



Nasal soft- and hard-tissue changes following tooth-borne and hybrid surgically assisted rapid maxillary expansion: A randomized clinical cone-beam computed tomography study

Emre Kayalar ^{a, b, *, 1}, Michael Schauseil ^c, Andreas Hellak ^c, Ufuk Emekli ^d, Sönmez Fıratlı ^a, Heike Korbmacher-Steiner ^c

^a Departments of Orthodontics, Faculty of Dentistry, Istanbul University, Istanbul, Turkey

^b Private Practice, Orthodontist (PhD), Istanbul, Turkey

^c Department of Orthodontics, University of Marburg, Marburg, Germany

^d Department of Oral and Maxillofacial Surgery, Istanbul Faculty of Medicine, Istanbul University, Istanbul, Turkey

ARTICLE INFO

Article history:

Paper received 3 October 2018

Accepted 4 January 2019

Available online 10 January 2019

Keywords:

Surgically assisted rapid maxillary

expansion

SARME

Hybrid hyrax RME

Nasal changes

Alar width

CBCT

ABSTRACT

Purpose: The aim of this study was to assess the effects of tooth/bone-borne (hybrid) and tooth-borne (TB) surgically assisted rapid maxillary expansion (SARME) on the width of the nasal soft and hard tissue. **Patients and methods:** Twenty skeletally mature patients (nine males and 11 females; mean age 19.4 years) with transverse maxillary hypoplasia were randomly assigned to hybrid or TB devices. The patients had undergone SARME operations, performed by the same surgical team using the same procedure (Le Fort I osteotomy with pterygomaxillary dysjunction, midline osteotomy, and no down-fracture). Nasal soft- and hard-tissue changes were analyzed using CBCT preoperatively (T0), at the end of the active expansion phase (T1), and after 6 months of retention (T2). The study was approved by the relevant ethics committee.

Results: The skeletal and soft-tissue nasal parameters increased significantly in the T0–T1 and T0–T2 periods in both groups ($P < 0.05$). No statistically significant differences between the groups were observed. The mean piriform aperture width increased from 1.26 mm in T0–T1 to 0.97 mm in T1–T2 and 2.17 mm in T0–T2 ($P < 0.008$). In the soft tissue, the alar base width increased to 2.78 mm and the alar width to 2.95 mm in T0–T2 ($P = 0.001$). There was a positive correlation (63.6%) between the changes in skeletal and soft-tissue values.

Conclusion: The hybrid and TB devices led to similarly significant widening effects in nasal soft and hard tissues in both the short term and 6 months after SARME.

© 2019 Published by Elsevier Ltd on behalf of European Association for Cranio-Maxillo-Facial Surgery.

1. Introduction

Surgically assisted rapid maxillary expansion (SARME) is a treatment option for skeletally mature patients with significant skeletal maxillary discrepancies. Both tooth-borne and bone-borne devices have been used successfully for transverse distraction of the surgically separated maxillary halves, but each of these

methods has certain disadvantages. Since tooth-borne devices (Haas or Hyrax appliances) apply a large amount of expansion force to the anchor teeth, periodontal tissues, and alveolar bone, they may cause buccal tipping of the anchoring teeth, maxillary dentoalveolar tipping, and complications such as root resorption, periodontal problems, tooth extrusion, cortical bone resorption and fenestration, and relapse. In addition, difficulties with bone-borne SARME devices have involved asymmetric expansion, mucosal ulceration, inflammation, and loosening or dislocation of the device (Timms et al., 1971; Bell et al., 1976; Mommaerts, 1999; Ramieri et al., 2005; Garib et al., 2006; Landes et al., 2009; Verlinden et al., 2011; Zandi et al., 2014).

To minimize the dentoalveolar side effects of tooth-borne devices and the surgical invasiveness of bone-borne expanders,

* Corresponding author. Istanbul Universitesi Dis Hekimligi Fakultesi, Ortodonti A.D. Kat 5, Fatih, Istanbul, 34093, Turkey.

