalometric variable. The JMP statistical software on a Macintosh computer was used to analyze the data. The intraclass correlation coefficient of reliability (*R*) was used to analyze cephalometric measurements. The *R* value could range from 0 to 1; any value greater than 0.90 indicated high reliability and was calculated according to the following formula:

R=(MSA-MSE)/MSA+[(k-1) MSE]

In this formula MSA represented the mean square error among all the variables, MSE the mean square error between the variables, and k the number of repeated measures. The *R* values for all sagittal, vertical, angular and superimposition errors were found to be greater than 0.90.

A 3x2 analysis of variance was used to determine significant differences in dentofacial morphology between the three groups during the two periods (T1 and T2). The

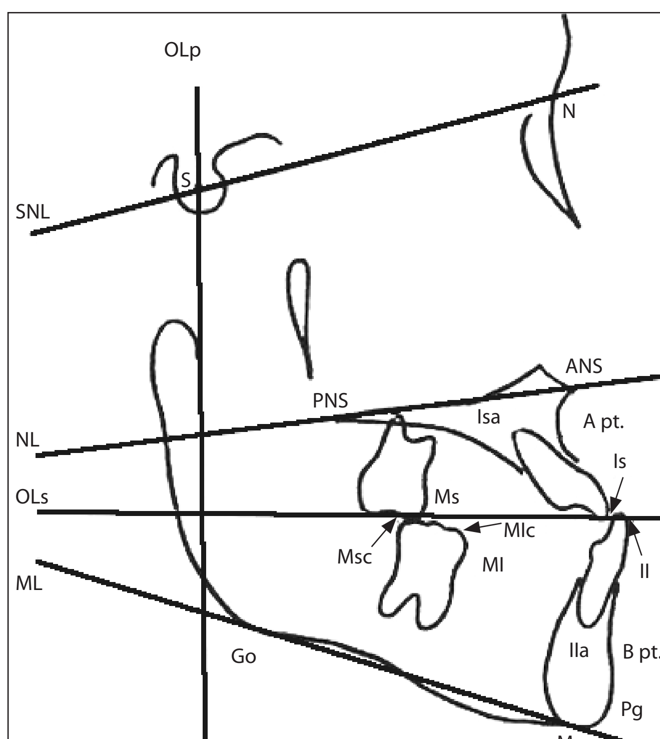

Figure 3 Skeletal and dental landmarks used for cephalometric analysis

Table 2	Sagittal, vertical, and angular changes with growth and treatment in the double-hinged expander (Alt-RAMEC), Hyrax expander (RME), and control (C) groups *			
Variable	**Alt-RAMEC**	**RME**	**Controls**	**Pairs showing significant difference**
Sagittal (skeletal) [mm]				
OLp-A pt	1.8 (0.9)	2.6 (1.4)	0.6 (0.9)	C, RME †
OLp-B pt	-1.2 (1.7)	-0.6 (1.5)	1.5 (1.7)	C, RME; C, Alt-RAMEC †
OLp-Pg	-1.1 (1.9)	-0.5 (1.8)	2.0 (2.2)	C, RME; C, Alt-RAMEC †
Sagittal (dental) [mm]				
Is/OLp	3.3 (2.1)	3.2 (2.2)	1.3 (1.9)	-
Ii/OLp	-2.0 (2.3)	-1.5 (2.6)	1.8 (2.0)	C, RME; C, Alt-RAMEC †
Overjet	5.2 (2.1)	4.7 (2.9)	-0.5 (0.9)	C, RME; C, Alt-RAMEC ‡
Ms/OLp	2.1 (1.2)	3.4 (2.1)	1.6 (1.5)	-
Mi/OLp	-1.3 (1.4)	1.1 (1.9)	2.0 (2.0)	RME, Alt-RAMEC; C, Alt-RAMEC †
Molar relationship	3.4 (1.6)	5.5 (2.0)	-0.5 (0.9)	C, RME; C, Alt-RAMEC ‡
Vertical (skeletal) [mm]				
N-A pt	0.5 (1.4)	0.1 (1.1)	1.6 (1.1)	C, RME §
ANS-Me	1.3 (2.4)	3.1 (2.3)	1.9 (1.7)	-
Vertical (dental) [mm]				
Is-NL	0.1 (1.1)	0.9 (0.6)	2.2 (1.6)	C, Alt-RAMEC †
Ii-ML	1.9 (1.2)	2.6 (3.5)	1.5 (0.7)	-
Overbite	-0.1 (1.7)	-1.3 (3.1)	1.9 (1.1)	C, RME §
Msc-NL	-0.02 (2.1)	1.2 (0.9)	1.5 (1.1)	-
Mic-ML	0.7 (1.4)	1.4 (1.2)	1.0 (0.9)	-
Angular (skeletal) [°]				
SNA	1.4 (2.0)	2.1 (0.7)	-0.6 (1.9)	C, RME; C, Alt-RAMEC †
SNB	-1.1 (0.9)	-1.0 (1.4)	0.3 (1.7)	-
ANB	2.6 (1.9)	3.6 (2.2)	0.1 (1.4)	C, RME; C, Alt-RAMEC †
SNL-ML	1.6 (0.5)	1.7 (0.5)	-0.2 (0.5)	C, RME; C, Alt-RAMEC §
SNL-OLs	-0.2 (1.2)	-1.5 (2.6)	1.1 (2.6)	-
SNL-NL	0.0 (2.7)	-0.5 (1.5)	-0.2 (2.8)	-
Angular (dental) [°]				
Is/SNL	5.5 (5.5)	4.7 (6.6)	0.2 (6.2)	-
Ii/ML	-1.3 (5.9)	-3.2 (6.8)	-0.2 (6.3)	-

