Original Article

Nonsurgical Rapid Maxillary Expansion Effects on Craniofacial Structures in Young Adult Females

A Bone Scintigraphy Study

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ABSTRACT

Objective: To evaluate the skeletal effects of nonsurgical rapid maxillary expansion (RME) on craniofacial structures with bone scintigraphy in young adult female subjects.

Materials and Methods: The material of the present study consists of scintigraphic records taken from 17 early adult females treated with RME. All patients had a bilateral posterior crossbite, transverse maxillary deficiency, deep palatal vault, and dental crowding at the beginning of the treatment. The age range of the patients was 16.1 to 18.8 years, and the mean age was 17.3 ± 0.86 years. Bone scintigraphy records were obtained before RME (T1), during the splitting of the midpalatal suture (T2), and after the end of active widening period (T3). Repeated measure analysis of variance was used to assess the differences between the periods. In addition, Bonferroni multiple comparison tests were applied to the measurements at which F values were found to be statistically significant.

Results: According to the statistical analysis, significant activity changes were found in all regions studied and in all slices. The metabolic activity in all regions showed significant increases up to the separation of the midpalatal suture (T1-T2), whereas the metabolic activity exhibited a remarkable decrease (T2-T3) after the opening of the midpalatal suture.

Conclusions: Scintigraphic records revealed an increase in the regions of interest scores during RME in all regions and all slices. Therefore, it can be speculated that RME has had not only dental effects but also skeletal effects on young adult patients.

KEY WORDS: Nonsurgical; Rapid maxillary expansion; Bone scintigraphy; Young adult

INTRODUCTION

Rapid maxillary expansion (RME) is indicated in the treatment of maxillary deficiency or constriction (or both). Maxillary constriction is a discrepancy secondary to genetic, environmental, and functional factors. The most important indication of skeletal and dental upper arch narrowness is a buccal crossbite. RME is able to eliminate a buccal crossbite and the transverse discrepancy between the dental arches due to maxillary constriction.[1–7]

Although the main objective of RME is to correct maxillary arch narrowness, its effects are not limited to the upper jaw. The maxilla is associated with 10 bones in the face and head, so RME may affect structures directly or indirectly related to the maxilla,[8–11] mandible,[1,3,5–7,10–13] nasal cavity,[1,3,5–7,13] pharyngeal structures,[12,14] temporomandibular joints,[10] and the pterygoid process of the sphenoid bone.[12]

During RME, high forces are directed to the maxillary basal bone and perhaps to other adjacent skeletal bones. Such heavy RME forces can easily separate the midpalatal suture in young individuals and force the two maxillary halves laterally.[1,3–5,9,15] Widening has been reported to be associated with sensations of pressure at various craniofacial areas, especially in the areas of articulation of the maxilla.[16–18]

Recently, expansion of midpalatal suture in adult

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cases presenting with narrow maxillary arch has been increasing. However, many clinicians have reported difficulty in producing palatal expansion after the pubertal growth period,[2,5,13,15] unlike the favorable orthopedic responses indicated before[5,6] or during pubertal growth (or both).[2,15,19]

It has been stated that correction of the maxillary deficiency and posterior crossbite in young patients is often accomplished by a combination of skeletal and dental expansion.[20] Skeletal expansion involves separating the right and left maxillary halves at the midpalatal suture; dental expansion results from buccal tipping of the maxillary posterior teeth.[1,5,6,11,16,21,22] The goal of maxillary expansion is to maximize skeletal effects and minimize dental effects.[1,21,22] However, once patients are past their growth spurt, which occurs at about the age of 12–13 years in females and 14–15 years in males, the protocol for RME is less clear.[23] According to some authors, expansion of the maxillary arch in mature patients is not feasible.[11,24,25] Other recent evidence has suggested that it is indeed possible to successfully expand the palate in young adults.[26] Clinicians are thus faced with a dilemma when treating patients after the pubertal growth spurt.

