

Quantitative Evaluation of Consecutively Rapid Maxillary Expansions and Constrictions Effects on Circum-Maxillary Sutures in Boys by SPECT Bone Scintigraphy

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Abstract

Objective: The aim of the study was to ascertain bone activity changes at biomechanically induced circum-maxillary sutures by Consecutively Rapid Maxillary Expansions and Constrictions (CRME-C).

Materials and Methods: A banded type maxillary expansion device with Double Hinged Expansion Screw was used for CRME-C in 9 growing male patients having 11.29 ± 0.76 chronologic age (range from 9.8 to 13.6 years) and skeletal Class III malocclusion with transvers maxillary deficiency. Screw was 4 times a day as twice at the morning and twice in the evening. CRME-C started by opened the screw in first week and closed it next week was applied during consecutively 9 weeks. After under-jet was reduced and/or maxillary constriction was eliminated, the screw was fixed, and the device was kept in mouth for retention for six months. Single photon emission computed tomography bone scintigraphy records were obtained before (T1) and at the end of CRME-C (T2) and six months after the retention period (T3). Nonparametric Test-Friedman's Two-Way Analysis of Variance was used to assess the differences between the periods and Tukey multiple comparison tests were applied.

Results: Statistically significant bone activity increase was determined in the right posterior site of the mid-palatal suture region, both right and left zygomatic maxillary suture regions and left zygomaticotemporal suture regions in T2 period, whereas, it was decreased after six months' retention period.

Conclusion: It has been revealed that bone activity is increased on posterior mid-palatal suture region within 9-weeks of CRME-C in early growth period of the boys.

Keywords: Class III Malocclusion; Maxillary Transvers Deficiency; Rapid Maxillary Expansion; Scintigraphy

Introduction

Rapid maxillary expansion (RME) being increasingly employed recently was firstly introduced by Angell (1860) to overcome maxillary transverse deficiency before the advent of X-ray technology [1,43]. As maxillary bone relates to most contiguous bones via sutures, the expansion force is distributed both in the maxilla and extends into the surrounding maxillary structures [10,28]. The purpose of RME in Class III malocclusion combined with maxillary retrusion, whether maxillary transverse deficiency exists or not, is to mobilize directly and indirectly articulated surrounding sutures in the maxilla [44]. The nature of maxillary expansion's force, where it is transmitted through the craniofacial complex, and how it triggers a cellular reaction was revealed in studies employing a dry skull, rhesus monkeys, and finite element models [7,10,11,15,16,22,27-29,33,37,40,42,47].

According to Starnbach., *et al.* palatal expansion does not just separate the mid-palatal suture, it separates the circum-zygomatic and circum-maxillary sutural systems as well [10]. Moreover, there is evidence from animal studies that the widened sutural area (induced by strong expansion forces) is rapidly filled in by new bone growth [6,9,12,18,19,24,25,48]. On the other hand, the effect of RME is less significant on surrounding sutures in the maxilla than expected. Significant maxillary protraction requires well opened circum-maxillary sutures.

One hypothesis regarding the biomechanics of RME is that to conceive downward and forward movement of the maxillary bone disarticulating to the circum-maxillary sutures [14]. Several studies have revealed that factors that play a role during sutural synostosis are the type of rapid maxillary expander, and rate and rhythm of the expansion protocol on the type of maxillary movement [20,34,39,45]. The expansion width and frequency of RME, direct versus indirect articulation of the circum-maxillary suture to the maxilla, or orientation of circum-maxillary sutures to the maxilla all affect the amount of maxillary-suture opening also [31,46].

Although most clinical and radiographic studies have evaluated the effects of expansion forces induced by different expansion protocols on both maxilla and far away from maxillary articulations [5,8,13,17,31]; quantitatively detailed information on the effect of alternated rapid maxillary expansion and the constriction (Alt-RAMEC) on both maxilla and surrounding sutures of the maxilla has not been well explored in human beings. Recently, bone imaging with injected radiopharmaceuticals, as an imaging modality, offers many advantages over conventional radiographs, since it enables us to detect early stages of metabolic or functional changes in human skeletal structures. Bone scintigraphy labelled with ^{99m}Tc diphosphonates (^{99m}Tc -MDP) has become a widely accepted method for assessing pediatric bone metabolism as well.

Therefore, the aim of this study was to, by using single photon emission computed tomography (SPECT) bone scintigraphy labeled by ^{99m}Tc -MDP scans, quantitatively assess bone activity changes occurring on the maxillary sutures directly and indirectly articulated to the maxilla and sagittally or coronally oriented circum-maxillary and circum-zygomatic sutures in growing Class III malocclusion combined with maxillary retrusion following consecutive rapid maxillary expansion and constriction (CRME-C) and after 6-months of CRME-C.