* Values are expressed as mean (standard deviation), unless otherwise specified
† $p<0.01$
‡ $p<0.001$
§ $p<0.05$

Tukey-Kramer multiple comparison test was used post-hoc for comparison of pairs. Significant levels were set at $p<0.05$, $p<0.01$, and $p<0.001$.

Results

Table 2 shows the sagittal, vertical, and angular changes with growth and treatment for the Alt-RAMEC, RME, and control groups. Significant differences were found between the Alt-RAMEC and the control groups for the variables OLp-B pt, OLp-Pg, Ii/OLp, overjet, Mi/OLp, molar relationship, Is-NL, SNA, ANB, and SNL-ML. Significant differences were found between the RME and the control groups for the variables OLp-A pt, OLp-B pt, OLp-Pg, Ii/

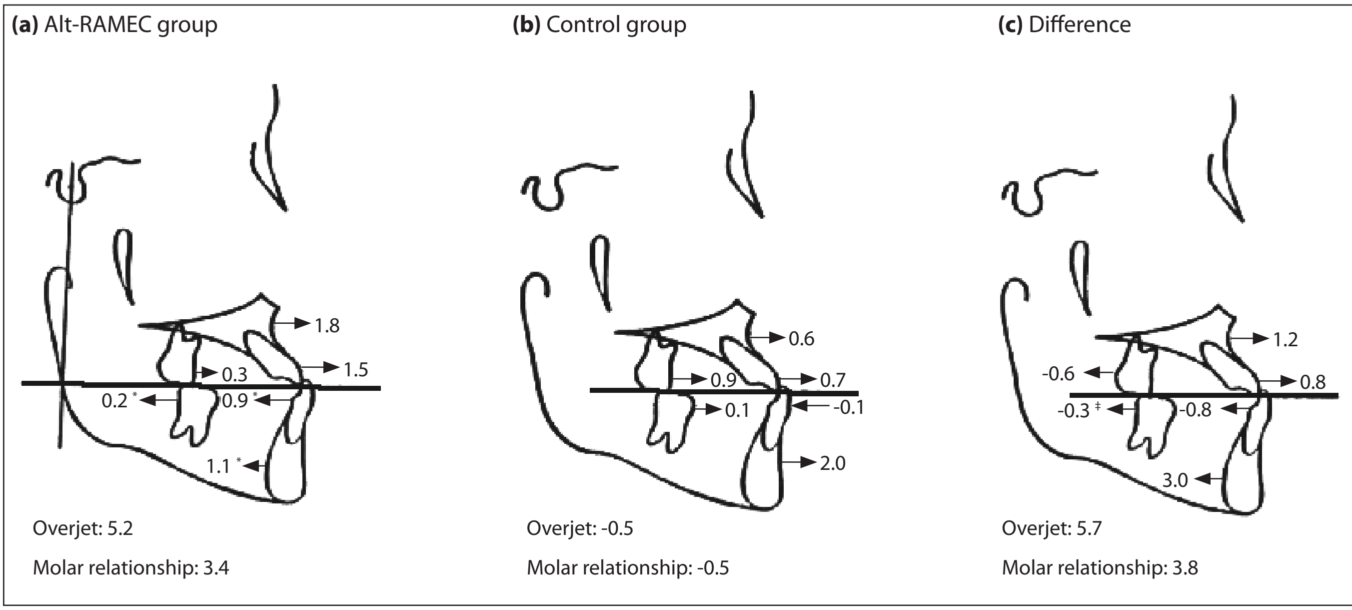

Figure 4 Mean dental and skeletal changes in overjet and molar relationship in the alternate rapid maxillary expansions and contractions (Alt-RAMEC) and control groups (mm)
* $p<0.05$ (Alt-RAMEC vs controls)
‡ $p<0.05$ (Alt-RAMEC vs rapid maxillary expansion)