The effects of RME on the craniofacial structures are generally investigated using radiological imaging and histological methods. Conventional radiographs are easy to obtain, but they are not sufficient to assess the bone activity in the midpalatal suture and its surrounding tissues. Histological findings, on the other hand, are limited to experimental studies.[27]

Bone scintigraphy is another imaging modality that has the sensitivity to reflect skeletal metabolic activity.[28] Bone scintigraphy has been widely used for the detection of abnormal vascularity or osteogenesis in the skeletal system. Because of its ability to detect functional change, a bone scan can be more informative well before visible structural changes occur on radiographs.[27–30]

The aim of this study is to evaluate the skeletal effects of nonsurgical RME on craniofacial structures with bone scintigraphy in young adult female subjects.

MATERIALS AND METHODS

The material for this prospective study consisted of scintigraphic records taken from 17 adult females treated with RME at the Department of Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey. All patients had a bilateral posterior crossbite, transverse maxillary deficiency, deep palatal vault, and dental crowding at the start of the treatment. The mean chronological age of the patients was 17.3 $\pm$ 0.86 years (range 16.1 to 18.8 years). Patients with traumatic injury, malign and benign jaw lesion, and inflammatory disorders such as periodontal diseases and periapical lesions and patients who had undergone orthodontic treatment were not included in this study. The patients were informed about all possible sequelae, risks, and benefits, including possible termination of the nonsurgical treatment and the possible use of surgical expansion in case of failure of the nonsurgical RME procedure. For the ethical requirements, all procedures were explained to the patients and their parents and written consents were obtained.

All patients had completed their pubertal growth spurt, as evaluated on hand-wrist films. Young adults were defined by hand-wrist radiographic stages R-IJ (fusion of the distal epiphysis of the radius with its metaphysis is almost complete) and R-J (fusion of the distal epiphysis of the radius with its metaphysis is complete). All patients were at R-J radiographic stage except two patients, who were at R-IJ stage.

We used a Biederman-type RME appliance with Hyrax screw (602-813, Dentaurum, Ispringen, Germany).[31] Patients were instructed to activate the jackscrew twice a day (0.5 mm), once in the morning and once in the evening. Expansion was considered adequate when the occlusal aspect of the maxillary lingual cusp of the permanent first molar contacted the occlusal aspect of the mandibular facial cusp of the permanent first molar.

The amount of overexpansion was designed to compensate for relapse after expansion. The average active expansion time was 20 days. The appliance was left in place for approximately 6 months after the active expansion.

Bone Scintigraphy

The single-photon emission computed tomography (SPECT) bone scintigraphy with ^{99m}Technetium-Methylene Diphosphonate (^{99m}Tc-MDP) records were obtained before RME (T1), during the splitting of the midpalatal suture (T2), and after the end of active widening period (T3).

SPECT bone scintigraphy was used to assess bone activity in craniofacial areas surrounding the midpalatal suture in each period. For bone scintigraphy, patients were given an intravenous injection of 0.4 mCi/kg (15 MBq/kg) of ^{99m}Tc-MDP. Imaging was performed 3 hours after injection of the radiopharmaceutical. The SPECT images of the head were obtained with a single-head gamma camera system (GE 3200 XCT General Electric Medical System Ltd, St Albans, Herts, England) using a low-energy, all-purpose, high-resolution collimator. SPECT images were acquired for 25 s/frame over 360° rotations in a 256 $\times$ 256 matrix, and a 1.33 zoom was selected. Two pixel-sized transaxial,

