J Istanbul Univ Fac Dent 2017;51(3):1-10.
http://dx.doi.org/10.17096/jiufd.85884 ORIGINAL RESEARCH

THE EFFECTS OF MAXILLARY EXPANSION ON THE SOFT TISSUE FACIAL PROFILE

Yüz Yumuşak Doku Profili Üzerine Üst Çene Genişletmesinin Etkileri

Işıl ARAS [1], Sultan ÖLMEZ [2], Mehmet Cemal AKAY [3], Tayfun GÜNBAY [3], Aynur ARAS [1]

Received: 11/06/2016
Accepted:20/07/2016

ABSTRACT

Purpose: *The aims of this retrospective study were to evaluate the possible changes in soft tissue facial profile induced by orthopedic rapid maxillary expansion (RME) and surgically assisted rapid maxillary expansion (SARME), and to correlate them with the underlying hard tissue alterations.* ***Materials and Methods:*** *16 patients who received bone borne SARME and 25 patients who were subjected to RME using metal cast splint hyrax appliance were analyzed retrospectively. This research was conducted on lateral cephalometric radiographs taken on 2 occasions: before expansion (T1) and at the beginning of any further orthodontic treatment (T2). Investigated lateral cephalometric parameters consisted of Holdaway soft tissue measurements with some supplementary soft tissue, skeletal and dental assessments.* ***Results:*** *The acquisition of T2 cephalograms which conforms to the initiation of further orthodontic treatment corresponded to 83.25±3.51 days for SARME and 85.68±4.37 days for RME after the expansion was completed. The only significant change in soft tissue profile of the SARME group was a decrease in upper lip thickness ($p<0.05$), whereas in the RME group, decrease in soft tissue facial profile angle and increase in H angle were found to be statistically significant ($p<0.05$ for each). For the RME group, the changes in soft tissue facial profile angle and H angle correlated only with the changes in SNB angle ($p<0.05$).* ***Conclusion:*** *While bone-borne SARME did not seem to possess the potential to alter soft tissue profile, tooth-borne RME caused a more convex soft tissue profile related to a reduction in SNB.*

Keywords: *Maxillary expansion; palatal expansion techniques; lateral cephalometry; soft tissue profile; orthognathic surgery*

ÖZ

Amaç: *Bu retrospektif çalışmanın amacı hızlı üst çene genişletmesi (RME) ve cerrahi destekli hızlı üst çene genişletmesi (SARME) ile meydana gelen değişiklikleri değerlendirmek ve altta yatan sert doku değişimleri ile korelasyonlarını araştırmaktır* ***Gereç ve Yöntem:*** *Kemik destekli SARME ile tedavi gören 16 hasta ve döküm hyrax apareyi kullanılarak RME ile tedavi gören 25 hasta retrospektif olarak incelendi. Bu çalışma genişletmeden önce (T1) ve genişletmeden sonra sabit ortodontik tedavi başlamadan önce (T2) alınan sefalometrik filmler üzerinde yürütüldü. Araştırılan lateral sefalometrik parametreler, Holdaway yumuşak doku ölçümleri ile birlikte destekleyici bazı yumuşak doku, iskeletsel ve dental değerlendirmelerden oluştu.* ***Bulgular:*** *T2 rontgenleri, genişletmeden sonra sabit ortodontik tedavi başlamasından hemen önce olup SARME ve RME gruplarında sırası ile 83.2±3.51 ve 85.68±4.3 günlerde alındı. Yumuşak doku profiliyle ilgili SARME grubundaki tek önemli değişiklik üst dudak kalınlığındaki azalma iken ($p<0.05$), RME grubunda yüz profili açısındaki azalma ve H açısındaki artış istatistiksel olarak önemli bulundu ($p<0.05$). RME grubunda, yumuşak doku yüz profili ve H açılarındaki değişiklikler, SNB açısındaki değişimler ile korelasyon gösterdi ($p<0.05$).* ***Sonuç:*** *Kemik destekli SARME yumuşak doku profilini değiştirecek potansiyele sahip gibi görünmese de, diş destekli RME, SNB açısındaki azalma ile ilişkili olarak daha konveks bir profile sebep oldu.*

Anahtar kelimeler: *Üst çene genişletmesi; palatal genişletme teknikleri; lateral sefalometri; yumuşak doku profili; ortognatik cerrahi*

[1] Department of Orthodontics Faculty of Dentistry Ege University
[2] Private Practice, Dentege ADSM
[3] Department of Oral and Maxillofacial Surgery Faculty of Dentistry Ege University

How to cite: Aras I, Olmez S, Akay MC, Gunbay T, Aras A. The effects of maxillary expansion on the soft tissue facial profile. J Istanb Univ Fac Dent 2017;51(3):1-10.