Materials and Methods

Ethical approval was obtained from ethical committee of the dental faculty, University of Ankara, Turkey, and informed consent was obtained from all individual participants for whom identifying information is included in this study. The material for this prospective study consisted of lateral cephalometric radiographs and SPECT scintigraphy records taken from 9 growing male patients with Class III combined with maxillary retrusion (SNA, 77°; SNB, 81.5°; ANB, -4.5°; GoGn-SN, 32°), sequentially treated with CRME-C at the Department of Orthodontics, Dental Faculty, Ankara University, Ankara, Turkey. Mean age of patients at the time of the first imaging appointment in this study was 11.29 ± 0.76 (range from 9.8 to 13.6 years). Inclusion criteria of the patients were:

- Skeletal transverse maxillary discrepancy,
- Bilateral posterior cross-bite and deep palatal vault,
- Upper dental arch crowding.

Exclusion criteria of the patients were:

- Craniofacial anomalies, including cleft lip and palate,
- Orthodontic appliances treatment with RME before then.

Each patient was outfitted with a tooth-borne RME appliance consisting of a double-hinged expansion screw (Best Dent, Kaohsiung, Taiwan) created by Liou [32] (Figure 1A). The appliance design requires banding four teeth (two maxillary first premolars or deciduous first molars and two maxillary first molars). Two anterior extension arms (0.051-inch stainless steel wires) extending bilaterally from

the premolar bands toward the central incisors were soldered onto the premolar bands. The anterior extension arms were bonded to the anterior teeth with composite resin (Figures 1B and 1C). The appliance screw was activated according to the CRME-C protocol, which was opened via two quarter turns in the morning and two quarter turns at night during the first week. The following week, it was closed in the same rhythm. The repetitive weekly sequence consisted of one week with the double-hinged screw opened and another week with it closed. Daily amount of activation was 1 mm. The complete protocol took 7 to 9 weeks of CRME-C. The expander was kept open at the end of the protocol because an expanded maxilla permits more maxillary protraction than an unexpanded maxilla. Posterior and anterior cross-bites had been corrected at the end of an average of 8 weeks of CRME-C. The appliance was left in situ as a passive retainer for 6 months, after which it was removed. We had access to a complete set of SPECT scintigraphy images including one prior to appliance delivery (T1), one taken immediately after the active expansion phase of treatment (T2) and one taken 6 months later of at the end of the active expansion phase of treatment (T3). Our patients' skeletal maturation stage was defined by hand-wrist films as PP2=, S and MP3cap stages.



Figure 1: A. DHES and its key. B. Tooth-borne rapid maxillary expansion appliance consisted of a DHES view on cast. C. Intraoral view of tooth-borne rapid maxillary expansion appliance consisted of a DHES.

SPECT bone scintigraphy with labeled ^{99m}Tc -MDP

Bone activity in both the mid-palatal suture and surrounding maxillary sutures was evaluated via SPECT bone scintigraphy with labeled ^{99m}Tc -MDP before CRME-C (T1), capturing the end-to-end incisor relationship (T2) and 6 months later the T2 period (T3). For the ethical requirements, all SPECT bone scintigraphy procedure including the need for hydration, time/duration of the scan, and details of the procedure itself, the waiting time between injection and image acquisition was explained to the patient and his/her parents and written consents were obtained. Intravenous injection (I.V.) dose of ^{99m}Tc -MDP was adjusted to the patient's weight according to the latest version of the European Association of Nuclear Medicine (EANM) dosage card for children [30].

Recommended injection amounts for ^{99m}Tc -MDP imaging based on the dosage EANM card are listed in table 1 [21,30]. The minimum is 30 MBq I.V. injection dose of ^{99m}Tc -MDP for children weighing 30 kg was adjusted to approximately 240 MBQ (6,48 mCi). SPECT images on the trans-axial, coronal and sagittal planes were taken almost three hours after the I.V. injection of ^{99m}Tc -MDP.

Bone SPECT images of the skull were obtained with a dual headed gamma camera (Siemens ICAM 2000) by using a low energy, high resolution collimator. Thirty-two 30-second views were acquired over 180° rotations in a 64 × 64 matrix. Trans-axial and coronal slices on medial slices included twenty pixel-sized circular regions of interest (ROI) were reframed for quantitative analysis of circum-maxillary suture regions on both right and left sides (Figure 2 and 3). According to the orientation, circum-maxillary suture regions were evaluated by classifying into three groups:

- **Group 1:** Suture orienting sagittally and articulating directly to maxilla: The mid-palatal suture region.
- **Group 2:** Sutures orienting coronally and articulating directly to maxilla: The fronto-maxillary suture region and the zygomatico-maxillary suture region.
- **Group 3:** Suture orienting coronally and articulating indirectly to the maxilla: The zygomatico-temporal suture region.