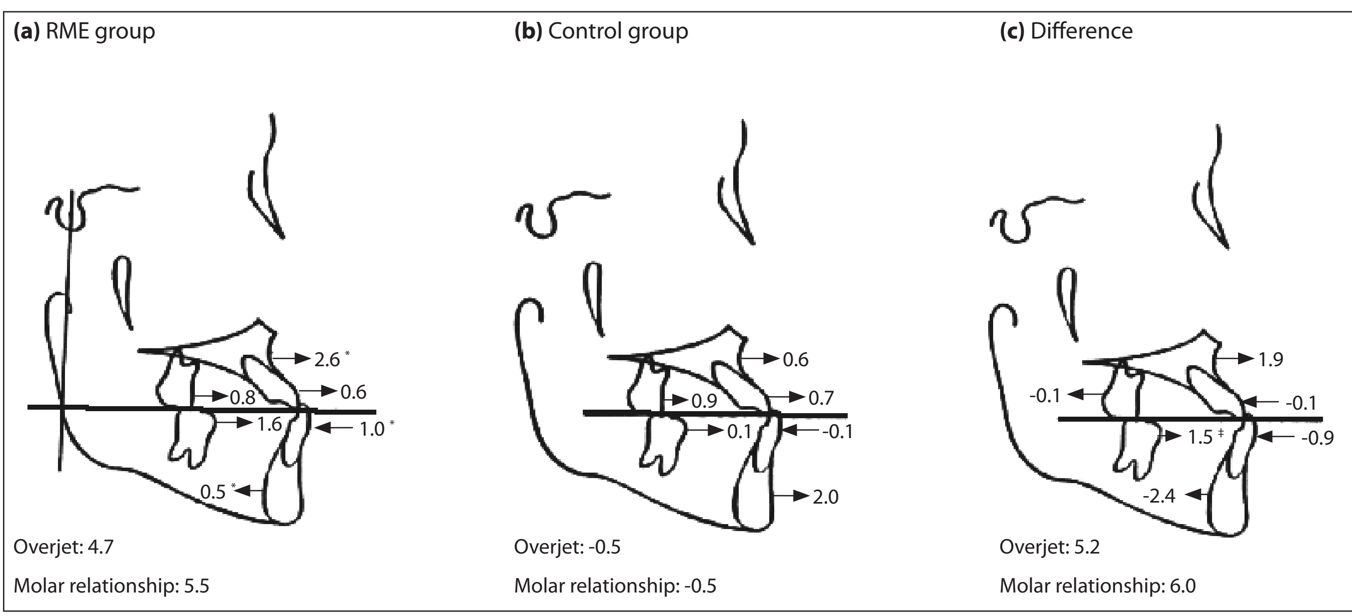

Figure 5 Mean dental and skeletal changes in overjet and molar relationship in the rapid maxillary expansion (RME) and control groups (mm)
* $p<0.05$ (RME vs controls)
‡ $p<0.05$ (RME vs alternate rapid maxillary expansions and contractions)

OLp, overjet, molar relationship, N-A pt, overbite, SNA, ANB, and SNL-ML.

Figures 4 and 5 show the dental and skeletal contributions to the changes in overjet and molar relationship in the two experimental groups. To truly appreciate the treatment effects of the appliance, the changes due to growth (control group) were subtracted