Introduction

Various treatment protocols have been proposed for the correction of constricted maxillary arches depending on the severity of discrepancy and the age of the patient. While some techniques provide expansion of the dental arch, substantial enlargement of the maxillary apical base by opening the midpalatal suture is also possible with rapid maxillary expansion (RME) (1-3). RME via an orthodontic appliance with a midpalatal jackscrew that is attached to posterior teeth is the simplest and safe method utilized in the prepubertal or pubertal period. This sutural expansion, however, is usually futile in skeletally mature patients because of the increasing rigidity of the facial skeleton and the progressive fusion of the midpalatal suture with advancing age. Thus, surgically assisted rapid maxillary expansion (SARME) which incorporates various maxillary osteotomies to eliminate the bony resistance that restrain expansion would be necessary for adults (3-6). Recently, SARME through bone-borne devices, also named as transpalatal distraction, has been proposed as a valuable alternative to conventional SARME which offers the advantages of providing more skeletal expansion, avoiding dental tipping, root resorption, cortical fenestration and orthodontic relapse (3-14).

Since maxilla is the principal bone contributing to the configuration of the midface, considerable amount of physical changes are to be anticipated through RME and SARME considering the bony disintegration that will be taking place. Although the dental and skeletal effects of expansion using dental or skeletal anchorage are well documented, little information is available concerning the overlying soft tissue changes following these treatment modalities. The authors who have analyzed soft tissue changes associated with RME and SARME were more interested with naso-maxillary region (15-23). They reported modifications in cheek, upper lip and nasal morphology which were explained majorly by the transversal enlargement of the maxilla, except for few studies (19, 23) reporting that RME did not have significant clinical effects on the nose. Furthermore, it has been pointed out that the immediate maxillary advancement with downward and backward mandibular rotation during maxillary expansion could have an effect on the patients' soft tissue profiles (24-30). While the influence of RME on overall facial profile has been discussed in a few studies with conflicting results (31-33), no attempt has been made to test the correlations between the soft tissue changes and the underlying dentoalveolar alterations. Although previous SARME studies correlated soft tissue changes with changes in the hard tissue, those studies included nasolabial area only (18, 22). Thus it becomes apparent that new studies involving more detailed assessment of the alterations in the overall soft tissue profile induced by RME and SARME as well as their correlations with the hard tissue changes are needed.

The aims of this retrospective study were to assess the possible changes in soft tissue facial profile caused by bone-borne SARME and RME using cast hyrax expander, and to determine whether there exists a correlation between the soft tissue alterations and the underlying hard tissue changes.

Materials and methods

Sample selection

This retrospective research was carried out on the lateral cephalometric radiographs of 41 patients who exhibited posterior crossbite and underwent either orthopedic RME or SARME between the years of 2000 and 2014. The radiographs were selected from the archives of Orthodontic Department of Faculty of Dentistry, Ege University, Izmir, Turkey. The study protocol was approved (no: 15-3.2/4) by the Ethics Committee of the School of Medicine, Ege University. The sample size for each group was based upon previous measures of projections to a vertical line of the soft tissue point A and upper lip (32), which indicated that a minimum of 15 subjects for each group was required to detect a 1.7 mm group difference with SD= 1.6 mm, $\alpha=0.05$, $1-\beta=0.80$.

Surgical techniques

SARME group included 16 patients (9 male, 7 female) with a mean pretreatment age of 27.4±4.6 years. Exclusion criteria were the presence of developmental deformities, syndromes and craniofacial anomalies. Also subjects were excluded from the study if they possessed a history of any soft tissue trauma or surgery. Cephalometric radiographs were not included if the lips were not in rest position during image acquisition. Maxillary expansion was obtained using a bone-anchored device (TransPalatal Distractor, "TPD"; SurgiTec® NV, Bruges, Belgium) with the same surgical procedure implemented for all cases. The horizontal osteotomies were made at the anterolateral maxillary wall, from the piriform aperture to the pterygomaxillary suture. An additional vertical midline osteotomy between the upper central incisors extending from the anterior nasal spine to the alveolar crest was made. No pterygoid separation was performed. After a latency period of 7 days, the activation was started with a uniform rate of 1 mm per day and continued until the posterior crossbite was eliminated (7-10 days). Thus, the TPD device had a total activation of 8.06±0.93 mm. Further orthodontic treatment was initiated after an average of 83.25±3.51 days following the completion of the expansion while the TPD device was left in situ as a passive retainer. RME group consisted of 25 subjects (12 boys and 13 girls; mean age, 13.7±1.9 years) in the permanent dentition that included erupted second molars and had an initial treatment by cast splint Hyrax expander. The protocol used for activation of the appliance was a one-quarter turn (0.25 mm) twice a day until the posterior crossbite was overcorrected by approximately 2-3 mm. Hence an average activation of 7.58±0.64 mm was achieved in 15.16±1.28 days. After completion of the expansion, the appliance was kept in place as a retainer for 85.68±4.37 days and then it was replaced by a transpalatal arch for further multibracket appliance treatment. Figure 1 shows the appliances which were used for expansion in RME and SARME groups.