Weight (kg)	^{99m} Tc-MDP activity (MBq)	Weight (kg)	^{99m} Tc-MDP activity (MBq)
3	40	32	255
4	40	34	270
6	60	36	280
8	75	38	295
10	95	40	310
12	110	42	320
14	125	44	335
16	140	46	350
18	155	48	360
20	170	50	375
22	185	52 - 54	395
24	200	56 - 58	420
26	215	60 - 62	445
28	225	64 - 66	470
30	240	68	490

Table 1: Recommended activities for ^{99m}Tc-MDP based on the EANM dosage card [30,41].

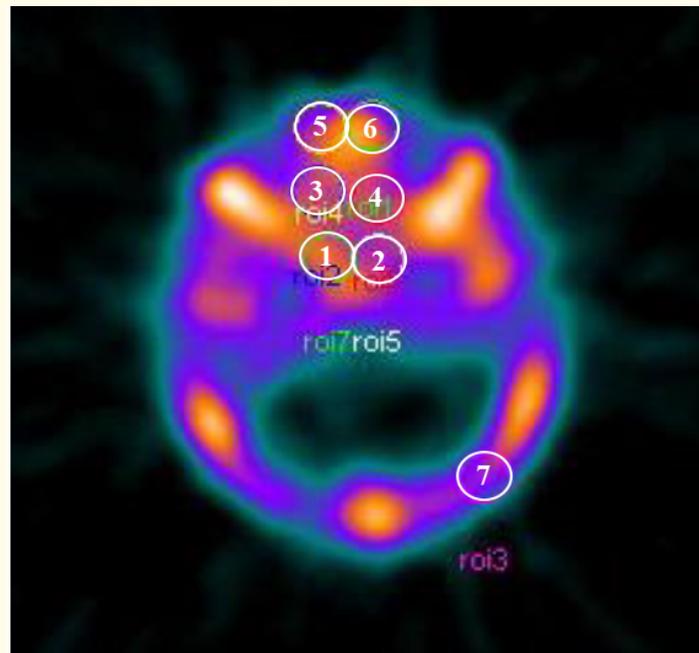


Figure 2: The ROI examined on trans-axial slice of SPECT images. 1. Right (P) mid-palatal suture region. 2. Left (P) mid-palatal suture region. 3. Right (M) mid-palatal suture region. 4. Left (M) mid-palatal suture region. 5. Right (A) mid-palatal suture region. 6. Left (A) mid-palatal suture region. 7. Left occipital bone region used to define background bone activity.

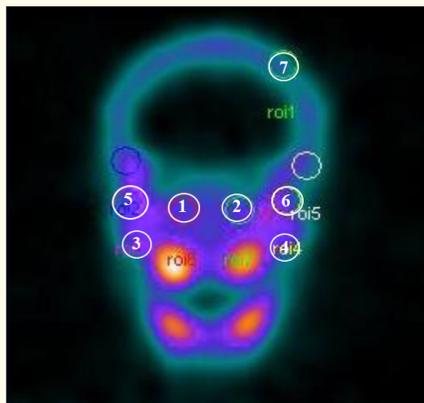


Figure 3: The regions of interest examined on coronal slice of SPECT images. 1. Right fronto-maxillary suture region. 2. Left fronto-maxillary suture region. 3. Right zygomatico-maxillary suture region. 4. Left zygomatico-maxillary suture region. 5. Right zygomatico-temporal suture region. 6. Left zygomatico-temporal suture region. 7. Left occipital bone region used to define background bone activity.

Suture region in the Group 1 was evaluated on trans-axial slices separated three sections as anterior (A), median (M) and posterior (P) (Figure 2). Suture regions in Groups 2 and 3 were evaluated on coronal slices (Figure 3). The average counts in each ROI were determined using a computer to define bone activity changes in trans-axial and coronal slices. Background bone activity was defined from the left occipital bone region (Figure 2 and 3). Bone activity indices (BAI) were defined in all trans-axial and coronal slices by dividing activity counts ROI on the craniofacial regions by background bone activity counts. All results were expressed as the ratio of uptake of the ROI to that of the left occipital bone. BAI was calculated for mid-palatal suture on trans-axial slice and surrounding suture of the maxilla on coronal slices in this study. All scintigraphic records and evaluations were done by the same radiologist.

Statistical method

Descriptive statistics, including the means and standard deviations, were calculated separately for each period. Mann-Whitney U test and Friedman’s two-way analysis of variance (ANOVA) were used to assess differences between the periods (Table 2-5). Tukey multiple comparison tests were applied to the measurements at which p values were found to be statistically significant. Data were analyzed using SPSS for Windows, version 16.0 (SPSS Inc, Chicago, III). p value of .05 and .01 was considered statistically significant.

