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ORIGINAL ARTICLE

Soft tissue changes in the orofacial region after rapid maxillary expansion

A cone beam computed tomography study

Orofaziale Weichgewebeveränderungen nach forcierter Gaumennahterweiterung

Eine Studie mit digitaler Volumentomographie

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Abstract
Objective Rapid maxillary expansion (RME) is usually used for expanding the maxillary bony segments. Many studies have assessed the dental and skeletal effects of the expansion treatment but few studies evaluated soft tissue changes using cone beam computed tomography (CBCT) images. This study aims to compare soft tissue changes after RME in prepubertal and postpubertal subjects using CBCT images. The null hypothesis of this study is there is no difference between prepubertal and postpubertal patients in soft tissue changes after RME treatment.
Materials and methods A total of 28 patients (10 males, 18 females) with a bonded type of rapid maxillary expander were included in this study. The patients were divided into two subgroups according to cervical vertebral maturation stage. Prepubertal and postpubertal groups were obtained. Following the selection of CBCT images from the archive, pretreatment (T0) and postretention measurements (T1) were performed. Nine linear and one angular measurement for a total of 10 measurements were evaluated on each CBCT image. The mean differences between T0 and T1 measurements were compared by using the paired-samples t test and significance was set at $P < 0.05$.
Results The largest median increase was found in cheek projection of the prepubertal group. Changes in soft tissue nasal base, philtrum width, upper lip length, columella width, columella height, and cheek projection were statistically significant ($P < 0.001$) in both groups. No significant differences were observed in soft tissue alar base, nostril width, nostril height, and nasolabial angle.
Conclusion Some significant changes in facial soft tissues were observed after RME treatment but there were no significant differences between prepubertal and postpubertal subjects. The null hypothesis is accepted because there were no significant differences between the groups.

Keywords Rapid maxillary expansion · Cone beam computed tomography · Bonded expander · Soft tissue

Zusammenfassung
Ziel Die forcierte Gaumennahterweiterung (GNE; "rapid maxillary expansion", RME) wird in der Regel eingesetzt, um knöcherne Anteile der Maxilla zu verändern. Zahlreiche Studien haben sich mit den dentalen und skelettalen Effekten einer Expansionsbehandlung ausgeinandergesetzt, aber nur in wenigen wurden auch die Weichgewebeveränderungen mittels digitaler Volumentomographie (DVT; "cone beam computed tomography", CBCT) bildgebend untersucht. In der vorgestellten Untersuchung sollten mögliche durch die forcierte Gaumennahterweiterung induzierte Weichteilveränderungen bei präpuberalen und postpubertären Probanden anhand von DVT-Aufnahmem ermittelt werden. Die Nullhypothese war, dass zwischen beiden Gruppen kein Unterschied hinsichtlich Weichteilveränderungen nach RME-Behandlung besteht.

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Material und Methoden Insgesamt 28 Patienten (10 Männer, 18 Frauen) mit einer direkt geklebten GNE-Apparatur wurden in die Studie aufgenommen. Je nach CVM ("cervical vertebral maturation")-Stadium wurden sie in 2 Untergruppen eingeteilt, sodass sich präpuberale und postpubertäre Gruppen ergaben. An den aus dem Archiv ausgewählten DVT-Aufnahmen wurden Messungen vor (T0) und nach (T1) Behandlung vorgenommen: auf jeder DVT-Aufnahme wurden 9 lineare Messungen und eine Winkelbestimmung evaluiert. Die Mittelwerte der Unterschiede zwischen den T0- und T1-Messungen wurden mit dem *t* Test für gepaarte Stichproben verglichen, das Signifikanzniveau wurde bei $p < 0{,}05$ festgelegt.
Ergebnisse Die im Mittel deutlichste Vergrößerung bestand bei der Wangenprojektion in der Gruppe präpuberaler Patienten. In beiden Gruppen waren statistisch signifikante Veränderungen ($p < 0{,}001$) zu beobachten bei den Parametern Nasenbasis, Philtrumbreite, Oberlippenlänge, Breite und Höhe der Columella nasi sowie "cheek projection". Bei den Parametern Flügelbasis (Weichgewebe), Nasenlochweite und -höhe sowie nasolabialer Winkel waren keine signifikanten Unterschiede zu beobachten.
Schlussfolgerungen Nach RME-Behandlung ließen sich Veränderungen in fazialen Weichgeweben beobachten, es bestanden jedoch keine statistisch signifikanten Unterschiede zwischen präpuberalen und postpubertären Patienten. Die fehlenden statistisch signifikanten Unterschiede zwischen den beiden Gruppen bestätigten die Nullhypothese.