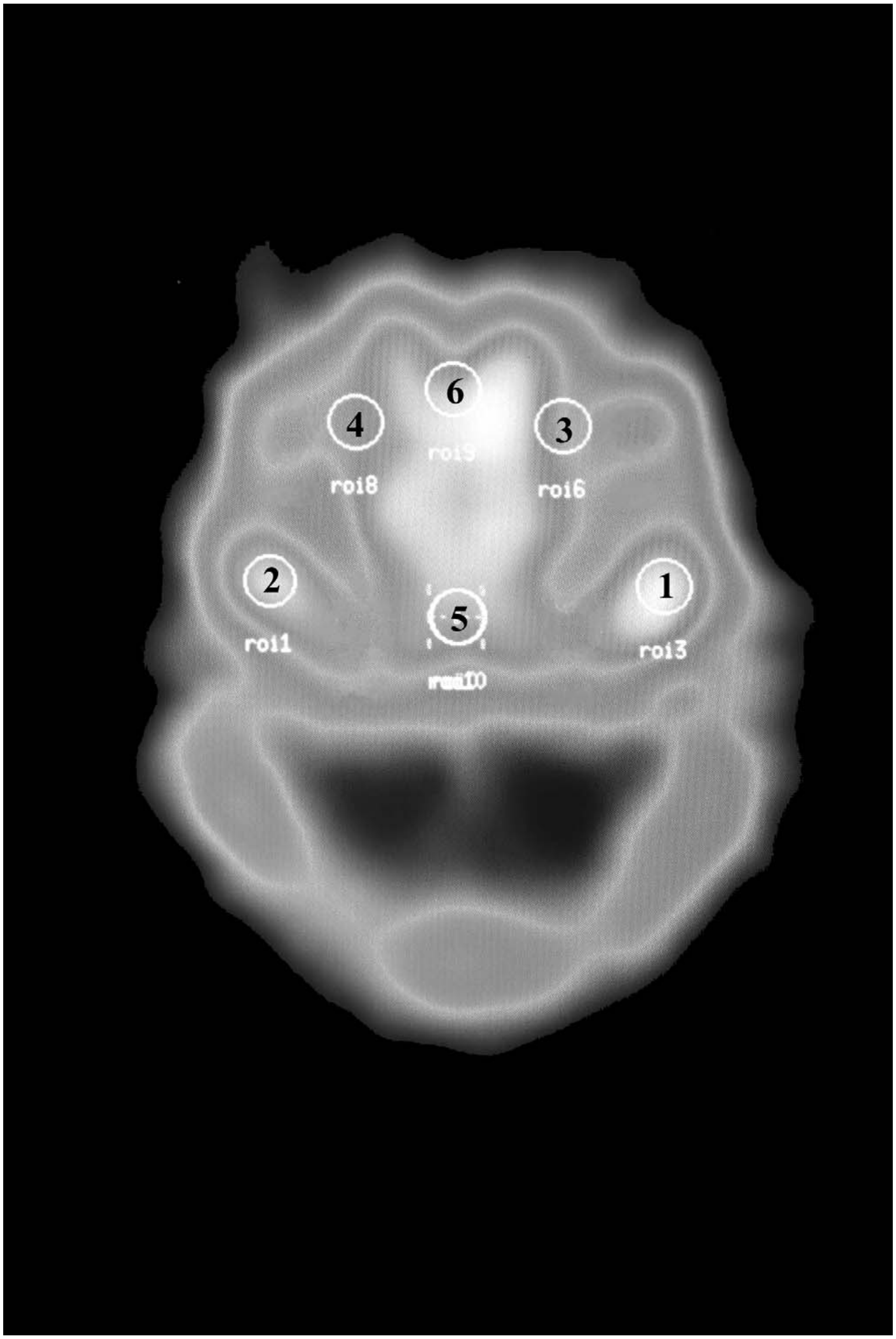

Figure 1. The regions of interest examined on transaxial slice: (1) sphenosquamous suture region (right), (2) sphenosquamous suture region (left), (3) zygomaticomaxillary suture region (right), (4) zygomaticomaxillary suture region (left), (5) sphenooccipital synchondrosis region, and (6) midpalatal suture region.

sagittal, and coronal slices were generated (Figures 1 through 3).