Group 1	Right Side			P	Test		
	T1	T2	T3		T1-T2	T2-T3	T1-T3
	Mean ± SD	Mean ± SD	Mean± SD				
Mid-palatal suture A	4.48 ± 2.42	7.57 ± 3.82	3.6 ± 1.06	0.254 ^{ns}	0.98 ^{ns}	0.32 ^{ns}	0.059 ^{ns}
Mid-palatal suture M	5.67 ± 2.37	6.82 ± 4.82	3.14 ± 0.55	0.368 ^{ns}	1.00 ^{ns}	0.43 ^{ns}	0.065 ^{ns}
Mid-palatal suture P	5.50 ± 2.06	8.16 ± 4.05	3.43 ± 0.85	0.050*	0.326 ^{ns}	0.048*	1.00 ^{ns}

Table 2: Descriptive statistics and the results of the Friedman’s Two-Way Analysis of Variance on trans-axial slice of right side anterior (A), medial (M) and posterior (P) sections of mid-palatal suture region in T1, T2 and T3 periods (Trans-axial slice).

The Results of the Tukey Multiple Comparison Test.

Significance level: ns: nonsignificant, p < 0.05*.

Abbreviations: A: Anterior; M: Medial; P: posterior.

Group 1	Left Side			p	Test		
	T1	T2	T3		T1-T2	T2-T3	T1-T3
	Mean ± SD	Mean ± SD	Mean ± SD				
Mid-palatal suture A	4.34 ± 2.27	7.40 ± 4.05	3.27 ± 0.88	0.276 ^{ns}	0.68 ^{ns}	0.39 ^{ns}	0.069 ^{ns}
Mid-palatal suture M	5.51 ± 1.98	8.48 ± 5.01	3.31 ± 0.73	0.317 ^{ns}	1.00 ^{ns}	0.73 ^{ns}	0.095 ^{ns}
Mid-palatal suture P	5.38 ± 1.97	8.67 ± 4.34	3.63 ± 0.76	0.102 ^{ns}	0.366 ^{ns}	0.88 ^{ns}	0.70 ^{ns}

Table 3: Descriptive statistics and the results of the Friedman’s Two-Way Analysis of Variance on trans-axial slice of left side anterior (A), medial (M) and posterior (P) region of Mid-palatal suture in T1, T2 and T3 periods (Trans-axial slice). The Results of the Tukey Multiple Comparison Test.

Significance level: ns: nonsignificant.

Abbreviations: A: Anterior; M: Medial; P: Posterior.

Groups 2 and 3	Right Side			p	Test		
	T1	T2	T3		T1-T2	T2-T3	T1-T3
	Mean ± SD	Mean ± SD	Mean ± SD				
Fronto-maxillary suture	4.25 ± 1.61	5.43 ± 3.35	2.70 ± 1.49	0.05*	1.00 ^{ns}	0.048*	0.32 ^{ns}
Zygomatico-maxillary suture	5.51 ± 2.69	6.66 ± 3.68	2.94 ± 1.09	0.004**	1.00 ^{ns}	0.004**	0.048**
Zygomatico-temporal suture	4.13 ± 1.48	6.37 ± 3.90	2.30 ± 1.09	0.01*	0.85 ^{ns}	0.010*	0.184 ^{ns}

Table 4: Descriptive statistics and the results of the Friedman’s Two-Way Analysis of Variance on coronal slice of right Fronto-maxillary, zygomatico-maxillary, zygomatico-temporal sutures in T1, T2 and T3 periods (Coronal Slice).

The Results of the Tukey Multiple Comparison Test.

Significance level: ns: nonsignificant, p < 0.05*, p < 0.01**.

Groups 2 and 3	Left Side			p	Test		
	T1	T2	T3		T1-T2	T2-T3	T1-T3
	Mean ± SD	Mean ± SD	Mean ± SD				
Fronto-maxillary suture	3.91 ± 1.51	5.06 ± 3.38	2.82 ± 1.25	0.276 ^{ns}	1.00 ^{ns}	0.076 ^{ns}	1.00 ^{ns}
Zygomatico-maxillary suture	5.14 ± 1.00	6.40 ± 4.07	3.07 ± 1.08	0.004*	1.00 ^{ns}	0.015*	0.015*
Zygomatico-temporal suture	3.76 ± 1.38	5.86 ± 4.96	2.50 ± 1.04	0.007*	1.00 ^{ns}	0.010*	0.069 ^{ns}

Table 5: Descriptive statistics and the results of the Friedman’s Two-Way Analysis of Variance on coronal slice of left Fronto-maxillary, zygomatico-maxillary, zygomatico-temporal sutures in T1, T2 and T3 periods (Coronal Slice).

The Results of the Tukey Multiple Comparison Test.

Significance level: ns: Nonsignificant, p < 0.05*.