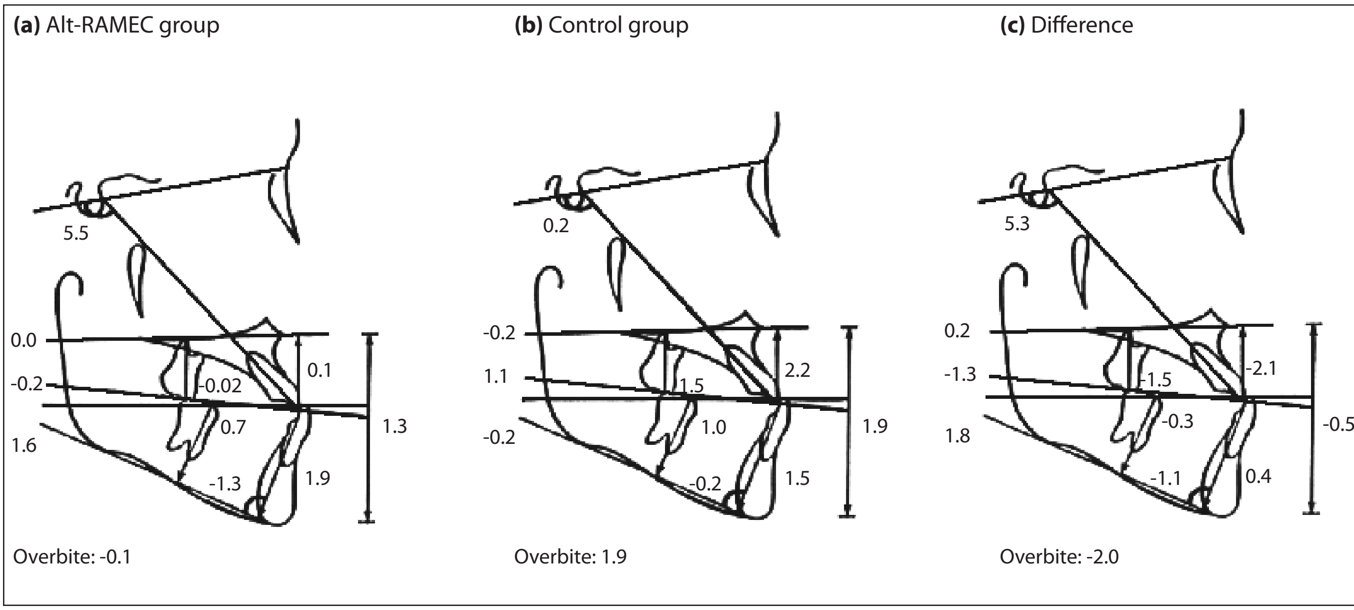

Figure 6 Mean dental and skeletal contributions to overbite changes in the alternate rapid maxillary expansions and contractions (Alt-RAMEC) and control groups (°)

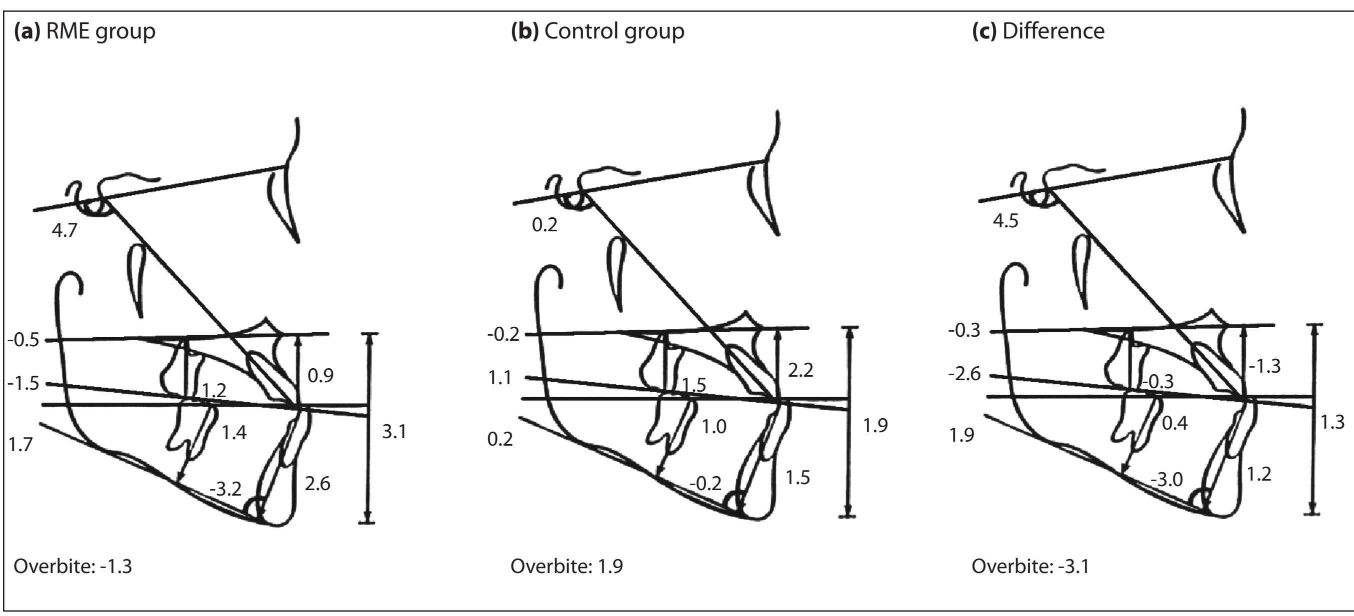

Figure 7 Mean dental and skeletal contributions to overbite changes in the rapid maxillary expansion (RME) and control groups (°)