The images of the craniofacial regions were viewed on the computer screen, and selected regions were magnified to locate the areas of interest. Ten pixel-sized circular regions of interest (ROI) were drawn on the medial slices of the transaxial, sagittal, and coronal slices. The average counts in each ROI were determined using a computer. Thus, the metabolic activity changes were defined in all

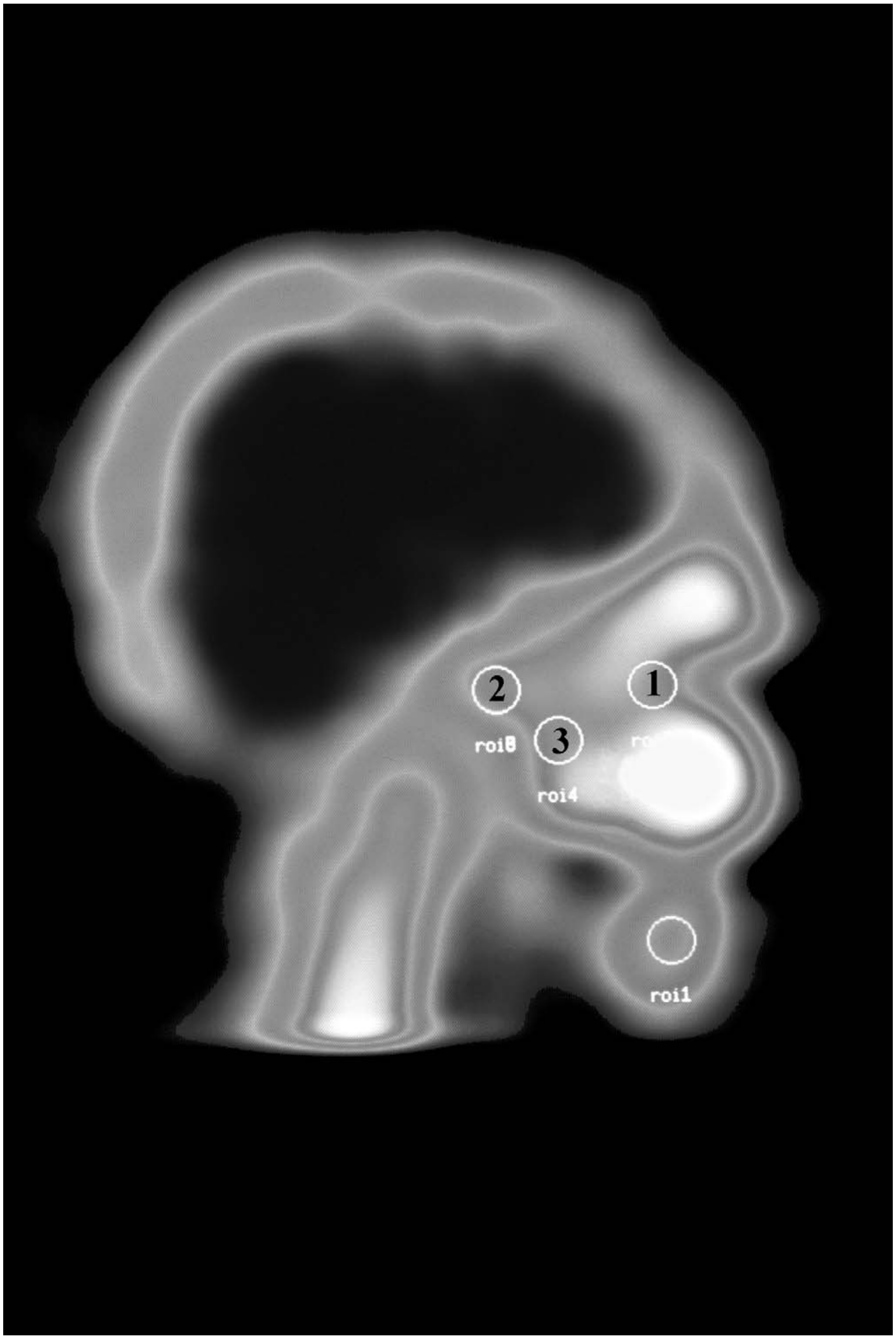

Figure 2. The regions of interest examined on sagittal slice: (1) cristanasalis region, (2) sphenooccipital synchondrosis region, and (3) vomerosphenoid suture region.