Results

Descriptive statistics, including the means and standard deviations for each region, and the p values obtained from the Friedman’s Two Way Analysis of Variance (ANOVA) are shown for Group 1 in all sections for each sides in tables 2 and 3; for Groups 2 and 3 each sides in table 4 and 5. Tukey multiple comparison tests between periods are also presented in the tables. As the quantity of each suture’s bone activation was significantly different in the right and left sides (p < .05; p < .001), they were separately analyzed in right and left sides.

Bone activity changes in each suture region between T1-T2-T3 periods were found to be statistically significant in each group except for the right A and M sections of Group 1, left side of Group 1, and left side of Group 2 (fronto-maxillary suture) regions in this study. These differences were identified extensively between T2 and T3 periods; and between T1 and T3 periods rather than between T1 and T2 periods after comparing the periods.

In the trans-axial slices, the mid-palatal suture region was evaluated in three sections as section-A, section-M, section-P and right and left sides (Table 2 and 3). On the right side, the mid-palatal suture exhibited a statistically significant bone activity increase in section-P between T1 and T2 periods, whereas a decrease in bone activity was detected in T3 period. That difference became apparent between periods T2 and T3 ($p < .05$, table 2).

In the coronal slices, we found bone activity changes to be statistically significant in all circum-maxillary sutures regions except on the left side in the fronto-maxillary suture region between all periods. We nevertheless detected an increase in bone activity during 8-weeks of CRME-C (T2), while it decreased during the six-month retention period (T3). Indeed, note that the difference appearing between periods resulted from bone activity decreases between T2 and T3 on Group 2's and Group 3's right side, in both sides, and between T1 and T3 for the zygomatico-maxillary suture regions on both sides (Table 4 and 5; $p < .05$ and $p < .01$). During the retention period (T3), bone activity decreased statistically significantly, as compared with the initial value from the zygomatico-maxillary suture region on both sides (Table 4, $p < .01$ and table 5, $p < .05$).

Discussion

There is considerable clinical and experimental data in the literature on the effects of RME on maxillary sutures articulated with adjacent maxillary bone and far away from it [10,18,23-25,27-29].

The quantitative evaluation of sutures both articulating directly or indirectly to the maxilla and orienting sagittally or coronally to the maxilla by RME is facilitated by a three-dimensional (3-D) imaging method [31]. While 3-D imaging reveals the amount of sutural displacement induced by RME, bone activity changes in the sutural regions remain unknown. However, bone activity around the mid-palatal suture and circum-maxillary sutures, especially the maxilla's exterior located far away from the palate where biomechanical force is applied by RME, has been addressed in only a few studies [2,5].

A new protocol requiring weekly repeated activation and deactivation of the mid-palatal suture (Alt-RAMEC) has been described in the literature as effectively protracting the maxilla, mobilizing the circum-maxillary sutures [32]. Indeed, in study carried out in cats, Wang et. al. demonstrated quantitatively that sequentially opening and closing the maxillary expansion screw over a 5-week period exerts an effect on sagittally-oriented circum-maxillary sutures [46]. The dentofacial effects of the Alt-RAMEC protocol have been evaluated by a few working groups [26,38]. On the other hand, bone activity changes to the circum-maxillary sutures articulating directly or indirectly and orienting sagittally or coronally to the maxilla via Alt-RAMEC has not been well explored quantitatively in human beings.

Because of the lack of quantitative evidence, the present study was designed to shed light on bone activity changes to the circum-maxillary sutures articulated directly or indirectly to the maxilla and oriented sagittally or coronally to the maxilla following CRME-C in growing Class III malocclusion combined with maxillary retrusion.

Conventional radiographs do not suffice to detect small changes in the rates of local bone formation in the early stages of disease. Bone lesions in early stages can be detected via skeletal imaging with injected, short-lived, bone-seeking radiopharmaceuticals. Since the introduction of ^{99m}Tc labelled diphosphonates, bone scintigraphy has become a widely accepted method for assessing bone metabolism. Although this clinical tool provides valuable diagnostic and therapeutic information on metabolism, it has seldom been used in orthodontics [2,3, 5,14,35,36].

RME does not only correct maxillary arch discrepancies, it also affects other adjacent structures in the face and cranium due to the maxilla articulates with other skull bones through the cranial and circum-maxillary sutures. These factors might affect the degree of the circum-maxillary suture opening, include the expansion width and frequency of RME, direct and indirect articulation of the circum-maxillary suture to the maxilla, or the sagittal and coronal orientation of circum-maxillary sutures [46].

In this study, the bone activity changes in circum-maxillary sutures during CRME-C and retention phase were examined via SPECT bone scintigraphy. While we observed significant bone activity increases in the fronto-maxillary, zygomatico-maxillary, zygomatico-temporal and mid-palatal sutures during CRME-C (T1-T2), in line with other RME studies demonstrating that those areas are affected by the generated forces, we also noted significant reductions in bone activity during the retention period (T2-T3) in this study.