from the treatment changes. Significant differences between the Alt-RAMEC and RME groups were only noted for forward movement of the lower molars (Mi/OLp). Figures 6 and 7 show the dental and skeletal contributions to the overbite changes in the Alt-RAMEC and RME groups. Notably, no significant differences between the two experimental groups were encountered.

Discussion

The method of cephalometric analysis used in this study was based on the one by Pancherz [25]. The errors of most variables were within acceptable limits for treatment changes and therefore considered reliable. It has been shown that the identification error for different cephalometric landmarks can vary widely. However, Tng *et al*. [26] performed a study on human skulls in which they took a series of cephalograms with reference steel ball markers glued on the skulls to represent the 'true' skeletal and dental landmarks. These were then compared with another series of cephalograms without steel ball markers, in order to check the accuracy of the sagittal and vertical landmarks. No significant differences were noted between the two series of cephalograms, both for sagittal and vertical landmarks. Thus, the Pancherz's method [26] of analyzing the sagittal and vertical landmarks on a cephalogram can be considered accurate.

In this study, the design of the appliance, anchorage device, treatment duration, force magnitude and direction were standardized so as to minimize the number of variables to be interpreted when reviewing the data. Maxillary protraction was initiated on patients with mixed dentition and a skeletal age between CVM stage 1 and 2. Takada *et al*. [27] reported that the forward maxillary displacement with protraction is more favorable before or during acceleration of a child's pubertal growth spurt.

Significant differences were found between the treated and control groups for the variable SNA. Regarding the forward/backward movement of the upper jaw, the maxilla was found to move forward 1.4º in the Alt-RAMEC and 2.1º in the RME groups compared with -0.6º in the control group. Haas [13] demonstrated that maxillary expansion alone can produce a slight forward movement of A pt along with a slight downward movement of the maxilla. Furthermore, the maxilla is articulated with nine other bones of the craniofacial complex, and so palatal expansion can help to initiate a cellular response, which helps to disarticulate the maxilla from the craniofacial complex and facilitate maxillary protraction [21]. The benefits of using rapid palatal expansion appliances in conjunction with maxillary protraction have been extensively documented in the literature [7,14,15,18,22,28-35]. The average forward movement of A pt varied between 1.5 and 3.0 mm over a period of 8 to 12 months [14,16,18]. Liou [21,22] was able to attain an average of 5.8±2.3 mm forward movement of A pt through the use of the Alt-RAMEC protocol along with a double-hinged expander. In the current pilot study, the average forward movement of A pt with the Alt-RAMEC protocol was only 1.8 mm. The main difference between the two studies was the number of hours of maxillary protraction per day. In our study, patients were asked to wear the protraction facemask for 10 to 12 hours/day. In the studies by Liou [21,22], a protraction spring was used which provided 24 hours/day of orthopedic protraction.

In the current study, when compared with the control group, treatment with the protraction facemask produced a backward movement of the mandible and the chin point. The mandible moved back 1.2 mm in the Alt-RAMEC group and 0.6 mm in the RME group, compared with a forward movement of 1.5 mm in the control group. Studies have shown that a counterclockwise tipping of the palatal plane and extrusion of the maxillary molar can result in a downward and backward rotation of the mandible [5,8,14,15,18,33,34,36,37]. This explains the difference in the changes in the mandibular base (OLp-B pt) and chin position (OLp-Pg) between the treatment and control groups.