E-mail addresses: drkayalar@me.com (E. Kayalar), schauseil@med.uni-marburg.de (M. Schauseil), hellak@med.uni-marburg.de (A. Hellak), uemekli@istanbul.edu.tr (U. Emekli), sfiratli@istanbul.edu.tr (S. Fıratlı), korbmacher@med.uni-marburg.de (H. Korbmacher-Steiner).

¹ Present address: DentaMedica, Zeytinlik mah. Sporcu sok. No.9 Bakirkoy, Istanbul, Turkey.

Wilmes et al. (2010) introduced the tooth/bone-borne (Hybrid Hyrax) rapid maxillary expansion (RME) device, using mini-implants in the palate for anterior skeletal anchorage and the first molars for posterior dental anchorage. Günyüz Toklu et al. (2015) evaluated the periodontal, dentoalveolar, and skeletal effects of tooth-borne and hybrid devices in growing patients, and showed that both tooth-borne and hybrid devices are effective methods for RME. However, the Hyrax appliance led to greater expansion in the premolar region and the hybrid devices did not cause changes in the bony support of the first premolars. Kayalar et al. (2016) compared the skeletal, dental, and periodontal effects of tooth-borne (TB) and hybrid devices in SARME, and reported that hybrid devices had similar skeletal effects but different dental movement patterns, along with fewer dental and periodontal side effects. They therefore appear to be a beneficial alternative to TB devices for adult patients.

Although the skeletal and dental effectiveness of SARME with either tooth-borne, bone-borne, or hybrid devices has been well documented (Landes et al., 2009; Nada et al., 2012; Zandi et al., 2014; Kayalar et al., 2016), the procedure has also been associated with postoperative changes in the surrounding soft tissues, most notably widening of the nasal complex. Consistent clinical findings after maxillary osteotomies and SARME include changes in the soft tissues and a widening of the nose. The increase in the nasal base width following SARME is an aesthetic concern for many clinicians (O’Ryan et al., 1989; Lagravere et al., 2006; Nada et al., 2013b; Lee and Perrino, 2017).

The literature includes a few published studies on the nasal soft and hard tissue changes that occur following SARME. Berger et al. (1999) carried out a photographic analysis of facial changes associated with both tooth-borne SARME and RME treatment and observed a relationship between the nasal skeletal width and nasal soft-tissue width. Nada et al. (2013b) showed that the increase in nasal width was comparable between tooth-borne and bone-borne SARME and was limited to 1.2 mm and 1.4 mm, respectively, in the two groups. In a meta-analysis including very few studies, Lee and Perrino, 2017 found that there was a significant increase (1.7 mm) in the mean alar base width 6 months after tooth-borne SARME. However, there have been no studies to date examining whether hybrid SARME is capable of having a different effect on the nasal soft and hard tissues in comparison with conventional dentally anchored SARME.

1.1. Specific objective

The aim of the present study was to evaluate the short-term and long-term effects of tooth-borne and tooth/bone-borne (hybrid) SARME on the nasal soft and hard tissues, using cone-beam computed tomography. The null hypothesis to be tested was that the choice of conventional dentally anchored or hybrid devices does not result in different changes in the nasal soft or hard tissue.

2. Materials and methods

From December 2012 to January 2014, patients who underwent SARME treatment at the Department of Orthodontics at the University of Istanbul, Turkey, were included in this single-center, two-arm, parallel, randomized clinical study.

The inclusion criteria were skeletal maturity (age range 18–35), severe transverse maxillary deficiency, and no developmental deformity. Exclusion criteria included continued growth, absence of maxillary first molars, previous periodontal disease, previous orthodontic treatment, and craniofacial injury or craniofacial syndrome. The study protocol was approved by the Clinical Research Ethics Committee of Istanbul University Medical Faculty (reference number: 2012/641-1044). The Helsinki Declaration guidelines were

followed. All of the patients provided written informed consent to the inclusion of their data in the study.