Our findings show that bone activity onto the mid-palatal suture articulating directly and orienting sagittally to the maxilla (Group 1) was more quantitatively than those indirectly articulated and coronally oriented to the maxilla (Groups 2 and 3) during the CRME-C period (T1-T2). Bone activity onto the fronto-maxillary suture placed remotely and oriented coronally was quantitatively less than Groups 2 and 3 despite being articulated directly to the maxilla. This finding stands in contrast with evidence that circum-maxillary sutures articulated directly to the maxilla are well opened [45]. The factor affecting the quantification of bone activity of fronto-maxillary suture in this study might be its apparent orientation. Indeed, there is evidence that coronally oriented circum-maxillary sutures were opened less than those sagittally oriented [46].

On the other hand, bone activation to the zygomatico-maxillary suture region was greater than that in the fronto-maxillary suture region in this study, despite being coronally oriented. Since the fronto-maxillary suture occupies a purely coronal position compared to the zygomatico-maxillary suture, this finding is conceivable.

Bone activity to the zygomatico-temporal suture region was higher also than the activation in the fronto-maxillary suture region for the same reason. These findings are incompatible with findings by Baydaş and co-workers, who evaluated effects of RME on circum-maxillary sutures in young adult females via bone scintigraphy [5]. They found that bone activation in the naso-frontal sutural area was higher than that in the zygomatico-maxillary sutural region.

In this study, scintigraphs document the bone activity around the mid-palatal suture in the posterior region were inconsistent with previous studies [2,5]. Mid-palatal suture exhibited a significant increase in bone activity in all regions due to CRME-C, with the amount of quantitatively bone activation greater in the posterior region than in the anterior region on both sides in this study. However, in previous scintigraphs taken during RME revealed that bone activity in the anterior and medial mid-palatal suture was significantly greater than that in the posterior region during the expansion period [2,5]. The paradoxical results in this study may be due to our subjects' growth period, the kind of maxillary expander used, and the daily rate and rhythm of expansion. There is ample evidence of the significant effect of a child's growth stage on the efficacy of treating maxillary transverse deficiency [2]. The expansion of the mid-palatal suture provokes other sutures in the maxilla. The transverse suture oriented coronally and positioned perpendicularly is the resistance area closest to the mid-palatal suture. Melsen demonstrated histologically in human autopsy material that the transverse suture can be disarticulated until the age of 13 to 15 years [34]. Bacetti and co-workers declared that maxillary expansion performed before the prepubertal peak affects both maxillary and circum-maxillary sutures as well [4]. In fact, this study has verified those data. The significant bone activity increase we observed in the posterior mid-palatal suture area in this study can be attributed to the fact that these subjects were boys in the juvenile growth stage. The maxillary palatal bone can be easily disarticulated from the pterygoid plate during this growth stage. The double-hinged rapid maxillary expander can overcome resistance occurring on the posterior border of palatal bone because of consisting two rotating hinges. It has also been surmised that major resistance to the RME is not the mid-palatal suture but rather the remaining maxillary articulations [24,25]. In any case, the aim of the double-hinged rapid maxillary expander is to disarticulate the circum-maxillary suture rather than the mid-palatal suture. There is experimental evidence that the circum-maxillary sutures running sagittally are opened

significantly wider than those running coronally [46]. Disarticulating the maxilla from adjoined bones entails opened sutures running coronally. Experimental evidence shows that opening the coronally running circum-maxillary sutures is possible in at least 7 weeks of Alt-RAMEC [46]. CRME-C was applied for an average of 8 weeks in the present study. Other studies reported bone scintigraphic findings indicating that expansion continues until the buccal crossbite is overcome [2,5]. There is convincing evidence that interrupted resistance onto the transverse palatine suture running coronally (due to differing rates and rhythm in CRME-C from RME) may increase the bone activity in the posterior region of the mid-palatal suture running sagittally in this study.

Quantitative examination of the mid-palatal suture region and more remote suture regions of the maxilla revealed that changes took place there as a result of alternating forces that separated the mid-palatal suture in this study. We found that bone activity diminished dramatically in all sutural regions between the T2 and T3 periods. This finding has been confirmed by animal studies [11,45]. We observed significantly less bone growth in the right posterior mid-palatal suture region than on left side between T2 and T3. The growth diminished after the 6-months retention period (T3) in comparison to immediately after the CRME-C period (T2). This decrease in bone growth may be due to biomechanical forces discharged in the palate, although this phenomenon was not apparent on the left side. This asymmetric expansion finding is consistent with those of Isaacson and Murphy, who found that the response of the buccal quadrants to rapid expansion forces may differ between patients and between the left and right quadrants in the same patients [23]. It is conceivable that diverse centers of resistance may be created via expansion forces alternating between the right and left postero-exterior margin of the maxillary halves because of the rigid palate articulations involved [6,12,19].