transaxial, sagittal, and coronal slices by dividing activity counts on the craniofacial regions by backgrounds activity counts. Background bone activity was defined from the symphysis area. All results were expressed as a ratio of uptake of the ROI to that of the mandibular symphysis. These quantitative evaluations in all the transaxial, sagittal, and coronal slices were performed using the Genie processing program (Genie version 2.6S, General Electric Medical System Ltd, Milwaukee, Wisconsin). All scintigraphic records and evaluations were made by the same radiologist.

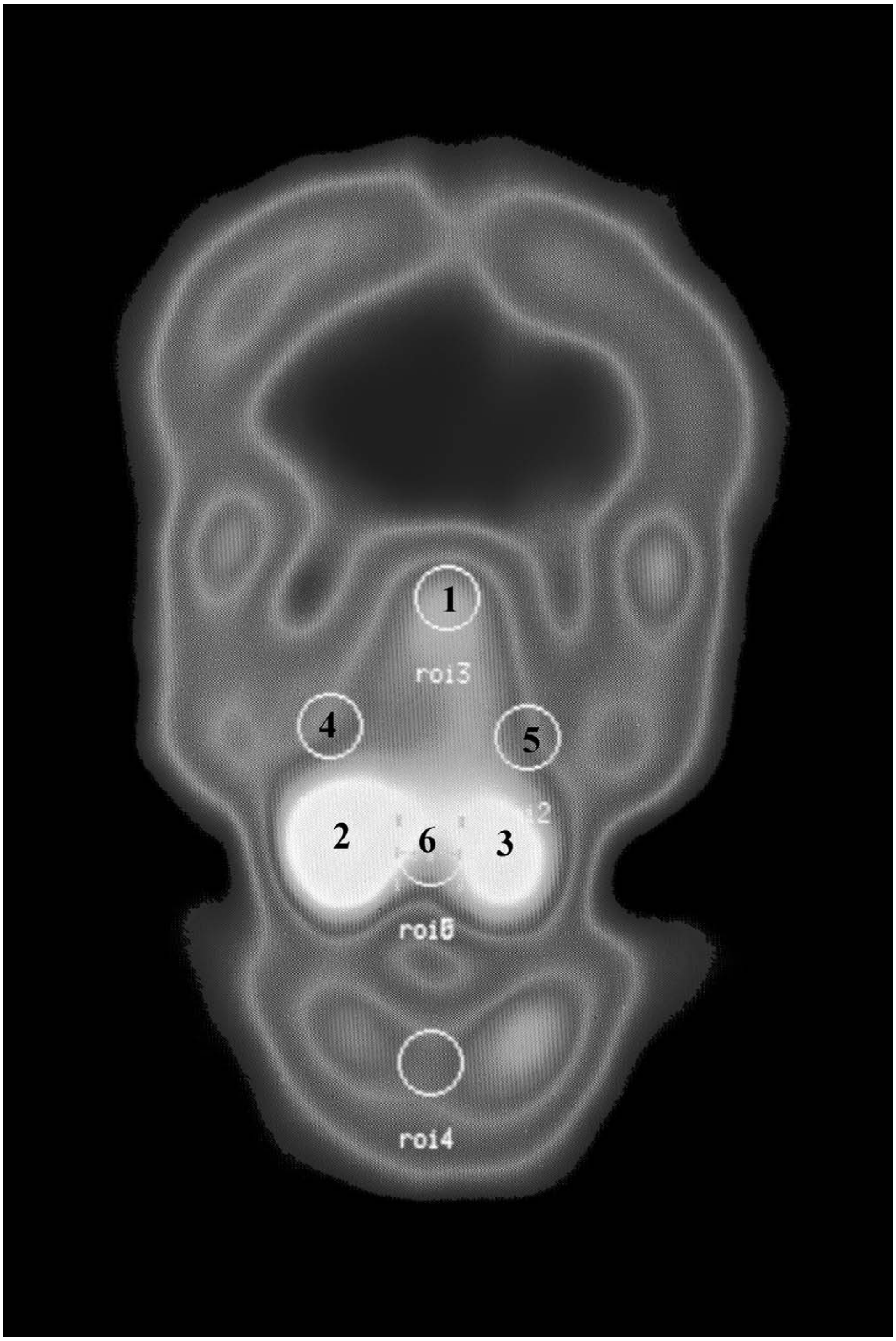

Figure 3. The regions of interest examined on coronal slice: (1) nasofrontal suture region, (2) maxillary region (right), (3) maxillary region (left), (4) zygomaticomaxillary suture region (right), (5) zygomaticomaxillary suture region (left), and (6) midpalatal suture region.

Statistical Analysis

Descriptive statistics, including the means and standard deviations, were calculated separately for each period. Repeated measures analysis of variance (ANOVA) was used to assess the differences between the periods. In addition, Bonferroni multiple comparison tests were applied to the measurements at which *F* values were found to be statistically significant. Data were analyzed using SPSS for Windows, version 10.0 (SPSS Inc, Chicago, Ill). $P < .05$ was considered to be statistically significant.

Table 1. Descriptive Statistics and the Results of the Repeated Measures Analysis of Variance (Transaxial Slice)

	T1		T2		T3		
N = 17	Mean	SD	Mean	SD	Mean	SD	*F*
Regions							
Sphenosquamous suture region (right) (1)	0.53	0.13	0.86	0.25	0.75	0.15	28.53***
Sphenosquamous suture region (left) (2)	0.60	0.15	0.89	0.21	0.75	0.10	23.68***