All clinical procedures were performed by same orthodontist (E.K.). In 10 randomly assigned patients, a tooth-borne (TB) expansion device (Hyrax; Forestadent, Pforzheim, Germany) was cemented onto dental bands that had been fitted onto the first premolars and first molars a few days before the operation. In the remaining 10 patients, a hybrid SARME device was inserted in accordance with the procedures described in previous studies by Wilmes et al. (2010) and Ludwig et al. (2010) (Fig. 1). Two mini-implants (Ortho Easy, 10.0 × 1.7 mm; Forestadent) were inserted into the anterior palate, perpendicular to the palatal bone surface, at 2 mm paramedian to the suture and between the canine and first premolar contact points and first and second premolar contact points (Ludwig et al., 2011), and the hybrid device was attached to the mini-implants in the anterior palate and to the first molar bands.

The operations were performed in all of the patients by the same surgeons in the Department of Plastic, Reconstructive, and Aesthetic Surgery at the Faculty of Medicine at Istanbul University. Osteotomy at the level of Le Fort I with an additional midline osteotomy and Glassman pterygomaxillary disjunction was performed under general anesthesia in all patients (Glassman et al., 1984; Schimming et al., 2000). To verify that the osteotomy had been successful, the expansion screw was rotated intraoperatively until a median diastema of 1 mm could be seen.

The expansion screw was activated at two turns per day (0.25 mm per turn) for 14 days, reaching the total amount of expansion of 7 mm in all patients in both groups. The expander was then kept in place on the teeth as a passive retainer for 6 months. No orthodontic forces were applied to the teeth during this 6-month retention period.

Cone-beam computed tomography (CBCT) scans were taken before rapid palatal expansion (T0), at the end of the active expansion phase (T1), and after the 6-month retention period, when the expander was being removed (T2). All of these scans were taken by a single trained radiographer with the same CBCT machine (Scanora 3D; Soredex, Tuusula, Finland). Subsequent scans were taken with a voxel size of 0.25 mm, at 12.5 mA, with a field of view (FOV) of 14.5 cm, and following a low-dose protocol with 90 kVp. Measurements were made using Mimics 16.0 (Materialise, Leuven, Belgium).

The primary outcome of this study was the extent of changes achieved with the hybrid or tooth-borne techniques in the nasal soft tissue — alar width (AW) and alar base width (ABW). Secondary outcomes were the extent of skeletal changes achieved with each technique in the nose — piriform aperture width (PAW).

On the CBCT images, measurements were made at the soft-tissue and skeletal levels (Figs. 2 and 3) in accordance with the definitions provided in previous studies by Hellak et al. (2015), Metzler et al. (2014), and Yuzbasioglu et al. (2014). Six anatomical landmarks were defined (Table 1). Using these landmarks as reference points, the alar base width, alar width, and piriform aperture width were measured.

The sample size was calculated with 95% confidence intervals (CI) and an α of 0.05, and 20 patients (10 patients in each group) were found to be sufficient to provide a power > 80%. The sample size for this clinical trial was similar to that in previous reports using computed tomography records to evaluate RME (Ballanti et al., 2009; Lagravere et al., 2010; Alves et al., 2017).

2.1. Randomization

Thirty-three patients with transverse maxillary hypoplasia were evaluated, and 20 patients fulfilled the inclusion criteria. Randomization was carried out using computer-generated tables;