Image acquisition and study variables

The lateral cephalograms were acquired on 2 occasions: before expansion (T1) and at the beginning of any further orthodontic treatment (T2). In selection of the material, special attention was also paid that the films were obtained with lips at the rest position and with the hyrax expander being removed. Measurements were carried out by same investigator using Dolphin Image Software, Version 11.0 (Dolphin Imaging and Management Solutions, Los Angeles, CA, USA). Besides soft tissue analysis of Holdaway (34), some supplementary soft tissue (basic upper lip to VerP and upper lip to VerP), skeletal and dental measurements were made (Figure 2).

Statistical analysis

For assessment of the method error, 10 randomly selected cephalograms were retraced and remeasured. Systematic errors were estimated using a two-tailed paired t-test and no significant differences were found. Dahlberg formula (35) was used for the calculation of combined method errors in locating and measuring the changes of the different landmarks √ Σ. , where d is the difference between two measurements of a pair and n is the number of double measurements. The method error did no exceed 0.73 mm and 0.67 degrees for any of the variables investigated. All statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS) version 13.0 for windows (SPSS Inc., Chicago, IL, USA). Firstly, the normality test of Shapiro-Wilks and the Levene variance homogenity test were applied to the data. The data were normally distributed, and there was homogenity of variance among the groups. Thus, the statistical evaluation was performed by using parametric tests. Paired t-test was used to determine the changes in cephalometric measurements from T1 to T2 within each group. The homogeneity of the groups regarding duration of the observation period and amount of screw activation were tested with the independent t-test. To evaluate the relationship between soft tissue changes and hard tissue alterations, Pearson's correlation coefficients were calculated. The statistical significance was determined at $p<0.05$ level.

Results

The acquisition of T2 cephalograms which conforms to the initiation of further orthodontic treatment corresponded to 83.25±3.51 days for SARME and 85.68±4.37 days for RME after the expansion was completed. The means and standard deviations of hard and soft tissue variables at T1 and T2 stages for both groups are shown in Table 1. The dentoskeletal and soft tissue profile changes with their significance in each group in Table 2. No significant difference was detected between groups concerning both the mean of screw activation amount and the mean of observation period (from T1 to T2).

In the SARME group, only significant change in the soft tissue profile was a decrease in upper lip thickness, while maxilla moved forward (SNA increased), clockwise rotation and backward displacement of the mandible was observed (SNGoGn increased, SNB decreased) with a consequent increase in the ANB and ANPg measurements ($p<0.05$). There was no correlation between the hard tissue changes and upper lip thickness

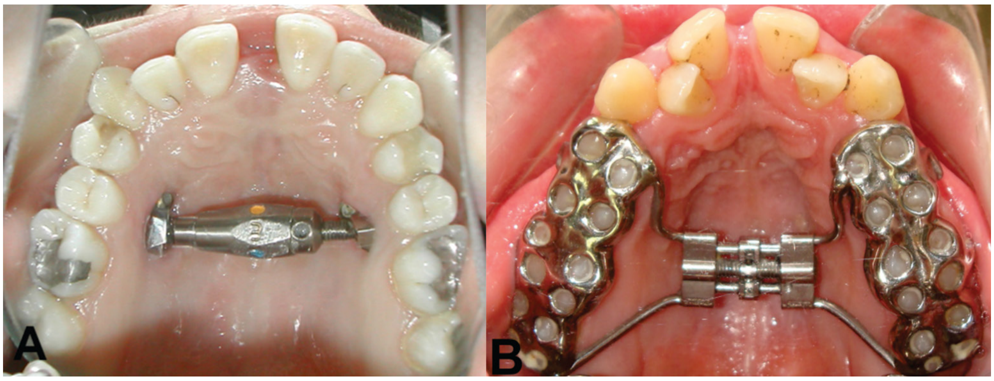

Figure 1. *(A) Transpalatal distractor used in SARME group and (B) Cast splint Hyrax expander used in RME group.*