Zygomaticomaxillary suture region (right) (3)	0.58	0.12	0.83	0.15	0.69	0.16	12.84***
Zygomaticomaxillary suture region (left) (4)	0.56	0.13	0.86	0.16	0.64	0.17	19.25***
Sphenooccipital synchondrosis region (5)	0.71	0.20	0.98	0.17	0.86	0.15	15.17***
Midpalatal suture region (6)	1.41	0.23	2.08	0.43	2.09	0.32	30.13***

*** $P < .001$.

Table 2. Descriptive Statistics and the Results of the Repeated Measures Analysis of Variance (Sagittal Slice)

	T1		T2		T3		
N = 17	Mean	SD	Mean	SD	Mean	SD	*F*
Regions							
Cristanasalis region (1)	0.92	0.22	1.24	0.20	1.18	0.20	17.26***
Sphenooccipital synchondrosis region (2)	0.89	0.11	1.27	0.19	1.10	0.14	30.24***
Vomerosphenoid suture region (3)	0.82	0.12	1.18	0.17	1.06	0.17	27.81***

*** $P < .001$.

Table 3. Descriptive Statistics and the Results of the Repeated Measures Analysis of Variance (Coronal Slice)

	T1		T2		T3		
N = 17	Mean	SD	Mean	SD	Mean	SD	*F*
Regions							
Nasofrontal suture region (1)	0.83	0.21	1.20	0.27	1.14	0.20	19.71***
Maxillary region (right) (2)	0.93	0.32	1.52	0.55	1.18	0.37	19.64***
Maxillary region (left) (3)	0.93	0.21	1.58	0.61	1.23	0.45	13.02***
Zygomaticomaxillary suture region (right) (4)	0.74	0.17	1.12	0.26	0.94	0.14	25.51***
Zygomaticomaxillary suture region (left) (5)	0.77	0.17	1.17	0.29	0.96	0.15	22.69***
Midpalatal suture region (6)	1.13	0.17	1.75	0.33	1.58	0.29	29.25***

*** $P < .001$.

RESULTS

Descriptive statistics, including the means and standard deviations for each record, and the *F* values obtained from the ANOVA are shown in Table 1 for transaxial slices, in Table 2 for sagittal slices, and in Table 3 for coronal slices. As can be seen in these tables, statistically significant metabolic activity changes were found for all regions investigated in the study ($P < .001$).