Schlüsselwörter Forcierte Gaumennahterweiterung · Digitale Volumentomographie · Bonded Expander/direkt geklebte GNE-Apparatur · Weichgewebe

Introduction

Rapid maxillary expansion (RME) is an effective treatment option that has been widely used to eliminate transversal deficiency of the maxilla. This procedure is especially preferred when a patient has posterior crossbite, arch perimeter problems, and buccal corridors. It is an alternative to extraction in some cases in which gaining space is possible; therefore, smile esthetics can also be established. [1, 10–14, 17, 21, 28, 29].

Besides the skeletal and dental effects, some previous studies reported that soft tissue changes occurred after RME [5, 6]. Berger et al. [5] performed a photographic analysis of the nasal soft tissue changes from both orthopedic and surgically assisted RME treatment and they found a relationship between the nasal skeletal width and nasal soft tissue width.

In contemporary orthodontics, it is possible to assess the craniofacial complex using cone beam computed tomography (CBCT). CBCT is a unique radiography technique in which superimposition and image distortion associated with two-dimensional radiographs can be avoided, and it provides perfect image quality in three dimensions (3D). In addition to normal occlusion, it is very important to achieve a well-balanced face after orthodontic treatment. The orthodontist should be aware of the normal pattern, growth, and development of facial soft tissue. In this manner, orthodontic treatment outcomes on facial soft tissue can be predicted. Today the hard tissue-based orthodontic concept in diagnosis and treatment planning has shifted to a soft tissue-based orthodontic concept. [27].

Although previous studies discussed the skeletal and dental responses after RME treatment in detail, limited information was found regarding 3D soft tissue changes after RME treatment. Kiliç et al. [20] studied changes in Holdaway soft tissue measurements and Johnson et al. [18] only evaluated changes in soft tissue nasal widths after rapid maxillary expansion in prepubertal and postpubertal patients. We aimed to evaluate 3D changes after rapid maxillary expansion in the orofacial region. The null hypothesis of this study is that there is no difference between prepubertal and postpubertal patients in soft tissue changes after RME treatment. This study aims to evaluate soft tissue changes in prepubertal and postpubertal patients.

Materials and methods

This study consisted 28 patients (10 males, 18 females) with a mean age of 13.91 ± 1.8 years who were applied for orthodontic treatment at Istanbul Medipol University. This is a retrospective study with two groups. Among 397 patients who had undergone RME treatment, 35 of them were included in this study. CBCT records of the patients were taken to evaluate possible buccal alveolar bone problems. Seven patients were not enrolled in the study according to exclusion criteria; thus, the records of 28 patients were included in the study. The Human Ethics Committee (Clinical Research) at Istanbul Medipol University approved this study (approval number 108400987-177). The patients were classified as prepubertal and postpubertal groups according to the cervical vertebral maturation (CVM) method [4]. The sample size was calculated with a 95% confidence interval (CI) and α of 0.05, and 28 patients ($n = 14$ patients of each group) were found sufficient to have a power >80%.

The CBCT images of the patients were taken at T0 (before RME device) and T1 (at the 6-month retention period). Inclusion criteria of this study were as follows:

- Patients between 11 and 16 years
- Maxillary transverse deficiency with bilateral cross-bite
- No history of craniofacial disease or a systemic disease
- No history of previous orthodontic treatment.

The i-CAT®dental CBCT device (model 17-19, Imaging Sciences International, Hatfield, PA, USA) was used to image the patients at T0 and at T1 by the same operator. The exposure settings were as follows: 120 kV, 5.0 mA for 26.9 s, and the voxel size was 0.2 mm. FOV of the images were 23 × 17 cm. The machine was calibrated before each exposure according to the manufacturer's instruction. The patients were imaged in a sitting position while Frankfort horizontal line was parallel to the floor for standardization of the data. The dataset was evaluated by using the volume-rendering feature of Invivo5 Software (Ver. 5.2, Anatomage Dental, San Jose, CA, USA). InVivo5 Software was an optional feature of the i-CAT's software program and after opening of the CBCT image with this software, the InVivo5 program can be used. The range of gray values in Hounsfeld Unit (HU) was automatically selected by the InVivo5 software. The threshold values of the airway was set at −400 HU.