Conclusion

There are several current methods for quantifying the skeletal and dental effects of rapid maxillary expansion. However, according to the literature, there is no agreement as to which approach is superior. In this study, we found quantitative evidence that the mid-palatal suture in section-P opened well despite resistance onto the transverse palatine suture. This may be due to biological and biomechanical factors such as the skeletal age of our subjects, features of the expansion screw and its activation rate and rhythm.

Ethical Approval

Ethical approval was obtained from ethical committee of the dental faculty, University of Ankara, Turkey and informed consent was obtained from all individual participants for whom identifying information is included in this article.

Bibliography

1. Angell EH. "Treatment of irregularities of the permanent or adult teeth". *Dental Cosmos* 1 (1860): 540-544, 599-601.
2. Arat ZM., et al. "99mTechnetium-Labeled Methylene Diphosphonate Uptake in Maxillary Bone During and After Rapid Maxillary Expansion". *The Angle Orthodontist* 73 (2003): 545-549.
3. Arat ZM., et al. "Evaluation of functional orthognathic therapy effects on temporomandibular joint with Scintigraphy". *European Journal of Orthodontics* 22 (2000): 570.
4. Baccetti T., et al. "Treatment Timing for Rapid Maxillary Expansion". *The Angle Orthodontist* 71 (2001): 343-350.
5. Baydas B., et al. "Nonsurgical Rapid Maxillary Expansion Effects on Craniofacial Structures in Young Adult Females A Bone Scintigraphy Study". *The Angle Orthodontist* 76 (2006): 759-757.
6. Biederman W. "Rapid correction of Class III malocclusion by midpalatal expansion". *The American Journal of Orthodontics and Dentofacial Orthopedics* 63 (1973): 47-55.

7. Boryor A, *et al.* "Stress distribution and displacement analysis during an intermaxillary disjunction: a three-dimensional FEM study of a human skull". *The Journal of Biomechanics* 41 (2008): 376-382.
8. Bouserhala J, *et al.* "Three-dimensional changes of the naso-maxillary complex following rapid maxillary expansion". *The Angle Orthodontist* 84 (2014): 88-95.
9. Braun S, *et al.* "The biomechanics of rapid maxillary sutural expansion". *The American Journal of Orthodontics and Dentofacial Orthopedics* 118 (2000): 257-261.
10. Chaconas SJ and Caputa AA. "Observation of orthopedic force distribution produced by maxillary orthodontic appliances". *The American Journal of Orthodontics and Dentofacial Orthopedics* 82 (1982): 492-501.
11. Cleall JF, *et al.* "Expansion of the midpalatal suture in the monkey". *The Angle Orthodontist* 35:23-35.
12. Davis WM and Kronman JH. "Anatomical changes induced by the splitting of the midpalatal suture". *The Angle Orthodontist* 39 (1969):126-132.
13. Franchi L, *et al.* "Modification of midpalatal sutural density induced by rapid maxillary expansion: A low-dose computed tomography evaluation". *The American Journal of Orthodontics and Dentofacial Orthopedics* 137 (2010): 486-488.
14. Garcia DA, *et al.* "Tc-99mpolyphosphate bone imaging of orthodontically treated dog teeth". *The American Journal of Orthodontics and Dentofacial Orthopedics* 66 (1974): 665-674.
15. Gardner GE and Kronman JH. "Cranioskeletal displacements caused by rapid palatal expansion in the rhesus monkey". *The American Journal of Orthodontics and Dentofacial Orthopedics* 59 (1971): 146-155.
16. Gautam P, *et al.* "Stress and displacement patterns in the craniofacial skeleton with rapid maxillary expansion: a finite element method study". *The American Journal of Orthodontics and Dentofacial Orthopedics* 32 (2007): 11-15.
17. Ghoneima A, *et al.* "Effects of rapid maxillary expansion on the cranial and circummaxillary sutures". *The American Journal of Orthodontics and Dentofacial Orthopedics* 140 (2011): 510-519.
18. Haas AJ. "Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture". *The Angle Orthodontist* 31 (1961): 73-90.
19. Haas AJ. "Treatment of maxillary deficiency by opening the midpalatal suture". *The Angle Orthodontist* 35 (1965): 200-217.
20. Haas AJ. "Palatal expansion: Just the beginning of dentofacial orthopaedics". *The American Journal of Orthodontics and Dentofacial Orthopedics* 57 (1970): 219-255.
21. Hahn K, *et al.* "Guidelines for bone scintigraphy in children". *The European Journal of Nuclear Medicine and Molecular Imaging* 28 (2001): BP42-47.
22. Holberg C. "Effects of rapid maxillary expansion on the cranial base-an FEM-analysis". *The Journal of Orofacial Orthopedics* 66 (2005): 54-66.
23. Isaacson RJ and Murphy TD. "Some effects of rapid maxillary expansion in cleft lip and palate patients". *The Angle Orthodontist* 34 (1964): 143-154.