The results of the Bonferroni multiple comparison tests are presented in Table 4 for transaxial slices, in Table 5 for sagittal slices, and in Table 6 for coronal slices. In transaxial slices, all regions examined exhibited significant metabolic activity increase between T1 and T2 periods ($P < .001$), whereas metabolic activity decreases were found in all regions except the midpalatal suture region between T2 and T3 periods. However, these activity decreases were not statistically significant in some regions. At the end of the 20-day-long active treatment, increases in the metabolic activity in the right and left zygomaticomaxillary suture regions returned almost to the initial status, whereas high ROI scores continued in the other sites as compared with the initial status (Table 4).

In sagittal slices, statistically significant metabolic activity increases in all regions examined were found between the T1 and T2 periods ($P < .001$), whereas metabolic activity in all regions decreased between the T2 and T3 periods. However, these decreases were statistically significant only in the sphenooccipital synchondrosis region. After the active treatment, metabolic activity changes in all regions were still statistically significantly different compared with the first records (Table 5).

In coronal slices, statistically significant increases in metabolic activity were found in all regions examined between the T1 and T2 periods ($P < .001$), whereas metabolic activity in all regions decreased between the

Table 4. The Results of the Bonferroni Multiple Comparison Test (Transaxial Slice)

	T1–T2	T2–T3	T1–T3
Regions			
Sphenosquamous suture region (right) (1)	0.33***	−0.11	0.22***
Sphenosquamous suture region (left) (2)	0.29***	−0.15*	0.14**
Zygomaticomaxillary suture region (right) (3)	0.25***	−0.14	0.11
Zygomaticomaxillary suture region (left) (4)	0.30***	−0.21**	0.08
Sphenooccipital synchondrosis region (5)	0.26***	−0.12	0.15*
Midpalatal suture region (6)	0.68***	0.01	0.68***

* $P < .05$, ** $P < .01$, *** $P < .001$.

Table 5. The Results of the Bonferroni Multiple Comparison Test (Sagittal Slice)

	T1–T2	T2–T3	T1–T3
Regions			
Cristanasalis region (1)	0.32***	−0.06	0.26***
Sphenooccipital synchondrosis region (2)	0.37***	−0.17*	0.20**
Vomerosphenoid suture region (3)	0.37***	−0.12	0.25***

* $P < .05$, ** $P < .01$, *** $P < .001$.

Table 6. The Results of the Bonferroni Multiple Comparison Test (Coronal Slice)

	T1–T2	T2–T3	T1–T3
Regions			
Nasofrontal suture region (1)	0.37***	−0.06	0.31**
Maxillary region (right) (2)	0.60***	−0.34*	0.26**
Maxillary region (left) (3)	0.65***	−0.33*	0.30*
Zygomaticomaxillary suture region (right) (4)	0.39***	−0.19*	0.20***
Zygomaticomaxillary suture region (left) (5)	0.40***	−0.21*	0.19***
Midpalatal suture region (6)	0.62***	−0.17	0.45***

* $P < .05$, ** $P < .01$, *** $P < .001$.

T2 and T3 periods. However, these activity decreases were not statistically significant in the nasofrontal suture and the midpalatal suture regions. After the active treatment, ROI scores in all regions were still statistically significant, as compared with the initial scores (Table 6).

DISCUSSION

The skeletal expansion of the upper jaw without expanding the teeth in their alveoli is the main objective of the RME. Therefore, RME is considered as an orthopedic approach.[27] However, it has been suggested that skeletal effects of the RME tend to be less significant with skeletal maturity because of the increased rigidity of the articulations of the maxilla with the face.[5]

To overcome the fusion and resistance of the adult sutures to expansion, surgically assisted RME has been advocated. Surgery, however, is costly and requires either outpatient surgery or hospitalization with attendant morbidity and time loss from work.[26] On the other hand, if nonsurgical RME in young adults proves to be effective and skeletal changes could be accomplished, the disadvantages of surgically assisted RME might be overcome. In this study, therefore, the skeletal effects of the nonsurgical RME on the craniofacial structures in young adults were investigated.