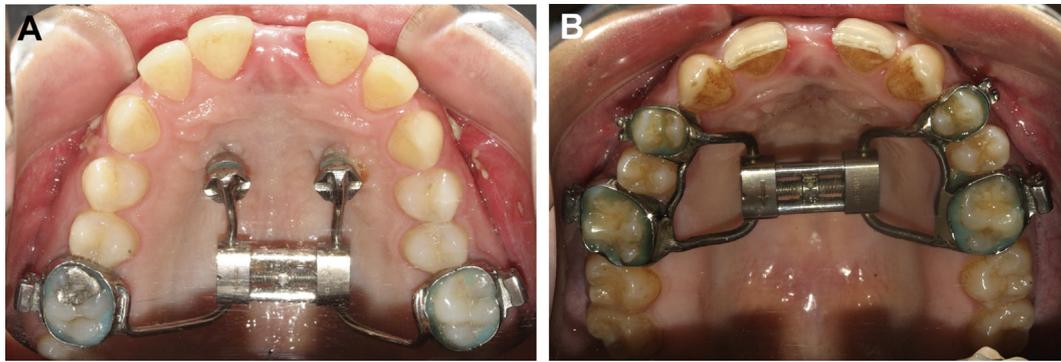


Fig. 1. The hybrid (A) and tooth-borne (B) rapid maxillary expansion devices.

allocation was concealed using sequentially numbered opaque and sealed envelopes. Twenty skeletally mature, nonsyndromic patients (nine males, eleven females) were prospectively included in the study. They were randomly distributed into two groups with 10 patients in each group. Hybrid devices were inserted in the first group and TB devices in the second.

2.2. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Mac, version 21.0 (IBM Corporation, Armonk, New York, USA). All of the measurements were made by same operator and were repeated after 4 weeks. Systematic and random errors were calculated by comparing the first and second measurements using paired *t*-tests and Dahlberg's formula, respectively (Houston, 1983). No statistically significant differences ($P > 0.05$) were found between the first and second measurements for any of the variables analyzed; the range for random errors was 0.01–0.19 mm. When the study data were evaluated, the normal distribution of parameters was evaluated using the Shapiro–Wilk test. The Mann–Whitney *U* test was used to compare the two groups of parameters without normal distribution in the comparison of quantitative data. The Friedman test was used for intragroup comparisons of non-normally distributed parameters, and the Wilcoxon signed rank test was used to determine the period of difference. Spearman's rho correlation analysis was used to examine the relationships between

parameters with a non-normal distribution. The significance level was set at $P < 0.05$.

3. Results

3.1. Baseline data and participant flow

Table 2 lists the demographic data and nasal characteristics of the two groups. The participants' average age was 19.37 ± 4.18 years (range 18–35 years). All of the parameters were similar between the two groups ($P > 0.05$).

Thirty-three consecutive patients were assessed for eligibility. Ten patients did not fulfill the inclusion criteria (three had missing first molars, six had periodontal problems, and another had genetic disease), and three patients declined to participate. Twenty patients were therefore randomly assigned either to the group with hybrid devices or the group with tooth-borne devices.

3.2. Numbers analyzed

Soft-tissue and skeletal nasal changes in the group that received hybrid devices are presented in Table 3, and those for the group

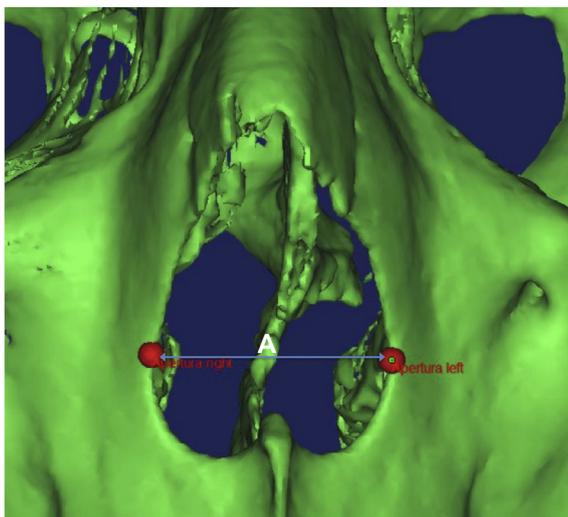


Fig. 2. Skeletal nasal parameters. The piriform aperture width (PAW) is the distance between the most lateral aspects of the piriform aperture on the right (rPA) and left (lPA) sides.