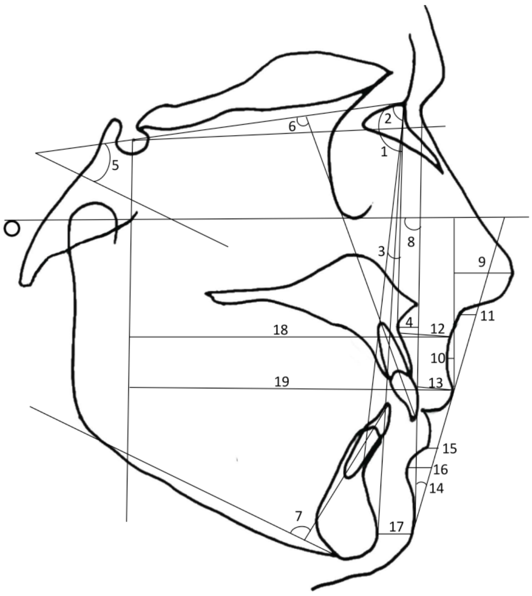

Figure 2*. Hard tissue cephalometric measurements: 1, SNA; 2, SNB; 3, ANB; 4, skeletal profile convexity; 5, SNGoGn; 6, U1-SN; 7, L1-MP Soft tissue cephalometric measurements: 8, soft tissue facial angle; 9, nose prominence; 10, superior sulcus depth; 11, soft tissue subnasale to H line; 12, basic upper lip thickness; 13, upper lip thickness; 14, H angle; 15, lower lip to H line; 16, Inferior sulcus to H line; 17, soft tissue chin thickness; 18, basic upper lip to Ver P; 19 upper lip to Ver P; (12-13) upper lip strain measurement*

In the RME group, decrease in soft tissue facial profile and increase in H angle were found to be statistically significant ($p<0.05$), while hard tissue variables revealed similar alterations with those of the SARME group, which are as follows; maxilla was positioned anteriorly, mandible displaced backward with a concomitant increase in the ANB, ANPg and SNGoGn measurements ($p<0.05$). A significant correlation was evident between soft tissue facial profile angle and SNB angle (r= 0.49, p= 0.014). Also H angle had a significant negative linear correlation with SNB changes (r= -0.42, p= 0.037).

Discussion

The present study primarily sought to determine the possible changes in overall soft tissue profile induced by two different maxillary expansion techniques for correction of posterior crossbite and correlate these soft tissue changes with the underlying hard tissue alterations. Thus, we would be able to carry out a clearer and more detailed discussion of the changes in facial soft tissues from sagittal perspective after RME using cast hyrax appliance and bone- borne SARME, unlike previous studies (32, 33).

In their RME study, Kılıç *et al. (33)* took into consideration of the soft tissue profile changes only, while Karaman *et al. (32)* studied the dentoskeletal effects as well. However, a statistical assessment of whether or not there existed a consistent relationship between soft tissue changes with the underlying hard tissue alterations was not performed in those studies (32, 33). Although detailed evaluation of soft tissue changes and their correlation with the underlying dento-alveolar changes have been described in previous SARME studies (18, 22), the soft tissue regions evaluated in three-dimensional study of Nada *et al.* (22) were limited to the upper lip and cheek region adjacent to the angle of the mouth, while Filho *et al.*'s (18) cephalometric study provided limited information associated with naso-labial area only. Considering that the residual loads at the termination of the appliance activation dissipated within 6 weeks, the retention phase of the current study via the expansion appliance can be deemed sufficient (36).

Table 1. *Means and standard deviations for the cephalometric measurements (SD: standard deviation, SARME: surgically assisted rapid maxillary expansion, RME: rapid maxillary expansion).*