24. Isaacson RJ, *et al.* "Force produced by rapid maxillary expansion. I. Design of the force measuring system". *The Angle Orthodontist* 34 (1964): 256-260.
25. Isaacson RJ and Ingram AH. "Forces produced by rapid maxillary expansion. Part II. Forces present during treatment". *The Angle Orthodontist* 34 (1964): 261-269.
26. Isci D, *et al.* "Activation-deactivation rapid palatal expansion and reverse headgear in Class III cases". *European Journal of Orthodontics* 32 (2010): 706-715.
27. Iseri H, *et al.* "Biomechanical effects of rapid maxillary expansion on the craniofacial skeleton, studied by the finite element method". *European Journal of Orthodontics* 20 (1998): 347-356.
28. Itoh T. "Photoelastic effect of maxillary protraction on the craniofacial complex". *The American Journal of Orthodontics and Dentofacial Orthopedics* 88 (1985): 117-124.
29. Jafari A, *et al.* "Study of stress distribution and displacement of various craniofacial structures following application of transverse orthopedic forces: a three-dimensional FEM study". *The Angle Orthodontist* 73 (2003): 12-20.
30. Lassmann M, *et al.* "The new EANM paediatric dosage card". *The European Journal of Nuclear Medicine and Molecular Imaging* 34 (2007): 796-798.
31. Leonardi R, *et al.* "Early post-treatment changes of circumaxillary sutures in young patients treated with rapid maxillary expansion". *The Angle Orthodontist* 81 (2011): 36-41.
32. Liou E J-W. "Tooth borne orthopedic maxillary protraction in Class III patients". *The Journal of Clinical Orthodontics* 29 (2005): 68-75.
33. Marcotte MR. "The instantaneous transverse changes in the maxilla due to different points of force application". *The Journal of Dental Research* 56 (1977): 465-470.
34. Melsen B. "Palatal growth studies on human autopsy material: A histologic microradiographic study". *The American Journal of Orthodontics and Dentofacial Orthopedics* 68 (1975): 42-54.
35. Nicolay OF, *et al.* "^{99m}Tc-Medronate uptake in the temporomandibular joints of young rats treated with a mandibular hyperpropulsor". *The American Journal of Orthodontics and Dentofacial Orthopedics* 100 (1991): 459-464.
36. Paulsen HU, *et al.* "Bone scintigraphy of human temporomandibular joints during Herbst treatment; a case report". *European Journal of Orthodontics* 20 (1998): 369-374.
37. Provatidis CG, *et al.* "Evaluation of craniofacial effects during rapid maxillary expansion through combined in vivo/in vitro and finite element studies". *European Journal of Orthodontics* 30 (2008): 437-448.
38. Sen Yilmaz B and Kucukkeles N. "Skeletal, soft tissue, and airway changes following the alternate maxillary expansions and constrictions protocol". *The Angle Orthodontist* 85 (2015): 117-126.
39. Silva Filho, *et al.* "Rapid maxillary expansion in the primary and mixed dentitions: A cephalometric evaluation". *The American Journal of Orthodontics and Dentofacial Orthopedics* 100 (1991): 171-179.
40. Starnbach HK and Cleall JF "The Effects of splitting the midpalatal suture on the surrounding structures". *The American Journal of Orthodontics and Dentofacial Orthopedics* 50 (1964): 923-924.

41. Starnbach HK., *et al.* "Facioskeletal and dental changes resulting from rapid maxillary expansion". *The Angle Orthodontist* 36 (1966): 152-164.
42. Timms DJ. "A study of basal movement with rapid maxillary expansion". *The American Journal of Orthodontics and Dentofacial Orthopedics* 77 (1980): 500-507.
43. Timms DJ. "The dawn of rapid maxillary expansion". *The Angle Orthodontist* 69 (1999): 247-250.
44. Turley PK. "Treatment of the Class III malocclusion with maxillary expansion and protraction". *Seminars in Orthodontics* 13 (2007): 143-157.
45. Vardimon AD., *et al.* "Rapid palatal expansion: Part 1. Mineralization pattern of the midpalatal suture in cats". *The American Journal of Orthodontics and Dentofacial Orthopedics* 113 (1998): 371-378.
46. Wang YC., *et al.* "Opening of Circumaxillary Sutures by Alternate Rapid Maxillary Expansions and Constrictions". *The Angle Orthodontist* 79 (2009): 230-234.
47. Yu HS., *et al.* "Three- dimensional finite-element analysis of maxillary protraction with and without rapid palatal expansion". *European Journal of Orthodontics* 29 (2007): 118-125.
48. Zimring JF and Isaacson RJ. "Forces produced by rapid maxillary expansion. III. Forces present during retention". *The Angle Orthodontist* 35 (1965): 178-186.

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