Dentally, a mean overjet change of 5.2 mm was found with the Alt-RAMEC group and 4.7 mm in the RME group, compared with -0.5 mm in the control group. This was contributed by a forward movement of the maxilla, backward and downward rotation of the mandible, as well as proclination of the maxillary incisors and retroclination of the mandibular incisors. Similar skeletal and dental contributions to overjet correction were reported in other studies [14,15,18,21,22,30,31,33-35,38]. The molar relationship was corrected towards a Class I relationship. The average change in molar relationship was 3.4 mm in the Alt-RAMEC group and 5.5 mm in the RME group (Figures 4 and 5), compared with -0.5 mm in the controls. Significant differences between the two treatment groups were only found for the position of the mandibular molar (Mi/OLp). Again, in determining the amount of molar correction, skeletal and dental changes are taken into consideration because the downward and backward movement of the mandible changes the position of the measuring points associated with the sagittal variables OLp-Pg, Ii/OLp, and Mi/OLp, making them more negative.

As for the vertical changes, significant differences were encountered between the Alt-RAMEC group and the controls for the eruption of the maxillary incisors (0.1 vs 2.2 mm). A possible explanation is the difference in proclination of the incisors between the Alt-RAMEC (5.5°) and the control groups (0.2°). This may have been due to the difference in the design of the expander. The double-hinged expander has a lingual bar that extends forward and touches the maxillary incisors' cingulum area.

Compared with the controls, the RME group had significantly less downward movement of the maxilla (N-A pt, 1.6 vs 0.1 mm). Thus, it can be concluded that with treatment, the RME group experienced more forward and less downward movement of the maxilla, which is opposite to the pattern for growth in the controls.

In addition, significant differences in overbite were found between the RME and the control groups. A mean decrease in overbite was encountered in the RME group (-1.3 mm), while an increase in overbite (1.9 mm) was found in the controls. Interestingly, the Alt-RAMEC patients did not experience a significant change in overbite (-0.1 mm) compared with the controls. Maxillary protraction together with vertical eruption of the maxillary and mandibular molars may have contributed to the decrease in overbite in the RME group. There were no significant changes in molar eruption (Msc-NL and Mic-ML) with the Alt-RAMEC group. Baik [37] reported 1.6 mm of mean maxillary molar extrusion and 1.7 mm of mean mandibular molar extrusion, when a banded-type rapid palatal expander was used in connection with protraction facemask over a period of 6 months. However, protraction treatment without expansion can also result in molar extrusion as noted by Takada *et al*. [27], who found significant molar extrusion of greater than 1.8 mm in pre- and mid-pubertal patients.

Hata *et al*. [39] showed that protraction of the maxillary arch causes an anterior rotation and forward movement of the maxilla, unless a downward vector of the protraction force was also used. This was related to the point of force application on the maxilla. In the present study, protraction of the maxilla at the maxillary canine region with a 30° average downward vector during a 6-month period of protraction facemask therapy did not produce a significant change in the palatal plane.

Results in the present study suggest that treatment of a skeletal Class III malocclusion at an early age, when the maxillary suture has not interlocked, can be beneficial to the patients. Clinically, both treatment groups showed improvement in Class III malocclusion when compared with the controls. The RME group appeared to have had a little more success, possibly due to a difference in patient compliance with regard to wearing the facemask for a requested period of 10 to 12 hours daily. Significant differences between the Alt-RAMEC and RME groups were found with respect to the movement of mandibular molars (Mi/OLp) after subtracting changes due to growth. This was because the RME group had more vertical and mesial molar movement than the Alt-RAMEC group. Hence, the former group also experienced a decrease in overbite compared with the latter. A bonded expansion appliance has been shown to reduce molar eruption during maxillary expansion, possibly due to the splinting effect as well as the occlusal bite-plate effect of the bonded expander [40]. Patients who exhibit a skeletal openbite tendency may benefit from expansion with an acrylic bite plate.

The success and failure of orthopedic treatment of children with skeletal Class III malocclusion is substantially dependent on patient compliance and growth potential. As observed, Alt-RAMEC did not attain as much overjet correction as the RME, primarily because patients using the former reported only wearing the facemask for an average of 8 to 10 hours per day, instead of the prescribed 10 to 12 hours/day. However, it should be noted that the Alt-RAMEC patients did show marked improvement in Class III malocclusion within the first few months of protraction, possibly due to the loosening of the maxillary sutures.

Conclusions

Significant sagittal and vertical changes were encountered with both expansion protocols when compared with the controls. The correction of anterior crossbite and molar relationship were due to a forward movement of the maxilla and a downward and backward rotation of the mandible. The RME group exhibited more forward movement of the maxilla, but the changes may have been due to the higher level of compliance in this group compared with the Alt-RAMEC group. These preliminary data suggest that Alt-RAMEC alone does not increase the amount of forward movement of the maxilla. Other factors including the age of patients, the duration of facemask wear, as well as treatment duration need to be considered in future studies.

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