	SARME				**RME**			
	Before		**After**		**Before**		**After**	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Hard tissue variables								
SNA	77.11	4.42	77,74	4.66	78.19	4.35	78.96	4.26
SNB	78.57	4.36	77.93	4.06	75.57	5.95	77.22	5.84
ANB	-1.46	3.02	-0.19	3.36	0.62	3.85	3.04	4.24
ANPg	-2.85	3.88	-1.79	3.95	0.50	3.89	2.82	3.54
SNGoGn	36.15	7.48	37.00	6.91	38.81	6.36	40.22	5.90
U1-SN	103.61	6.43	102.77	6.17	101.78	6.63	101.25	6.64
L1-MP	82.91	6.25	82.77	6.23	87.22	6.95	87.84	6.92
Soft tissue variables								
Soft tissue facial angle	90.26	8.02	89.64	7.49	85.09	5.41	83.59	5.44
Nose prominence	16.77	4.12	16.54	3.66	15.41	3.25	15.71	2.82
Superior sulcus depth	2.16	1.51	2.03	1.41	0.97	1.20	1.01	1.14
Soft tissue subnasale to H line	2.41	3.08	2.70	2.84	3.14	2.81	3.56	2.56
Basic upper lip thickness	16.57	2.50	15.96	2.34	15.39	1.92	15.06	1.84
Upper lip thickness	13.30	3.07	12.75	2.27	12.26	2.39	12.39	2.46
H angle	7.94	5.67	8.38	5.29	12.27	3.55	14.31	4.35
Lower lip to H line	1.46	1.35	1.59	1.69	1.16	1.48	0.82	1.67
Inferior sulcus to H line	3.43	2.05	3.66	1.89	3.57	1.65	3.89	1.83
Soft tissue chin thickness	12.35	1.85	12.61	1.78	11.71	2.42	11.84	1.99
Upper lip strain measurement	3.27	2.31	3.21	2.22	3.13	1.97	2.67	2.33
Basic upper lip to Ver P	76.22	7.72	76.03	6.98	75.33	6.41	75.20	6.45
Upper lip to Ver P	78.81	8.57	78.37	8.01	76.54	6.61	76.32	6.64

Table 2. *Changes in each group and intergroup differences for the cephalometric measurements (SD: standard deviation, SARME: surgically assisted rapid maxillary expansion, RME: rapid maxillary expansion).*

	SARME		Paired-t test	RME		Paired t-test
Variables	**Mean change**	**SD**	**p**	**Mean change**	**SD**	**P**
Hard tissue variables						
SNA	0.63	1.06	0.031*	0.77	1.30	0.007*
SNB	-0.64	0.92	0.014*	1.65	0.74	0.000*
ANB	1.27	1.51	0.004*	2.42	1.34	0.000*
ANPg	1.07	0.98	0.001*	2.32	1.84	0.000*
SNGoGn	0.85	1.30	0.019*	1.42	1.28	0.000*
U1-SN	-0.84	1.80	0.081	-0.53	1.73	0.138
L1-MP	-0.13	0.47	0.286	0.28	1.85	0.456
Soft tissue variables						
Soft tissue facial angle	-0.62	1.46	0.111	-1.50	1.49	0.001*
Nose prominence	-0.24	0.92	0.320	0.30	1.49	0.330
Superior sulcus depth	-0.13	0.77	0.505	0.03	.0.66	0.810
Soft tissue subnasale to H line	0.29	0.98	0.258	0.42	1.63	0.209
Basic upper lip thickness	-0.61	1.10	0.043*	-0.33	1.13	0.153
Upper lip thickness	-0.55	1.26	0.102	0.13	1.29	0.613
H angle	0.45	1.11	0.133	2.04	1.79	0.000*
Lower lip to H line	0.14	1.27	0.672	-0.35	1.15	0.145
Inferior sulcus to H line	0.23	0.87	0.305	0.32	0.87	0.076
Soft tissue chin thickness	0.26	1.59	0.519	0.12	1.03	0.554
Upper lip strain measurement	-0.06	1.13	0.836	-0.46	1.49	0.133
Basic upper lip to Ver P	-0.18	1.23	0.564	-0.13	1.03	0.542
Upper lip to Ver P	-0.44	0.98	0.094	-0.22	0.75	0.166