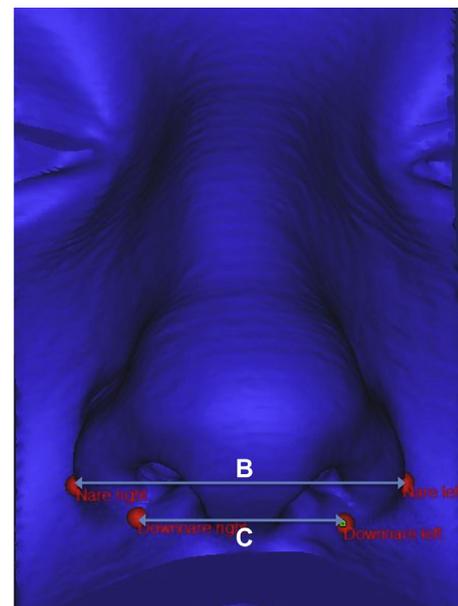


Fig. 3. Soft-tissue nasal parameters. The alar base width (ABW) is the distance between the right point (rAB) and the left point (lAB) of the facial insertion of the alar base. The alar width (AW) is the distance between the most lateral points of the alar curvatures on the right (rLAC) and left (lLAC) sides.

Table 1
Anatomical landmarks and hard-tissue and soft-tissue parameters.

Landmark	Abbreviation	Definition
Right alar base	rAB	Right point of facial insertion of the alar base
Left alar base	lAB	Left point of facial insertion of the alar base
Right lateral alar curvature	rLAC	Right most lateral point of the alar curvature
Left lateral alar curvature	lLAC	Left most lateral point of the alar curvature
Right piriform aperture	rPA	Right most lateral aspect of the piriform aperture
Left piriform aperture	lPA	Left most lateral aspect of the piriform aperture
Parameter		
<i>Soft tissue</i>		
Alar base width	AbW	Distance between rAB and lAB
Alar width	AW	Distance between rLAC and lLAC
<i>Hard tissue</i>		
Piriform aperture width	PAW	Distance between rPA and lPA

Table 2
Demographic data and nasal characteristics in the patients included in the study.

	Hybrid group		TB group		P value
	Mean	SD	Mean	SD	
Age	19.2	3.64	19.3	5.01	0.96
Gender					
Male	3		6		
Female	7		4		0.37
AbW	20.29	1.55	22.12	3.36	0.48
AW	31.87	3.29	32.72	4.01	0.37
PAW	21.69	1.72	20.77	2.54	0.59

P > 0.05 indicates no statistically significant change.

with TB devices in Table 4 (Figs. 4 and 5). Intergroup comparisons are shown in Table 5. All nasal changes in the overall study sample are listed in Table 6. Correlations between skeletal parameters (PAW) and soft-tissue parameters (ABW and AW) are shown in Table 7 (Fig. 6).

Significant and clear increases were apparent in the skeletal parameters (PAW) and soft-tissue parameters (ABW and AW) during the T0–T1 and T0–T2 periods in both groups ($P < 0.05$). All parameters were comparable in the two groups during the study period (T0–T2; $P > 0.05$). Significant differences between the two groups in the alar base width (ABW) were observed during the T1–T2 retention period ($P < 0.05$).

Skeletal nasal width (PAW) increased by 1.26 ± 0.79 mm in the T0–T1 period ($P = 0.001$) and by 0.97 ± 0.32 mm in the T1–T2 period ($P = 0.008$), and finally by 2.17 ± 0.83 mm ($P = 0.005$) over the whole study period (T0–T2). When the soft-tissue nasal parameters were evaluated, significant increases of 2.78 ± 1.76 mm in the alar base width (ABW) and 2.95 ± 1.43 mm in alar width (AW) were observed in the overall study sample in the T0–T2 period ($P = 0.001$) (Table 6).