Treatment protocol

A bonded type of RME device with a Hyrax expansion screw (Hyrax®, Dentaurum, Ispringen, Germany) and occlusal splint was bonded to the upper posterior teeth using a glass ionomer luting cement (Ketac™ Cem radiopaque, 3 M ESPE, Neuss, Germany). After the first clinical activation, the patients began to turn the expander two turns/day which means nearly 0.50 mm/day. The patient was recalled 1 week after the first activation. The expansion was continued for 3–4 weeks for a total expansion of 9–10 mm in the two groups. When the required expansion was achieved, the screw of the RME device was fixed using a wire ligature. No overcorrection was done. The appliance remained as a fixed retainer for 6 months.

Error of the method

Twelve CBCT images were randomly chosen and the measurements were repeated 1 month after the first measurements by the same researcher. The method error was calculated as 0.4 using Dahlberg's formula [16].

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Science (SPSS for Windows, version 23.0, SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test was used to test the normality of the data. Normally distributed data were evaluated with paired and unpaired samples t tests. The Wilcoxon signed-rank and Mann–Whitney U tests were used as nonparametric tests. The significance level was set at $P < 0.05$. P values less than 0.05 were considered statistically significant.

Results

Measurements and their description were shown in Table 1. Measurements and changes within the groups are shown in Table 2 (postpubertal group) and Table 3

Tab. 1 Description of the measurements.
Tab. 1 Beschreibung der Messungen

Measurement	Description
Soft tissue nasal base	Soft tissue nasal width was measured by tracing a line between the distal points of nostrils at the level of most inferior side of the nasal base
Soft tissue alar base	Soft tissue alar base measurements were obtained by measuring between the widest points of the nose by tracing a line at the level of most inferior points of the nose (Fig. 1)
Philtrum width	Philtrum width was measured by tracing a line between right christa philtri and left crista philtri at the vermillion border of the upper lip
Upper lip length	Upper lip length measurements were obtained by tracing a line between subnasal (*Sn* the point where the lower border of the nose intersects the upper lip) and labrale superius (*Ls* the median point in the upper margin of the lower membranous lip)
Nostril height	Nostril height was measured by tracing a line between nostril peak point (*np*) and lateral alar point of the alar base (*la*) (Fig. 2)
Nostril width	Nostril width was measured by tracing a line between mesiodistal width of the nostril in basilar plane (Fig. 3)
Columella width	Columella width measurement was done by tracing a line between the most medial point of each nostrils (the nearest point of nostril from one to the other one). The line was set as the shorter distance of columella
Columella height	Columella was measured by tracing a line between nostril peak point (*np*) where intersects columella and a line between subnasal
Nasolabial angle	Nasolabial angle was measured between nasion soft (*ns*), subnasale (*sn*) and labrale superius (Fig. 4)
Cheek projection	Cheek projection was measured by tracing a line from the fronter point of the tragus (*tragion*) and most prominent point of the cheek (*chk*) in sagittal plane for both of the right and left sides (Fig. 5)

Tab. 2 Measurements with changes in postpubertal group.
Tab. 2 Messungen mit Veränderungen in der postpubertären Gruppe

	Postpubertal group		
	Initial (T0) Mean ± SD	Postretention (T1) Mean ± SD	*P* value
Soft tissue nasal base	17 ± 2.8	17.8 ± 3.2	<0.001
Soft tissue Alar base	31.3 ± 2.8	32.4 ± 2.4	NS
Philtrum width	10.1 ± 1.8	10.7 ± 1.4	<0.001
Upper lip length	14.6 ± 2.3	15.7 ± 2.3	<0.001
Nostril height right	13.3 ± 3	13.2 ± 1.8	NS
Nostril width right	8 (5–10.9)	8.2 (5.1–9.9)	NS
Nostril height left	13 (10.7–24.4)	13.9 (10.7–24.8)	NS
Nostril width left	8.3 (5.4–11.2)	8.9 (5.3–19.2)	NS
Columella width	6.1 ± 0.8	7 ± 1.3	<0.001
Columella height	6.4 (4.9–18.2)	7.1 (5.3–22.6)	<0.001
Nasolabial angle	119.4 (101.2–126.5)	117.5 (103–126.3)	NS
Cheek projection right	91.1 ± 5.4	92.5 ± 4.8	<0.001
Cheek projection left	92.9 ± 4.5	93.4 ± 4.2	<0.001

NS nonsignificant, *SD* standard deviation

(prepubertal group). Mean significant increases were found between T0 and T1 in soft tissue nasal base width, philtrum width, upper lip length, columella width, and columella height ($P < 0.001$). No significant differences were found in soft tissue alar base, nostril height, nostril width, or nasolabial angle between T0 and T1 for either the postpubertal or the prepubertal group. No differences were found between the prepubertal and postpubertal groups in any of the soft tissue measurements. Intergroup changes are provided in Table 4.