Karaman *et al.*'s (32) study investigating changes in soft tissue profile following RME through cephalometry reported concomitant lip adaptations to forward movement of maxilla, such as anterior positioning of the soft tissue A point and upper lip tip in relation to the referenced vertical plane. However our findings were not in agreement with their data, as we found non-significant changes in above-mentioned soft tissue measurements despite the forward movement of maxilla which can be explained with the rotational movement of the maxillary halves in RME and SARME in which the pterygomaxillary disjunction was avoided, as previously theorized (9, 37). This finding held true for both groups in present study. On the other hand, Ramieri *et al.* (38) showed that bone-anchored distraction including pterygomaxillary disjunction had no influence on jaw positions and lips, while Nada *et al.* (22) using the same surgical procedure, detected posterior displacement of anterior maxillary region and slight retropositioning of the central part of the upper lip that correlated with remodeling in the anterior alveolar region to close the created midline diastema following tooth-borne and bone-borne SARME (22, 38). However, post-SARME records included in those studies were acquired at the end of fixed appliance therapy or during fixed orthodontics following SARME. Therefore, authors pointed out that the findings associated with lip position may have been influenced by the dental movement resulting from active orthodontics (22, 38). In the cephalometric study investigating the effects of different suturing techniques on the upper lip of patients undergoing SARME, Filho *et al.* (18) reported that a tendency for retro-positioning of the upper lip following SARME with conventional suturings when compared with SARME using simple V-Y suture. The dissimilar findings described in preceeding studies might also be attributable to multifactorial consequences of different elements, such as the surgical technique (localization and extent of maxillary osteotomies), complex anatomy and dynamics of the upper lip, amount of the soft tissues, facial type and measuring methods applied in the studies (21, 39, 40).

Decrease of the thickness of upper lip that had been observed immediately after RME (20) was not seen in present RME group. This was probably related to the fact that radiographs acquired in the current study was 85 days after the expansion whereas Kim *et al.* (20) carried out their measurements right after full activation of the appliance. Small but significant changes were found concerning the thickness of upper lip at the vermilion border in the present SARME group only. It is assumed that the decrease of thickness of upper lip at the vermilion border can be a result of possible stretching of lip caused by greater skeletal expansion of the maxillary segment through bone-borne SARME compared to tooth-borne RME and SARME. However we are unable to test the correlation between the upper lip thickness and the amount of transversal skeletal expansion, as only lateral cephalograms were used. On the other hand, it should also be noted also that the decrease of thickness of upper lip cannot be regarded as clinically significant. While mandible was positioned backwards in both groups, soft tissue chin became less prominent in RME patients as indicated by a significant decrease in the soft tissue facial angle. The other significant soft tissue change in RME group was a significant increase in H angle, meaning that upper lip became more prominent in relation to the overall soft tissue profile, compatible with the more convex skeletal profile as determined by increases in the ANB and ANPg measurements. These findings partially agree with those reported by Kılıç *et al. (33)* who recorded similar results to the present study in terms of H angle, but found non-significant changes in soft tissue angle at the end of a retention period of meanly 5.95 months.

The authors who analyzed the soft tissue changes associated with RME and SARME reported contradicting results regarding sagittal changes to external shape and form of the nose. While Altorkat *et al. (15)* acknowledged retraction and flattening of the nasal tip, Karaman *et al.* (32) noted forward movement of the nose tip (a mean of 2.53 mm) following RME. Also, employing a similar surgical technique with present study, Magnusson *et al. (21)* found minor but statistically significant changes demonstrating anterior movement of the nose following tooth-borne SARME, with no evident modification of subnasale. In the present study, there was no effect of RME on nose prominence, similar to the results reported by Kılıç *et al. (33)* and da Silva Filho *et al. (23)* suggesting that RME does not alter nasal morphology which also held true for the SARME group. The patients in the current study were not specified according to a certain growth pattern and no initial sagittal and vertical differentiations were made similar to other studies in this field. Also, it must be considered that the major difference between the groups were in their mean age, as RME or SARME decision is based on patient's age. Furthermore, differences in expender type and sample size related to RME and SARME groups were other limitations. Due to the lack of intergroup homogeneity, an analysis of significance comparing the RME and SARME groups was not carried out. The results of this study suggested that RME with cast Hyrax device has the potential to affect facial soft tissue profile, unlike the bone-borne SARME. A likely explanation is the multiple cuspal interferences possibly occurring as a result of buccal tipping of the posterior maxillary teeth related to the expansion method using tooth-borne appliances together with the overcorrection, which both have been held responsible for clockwise rotation of mandible resulting in a concomitant increase in soft tissue convexity. This hypothesis is supported by the RME study of Santos *et al. (31)* using modified acrylic hyrax device, which caused no significant alterations in the soft tissue profile at the end of the retention period, because of the presence of the thicker acrylic occlusal surface and palatal tissue support, both of which prevent buccal tipping of the anchored teeth when compared with the occlusal surface coverage only of the cast hyrax appliance. Also the findings in RME group demonstrated that the changes in the soft tissue facial angle and H angle followed the changes in SNB angle in a consistent manner. Although we found statistically significant correlations between these soft and hard tissues, the correlation coefficients were relatively weak hence it will not be possible to make precise predictions of soft tissue changes following RME.