According to scintigraphic records, statistically significant metabolic activity changes were found in all regions. In all regions the metabolic activity showed significant increases up to the splitting of the midpalatal sutures (T1-T2). After the opening of the midpalatal sutures, the activities exhibited remarkable decreases (T2-T3). After the active treatment, however, metabolic activity increases in all regions were still statistically significantly different as compared with the first records. In addition, the metabolic activity increase was the highest around the midpalatal suture and right and left maxillary areas during the RME. However, the metabolic activity changes in the regions far from the midpalatal suture were limited. These results indicate that the force concentration in sutural areas increases up to the opening of the midpalatal suture and that the further away from the midpalatal suture the greater the decrease in the forces resulting from RME. In addition, it can be said that high increases in metabolic activity in the midpalatal suture and maxillary region indicated new bone formation.

Arat et al[27] investigated bone activity using the scintigraphic method at the right and left maxillary areas and midpalatal suture during and after RME in three cases. They found an increase in bone activity during expansion in all slices and all cases. They also found a decrease in bone activity after the retention period. Similarly, we found that the metabolic activity in all regions showed significant increases up to the splitting of the midpalatal sutures and that the metabolic activity exhibited remarkable decreases after the opening of the midpalatal suture.

Handelman et al[26] investigated nonsurgical RME in adults and reported that it is a clinically successful and safe method for correcting transverse maxillary arch deficiency. This is in agreement with the results of this study.

İşeri et al[17] and Jafari et al[18] studied the biomechanical effects of the RME on the craniofacial structures by the finite element method. İşeri et al[17] reported that high stress levels were observed in the canine and molar regions of the maxilla, lateral wall of the inferior nasal cavity, and zygomatic and nasal bones, with the highest stress concentration at the pterygoid plates of the sphenoid bone in the region close to the cranial base. Similarly, Jafari et al[18] concluded that the zygomatic buttress and maxillary tuberosity showed areas of high stress. Jafari et al[18] also found high stresses around the frontal process of the maxilla, nasomaxillary suture, nasofrontal suture, frontomaxillary suture, zygomatic arch, and zygomaticomaxillary and zygomaticotemporal sutures. In agreement with the above studies, we found that there were statistically significant increases in metabolic activity around the maxillary, zygomatic, sphenoid, and nasal bones and midpalatal and the other sutures mentioned above.

In a study of RME on Rhesus monkeys, Gardner and Kronmann[8] reported the opening of the sphenooccipital synchondrosis. Similarly, in this study, a significant metabolic activity increase was found on the area of the sphenooccipital synchondrosis.

In this study, a midpalatal suture opening and clinically sufficient widening was achieved in all patients.

Furthermore, the results of this study revealed that, as determined by bone scintigraphy, RME has not only dental effects but also skeletal effects on young adult patients. These results indicate that a nonsurgical RME is an acceptable alternative to surgical RME in young adult female patients for correction of transverse maxillary arch deficiency.

CONCLUSIONS

- Radionuclide bone scanning is an appropriate method for early diagnosis of the metabolic activity changes in the maxillofacial region due to RME.
- According to scintigraphic records, the metabolic activity in all regions showed significant increases up to the separation of the midpalatal suture, whereas the metabolic activity exhibited remarkable decrease after the midpalatal suture opened. The highest metabolic activity increases were observed in the midpalatal suture and right and left maxillary regions, which is consistent with an increase in bone metabolism.
- The results of this study indicated that RME has both skeletal and dental effects on young adult patients. Therefore, nonsurgical vs surgical RME can be used as an alternative treatment modality for treatment of maxillary constriction in young adults.

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