Discussion

In contemporary orthodontics, it is possible to assess the craniofacial complex using CBCT. CBCT is a unique radiography technique in which superimposition and image distortion associated with two-dimensional radiographs can be avoided, thus, providing perfect image quality in three dimensions (3D).

In this study, we evaluated soft tissue changes after treatment with a bonded type of RME device by using CBCT. A bonded type of maxillary expansion device was

Tab. 3 Measurements with changes in prepubertal group.
Tab. 3 Messungen mit Veränderungen in der präpuberalen Gruppe

	Prepubertal group		
	Initial (T0) Mean ± SD	Postretention (T1) Mean ± SD	*P* value
Soft tissue nasal base	15.2 ± 3.2	16.6 ± 2.9	<0.001
Soft tissue alar base	30.7 ± 2.9	32.2 ± 2.6	NS
Philtrum width	9.9 ± 0.9	10.8 ± 0.9	<0.001
Upper lip length	14.4 ± 2.3	14.9 ± 2.4	<0.001
Nostril height right	11.7 ± 2.1	12.4 ± 1.9	NS
Nostril width right	7.3 ± 1.3	8.2 ± 2.1	NS
Nostril height left	11.5 ± 1.9	12.6 ± 1.7	NS
Nostril width left	7.7 ± 1.7	7.8 ± 1.8	NS
Columella width	6.2 (4.1–11.1)	6.8 (5.1–12.1)	<0.001
Columella height	5.9 (4.7–12.2)	5.9 (4.2–12.4)	<0.001
Nasolabial angle	116.6 ± 12.6	115 ± 10.2	NS
Cheek projection right	90.1 ± 4.6	91.7 ± 4.6	<0.001
Cheek projection left	90.3 ± 4.8	91.9 ± 4.7	<0.001

NS nonsignificant, *SD* standard deviation

Tab. 4 Intergroup differences.
Tab. 4 Unterschiede zwischen den Gruppen

Measurements	Postpubertal group	Prepubertal group	*P*
Soft tissue nasal base	0.6 (−0.3 to 4.8)	1 (0.1 to 4.9)	0.066 NS
Soft tissue alar base	0.5 (−1.2 to 6.8)	1 (−0.2 to 4.1)	0.491 NS
Philtrum width	0.3 (0 to 1.7)	0.5 (0 to 2.2)	0.214 NS
Upper lip length	1.1 ± 1.2	0.5 ± 0.8	0.139 NS
Nostril height right	0 (−7.8 to 4.8)	1 (−3.5 to 3.6)	0.270 NS
Nostril width right	0.1 (−3.2 to 2.1)	0.4 (−2 to 4.3)	0.108 NS
Nostril height left	0.5 (−2.3 to 3.1)	0.4 (−1.8 to 6.5)	0.713 NS
Nostril width left	0.2 (−3.8 to 10.1)	0.4 (−2.7 to 1.8)	0.982 NS
Columella width	0.6 (0 to 3.2)	0.3 (−5.7 to 3.8)	0.491 NS
Columella height	0.5 (−0.4 to 4.4)	0.1 (−4.3 to 2.4)	0.161 NS
Nasolabial angle	−0.5 (−20.7 to 17.6)	−1.8 (−9.7 to 5.4)	0.597 NS
Cheek projection right	1 (−0.7 to 5.8)	1.7 (0.1 to 3.7)	0.383 NS
Cheek projection left	0.8 (−9 to 2.6)	1 (0 to 3.6)	0.251 NS