Conclusion

In RME group, soft tissue chin prominence decreased and upper lip became more prominent in relation to overall soft tissue profile, meaning that the convexity of the soft tissue profile has increased. In the SARME group, the only significant change in soft tissue profile was characterized by a decrease in thickness of the upper lip at the vermilion border that was not significant clinically. Tooth-borne RME appeared to have a potential to alter the soft tissue profile, but not the bone-born SARME. In RME group, the changes in soft tissue facial angle and H angle showed a weak association with the changes in SNB angle. Prospective studies conducted on patients classified according to sagittal and vertical growth pattern, using 3-dimensional methods are needed.

Source of funding
None declared.

Conflict of interest
None declared.

References

1. Bishara SE, Staley RN. Maxillary expansion: Clinical implications. Am J Orthod Dentofacial Orthop 1987;91(1):3-14.
2. Podesser B, Williams S, Crismani AG, Bantleon HP. Evaluation of the effects of rapid maxillary expansion in growing children using computer tomography scanning: A pilot study. Eur J Orthod 2007;29(1):37-44.
3. Suri L, Taneja P. Surgically assisted rapid palatal expansion: A literature review. Am J Orthod Dentofacial Orthop 2008;133(2):290-302.
4. Koudstaal MJ, Poort LJ, van der Wal KG, Wolvius EB, Prahl-Andersen B, Schulten AJ. Surgically assisted rapid maxillary expansion (sarme): A review of the literature. Int J Oral Maxillofac Surg 2005;34(7):709-714.
5. Lagravere MO, Major PW, Flores-Mir C. Dental and skeletal changes following surgically assisted rapid maxillary expansion. Int J Oral Maxillofac Surg 2006;35(6):481-487.
6. Loddi PP, Pereira MD, Wolosker AB, Hino CT, Kreniski TM, Ferreira LM. Transverse effects after surgically assisted rapid maxillary expansion in the midpalatal suture using computed tomography. J Craniofac Surg 2008;19(2):433-438.
7. Gerlach KL, Zahl C. Transversal palatal expansion using a palatal distractor. J Orofac Orthop 2003;64(6):443-449.
8. Gunbay T, Akay MC, Gunbay S, Aras A, Koyuncu BO, Sezer B. Transpalatal distraction using bone-borne distractor: Clinical observations and dental and skeletal changes. J Oral Maxillofac Surg 2008;66(12):2503-2514.
9. Matteini C, Mommaerts MY. Posterior transpalatal distraction with pterygoid disjunction: A short-term model study. Am J Orthod Dentofacial Orthop 2001;120(5):498-502.
10. Mommaerts MY. Transpalatal distraction as a method of maxillary expansion. Br J Oral Maxillofac Surg 1999;37(4):268-272.
11. Nada RM, Fudalej PS, Maal TJ, Berge SJ, Mostafa YA, Kuijpers-Jagtman AM. Three-dimensional prospective evaluation of tooth-borne and bone-borne surgically assisted rapid maxillary expansion. J Craniomaxillofac Surg 2012;40(8):757-762.
12. Pinto PX, Mommaerts MY, Wreakes G, Jacobs WV. Immediate postexpansion changes following the use of the transpalatal distractor. J Oral Maxillofac Surg 2001;59(9):994-1000; discussion 1001.
13. Ramieri GA, Spada MC, Austa M, Bianchi SD, Berrone S. Transverse maxillary distraction with a bone-anchored appliance: Dento-periodontal effects and clinical and radiological results. Int J Oral Maxillofac Surg 2005;34(4):357-363.
14. Seeberger R, Kater W, Schulte-Geers M, Davids R, Freier K, Thiele O. Changes after surgically-assisted maxillary expansion (sarme) to the dentoalveolar, palatal and nasal structures by using tooth-borne distraction devices. Br J Oral Maxillofac Surg 2011;49(5):381-385.

15. Altorkat Y, Khambay BS, McDonald JP, Cross DL, Brocklebank LM, Ju X. Immediate effects of rapid maxillary expansion on the naso-maxillary facial soft tissue using 3d stereophotogrammetry. Surgeon 2016;14(2):63-68.
16. Berger JL, Pangrazio-Kulbersh V, Thomas BW, Kaczynski R. Photographic analysis of facial changes associated with maxillary expansion. Am J Orthod Dentofacial Orthop 1999;116(5):563-571.
17. de Carvalho APMC GF AF, Siqueira DF, Bommarito S, Scanavini MA, Kanashiro LK. . Assessment of changes in smile after rapid maxillary expansion. Dental Press J Orthod 2012;17(5):94-101.
18. Filho HN, Goncales ES, Berrentin-Felix G, de Souza Cesar U, Achja GL. Evaluation of the facial soft tissues following surgically assisted maxillary expansion associated with the simple v-y suture. Int J Adult Orthodon Orthognath Surg 2002;17(2):89-97.
19. Johnson BM, McNamara JA, Bandeen RL, Baccetti T. Changes in soft tissue nasal widths associated with rapid maxillary expansion in prepubertal and postpubertal subjects. Angle Orthod 2010;80(6):995-1001.
20. Kim KB AD AE, Behrents RG. Evaluation of immediate soft tissue changes after rapid maxillary expansion. Dental Press J Orthod 2012;17(5):157-164.
21. Magnusson A, Bjerklin K, Kim H, Nilsson P, Marcusson A. Three-dimensional computed tomographic analysis of changes to the external features of the nose after surgically assisted rapid maxillary expansion and orthodontic treatment: A prospective longitudinal study. Am J Orthod Dentofacial Orthop 2013;144(3):404-413.
22. Nada RM, van Loon B, Maal TJ, Berge SJ, Mostafa YA, Kuijpers-Jagtman AM, Schols JG. Three-dimensional evaluation of soft tissue changes in the orofacial region after tooth-borne and bone-borne surgically assisted rapid maxillary expansion. Clin Oral Investig 2013;17(9):2017-2024.
23. Silva Filho OG, Lara TS, Ayub PV, Ohashi AS, Bertoz FA. Photographic assessment of nasal morphology following rapid maxillary expansion in children. J Appl Oral Sci 2011;19(5):535-543.
24. Akkaya S, Lorenzon S, Ucem TT. A comparison of sagittal and vertical effects between bonded rapid and slow maxillary expansion procedures. Eur J Orthod 1999;21(2):175-180.
25. Alpern MC, Yurosko JJ. Rapid palatal expansion in adults with and without surgery. Angle Orthod 1987;57(3):245-263.
26. Basciftci FA, Karaman AI. Effects of a modified acrylic bonded rapid maxillary expansion appliance and vertical chin cap on dentofacial structures. Angle Orthod 2002;72(1):61-71.
27. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004;126(5):569-575.
28. Haas AJ. Palatal expansion: Just the beginning of dentofacial orthopedics. Am J Orthod 1970;57(3):219-255.
29. Majourau A, Nanda R. Biomechanical basis of vertical dimension control during rapid palatal expansion therapy. Am J Orthod Dentofacial Orthop 1994;106(3):322-328.
30. Wertz R, Dreskin M. Midpalatal suture opening: A normative study. Am J Orthod 1977;71(4):367-381.
31. dos Santos BM, Stuani AS, Stuani AS, Faria G, Quintao CC, Stuani MB. Soft tissue profile changes after rapid maxillary expansion with a bonded expander. Eur J Orthod 2012;34(3):367-373.
32. Karaman AI BF Gelgör IE, Demir A. Examination of soft tissue changes after rapid maxillary expansion. World J Orthod 2002;3(3):217-222.
33. Kilic N, Kiki A, Oktay H, Erdem A. Effects of rapid maxillary expansion on holdaway soft tissue measurements. Eur J Orthod 2008;30(3):239-243.
34. Holdaway RA. A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I. Am J Orthod 1983;84(1):1-28.
35. Dahlberg G. Statistical methods for medical and biological students. Sydney, G. Allen & Unwin ltd, 1940, p.78-79.
36. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion. 3. Forces present during retention. Angle Orthod 1965;35(3):178-186.
37. Biederman W. Rapid correction of Class III malocclusion by midpalatal expansion. Am J Orthod 1973;63(1):47-55.
38. Ramieri GA, Nasi A, Dell'acqua A, Verze L. Facial soft tissue changes after transverse palatal distraction in adult patients. Int J Oral Maxillofac Surg 2008;37(9):810-818.

39. Kasai K. Soft tissue adaptability to hard tissues in facial profiles. Am J Orthod Dentofacial Orthop 1998;113(6):674-684.
40. Oliver BM. The influence of lip thickness and strain on upper lip response to incisor retraction. Am J Orthod 1982;82(2):141-149.

Corresponding Author:
Işıl ARAS
Department of Orthodontics
Faculty of Dentistry Ege University
35080 Bornova-Izmir / Turkey
Phone: +90 0232 388 03 26
e-mail: isilaras@gmail.com