NS nonsignificant

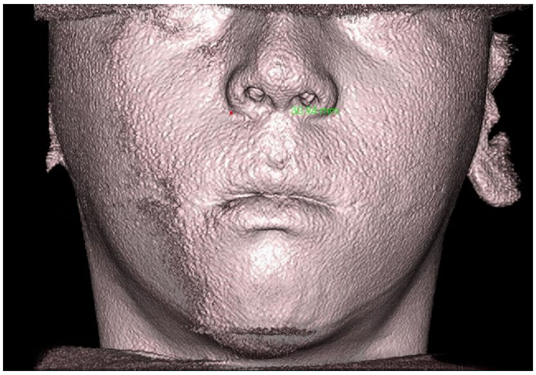

Fig. 1 Soft tissue alar base measurement.
Abb. 1 Messung der Flügelbasis

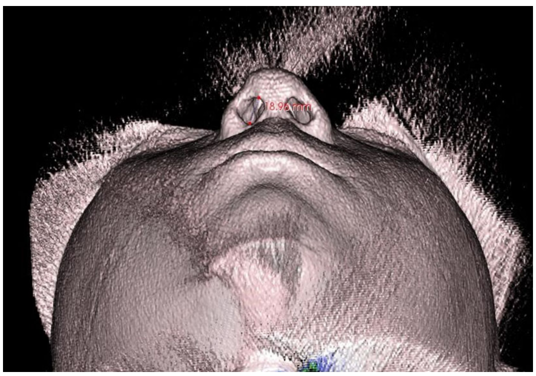

Fig. 2 Nostril height measurement.
Abb. 2 Messung der Nasenlochhöhe

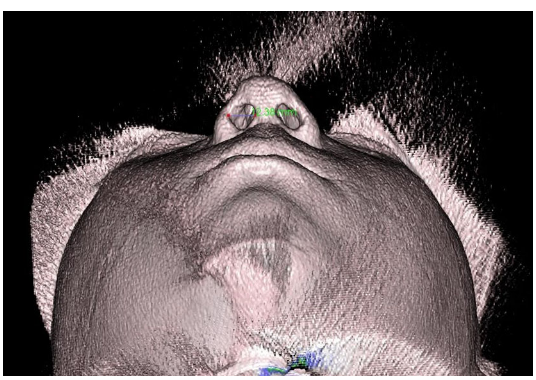

Fig. 3 Nostril width measurement.
Abb. 3 Messung der Nasenlochbreite

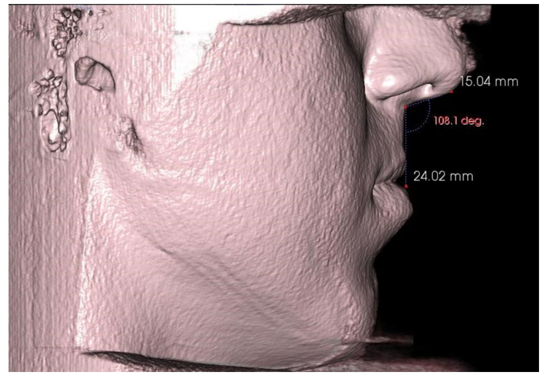

Fig. 4 Nasolabial angle measurement.
Abb. 4 Vermessung des nasolabialen Winkels

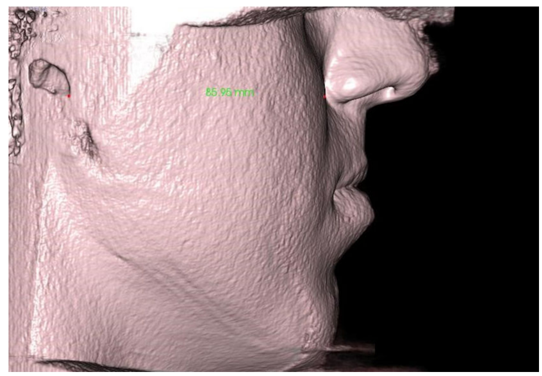

Fig. 5 Sagittal plane cheek projection measurement.
Abb. 5 Sagittale Ebene, Messung der "cheek projection"

used in this study because of its advantage of avoiding dental tipping and preventing clockwise rotation of the mandible [8, 12, 15, 29].

In the CBCT evaluation, with the use of different HU values, different segmentations can occur and measurements can change. In order to avoid this problem the HU scales of the CBCT scanners are usually automatically set by the producers [22]. Therefore, a default setting was present in the used CBCT program. The threshold HU value of the airway was set at −400 (HU) and the soft tissue measurements were performed according to this setting, as a result standardized measurements were managed in the study.

The soft tissue response to RME was described in several previous reports [9, 18, 20, 25], but the soft tissue alterations to RME were evaluated by using CBCT images in only a few of these studies [3, 23–25]. However, the soft tissue response after RME was not evaluated efficiently in several of these previous studies [3, 25]. Furthermore, Nada et al. [24] evaluated only the immediate soft tissue changes after surgically assisted RME by using CBCT.

According to soft tissue-based orthodontics, treatment results have an import influence on macroesthetics (e.g., profile, vertical proportions, chin projections, nasal projection) as well as miniesthetics (e.g., smile symmetry, incisor display, crowding) of the patients [27]. Different results may be observed in different patients as a result of same treatment: one can be worsened while the other may be improved [23].

In previous reports it was stated that minimal changes in external soft tissue of the nose can play important role in respiration [2, 7, 23]. Therefore, a special point was to evaluate the soft tissue effects of RME in the orofacial region. Johnson et al. [18] evaluated the widths of the alar base and greater alar cartilage in prepubertal and postpubertal subjects and they found between the groups in these soft tissue measurements. All the changes in these measurements were less than 1.5 mm in their study. The amount of change was higher in prepubertal subjects in soft tissue alar base and this was 1.5 mm. Magnusson et al. [23] evaluated the changes of the external features of the nose after surgically assisted rapid maxillary expansion (SARPE) and they found that the highest increase occurred in the alar base with a mean of 2.88 mm.

Dos Santos et al. [9] assessed soft tissue profile changes after RME treatment by using Steiner, Ricketts, McNamara Holdaway, Legan, Burstone, and vertical analysis, but they did not evaluate the soft tissue structure in the coronal plane. Pangrazio-Kulbersh et al. [25] reported that an increase was achieved in the nasal skeletal width and soft tissue nasal width at a 1:1 ratio in their study.

We measured the widths of the soft tissue nasal base and soft tissue alar base separately in this study, and the soft tissue nasal base showed mean significant increases between T0 and T1 in both groups. The values of increase in the alar base width changes in this study were nearly the same as those reported by Pangrazio-Kulbersh et al. [25]. Magnusson et al. [23] reported a nonsignificant increase in the soft tissue nasal base, which were different from our study.

A recent CBCT study that utilized 3D stereophotogrammetry reported an increase of 0.3 mm in the philtrum width after RME [3]; however, this value was slightly greater (0.6 mm in postpubertal and 0.9 mm in prepubertal group) in our study.

Furthermore, we found a minimal increase in lip length for both groups. This result is different from that of Altorkat et al. [3], who reported a nonsignificant decrease in this measurement. Berger et al. [6] reported a mean increase of 1.0 mm in their study.

There were no significant differences in the height and length of left and right nostrils between the pre- and posttreatment measurements. Similarly, Altorkat et al. [3] reported no significant differences in nostril height and width measurements between pretreatment and posttreatment results. A significant increase (1.47 mm) in nostril width after SARPE was previously reported. On the other hand, in the present study nostril width changes were found to be approximately less than 1 mm which were not clinically significant.

The increase of columella width was 0.6 mm in postpubertal subjects and 0.9 mm in the prepubertal group in this study, which is greater than the increase of 0.5 mm in columella width after RME treatment previously reported [3]. Furthermore, we evaluated the columella height and found an increase, which could result from protrusion of the nasal tip, as reported previously [3].

We found a slight decrease in the nasolabial angle, but the changes were not statistically significant. Karaman et al. [19] reported an increase of 5.4° in the nasolabial angle after their treatment but in contrast to our study, this change was statistically significant. However, the decrease in the nasolabial angle was reported to be nonsignificant in a previous study [3], which is consistent with our findings.

We found that the cheek projection significantly increased on both the right and left sides in both groups. Nada et al. [24] and Ramieri et al. [26] reported that an increase in cheek projection may be expected after maxillary expansion because of the alveolar bone expansion that occurs.

Although some significant increases were found in most of the soft tissue measurements, none of them were clinically significant because the values were less than 2 mm [18].

Conclusions

There are statistically significant increases in soft tissue nasal base width, philtrum width, upper lip length, columella height, columella width, and cheek projection in prepubertal and postpubertal groups. There were no statistically significant differences between intergroup measurements, and the null hypothesis is accepted. The greatest increase (1.60 mm) was seen in cheek projection of the prepurtal group, but the changes were not clinically significant. Finally, other types of expansion devices can be used to evaluate the effects of rapid maxillary expansion on soft tissues.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the author.

Conflict of interest GS. Torun states that there are no conflicts of interest.

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