When the correlation between skeletal (PAW) and soft-tissue (ABW and AW) parameters was examined, statistically significant relationships were found in a positive direction at a level of 63.6% between the T0–T2 PAW changes and the T0–T2 AW changes (Table 7; Fig. 6).

Table 3
Nasal changes in the group with hybrid devices.

	T0	T1	T2	T0-T1	T0-T2	T1-T2	T0-T1	T0-T2	T1-T2
	Mean \pm SD (Median)	Mean \pm SD (Median)	Mean \pm SD (Median)	Mean \pm SD (Median)	Mean \pm SD (Median)	Mean \pm SD (Median)	^a p	^a p	^a p
AbW	20,69 \pm 1,55 (20,9)	23,17 \pm 2,88 (23,2)	23,73 \pm 3 (23,6)	2,19 \pm 2,29 (2,3)	3,08 \pm 2,54 (3,2)	1,17 \pm 1,34 (1,2)	0,036*	0,018*	0,063
AW	31,87 \pm 3,29 (30,9)	35,83 \pm 2,37 (35,7)	35 \pm 3,01 (33,8)	3,74 \pm 2,97 (4,2)	2,82 \pm 1,76 (3,3)	-0,57 \pm 1,64 (-0,4)	0,017*	0,017*	0,499
PAW	21,69 \pm 1,72 (21)	22,37 \pm 1,48 (22,1)	24,37 \pm 1,23 (24,3)	1,16 \pm 1 (1)	2,46 \pm 1,18 (2,4)	1,16 \pm 0,46 (0,9)	0,018*	0,036*	0,102

Bold values denote statistically significant changes.

^ap < 0.05.

^a Wilcoxon Sign Test.

3.3. Harm

No serious harm was observed during the whole study period.

4. Discussion

Surgically assisted rapid maxillary expansion (SARME) is currently used routinely for the treatment of transverse maxillary deficiency in adult patients. Many studies have been published evaluating the skeletal and dental changes associated with SARME using either tooth-borne, bone-borne, or hybrid devices; however, comparatively few studies have investigated changes in the nasal soft and hard tissues (Landes et al., 2009; Nada et al., 2012; Zandi et al., 2014; Kayalar et al., 2016). The present study compared the skeletal and soft-tissue nasal effects of tooth-borne (TB) and hybrid devices in SARME.

In addition to traditional two-dimensional cephalograms (Altug-Atac et al., 2010), several methods have been used to evaluate nasal hard and soft tissues, such as photography (Berger et al., 1999), direct measurements (de Assis et al., 2010), three-dimensional photographs (Metzler et al., 2014), laser scanning (Ramieri et al., 2008; Bianchi et al., 2017), and tomography (Magnusson et al., 2013; Nada et al., 2013a, 2013b; Alves et al., 2017; Bianchi et al., 2017; Torun, 2017). CBCT has the advantage that it allows evaluation of skeletal and related soft-tissue changes, and it is recognized as a reliable method for evaluating facial soft-tissue changes (Lee and Perrino, 2017). This study therefore used CBCT to assess changes in the nasal soft and hard tissue.

In both groups, significant and clear increases in the skeletal and soft-tissue nasal parameters were apparent during the study period. The mean skeletal and soft-tissue nasal widening was found to be comparable in the hybrid and TB groups during the active expansion phase (T0–T1) and 6 months after SARME (T0–T2; Table 5). Both the hybrid and TB devices thus appear to lead to similar widening effects in the nasal soft and hard tissues during SARME procedures.

Table 4
Nasal changes in the group with tooth-borne (TB) devices.

	T0	T1	T2	T0-T1	T0-T2	T1-T2	T0-T1	T0-T2	T1-T2
	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	^a p	^a p	^a p
AbW	22,12 ± 3,36 (22,4)	24,93 ± 2,44 (24,6)	24,55 ± 3,62 (23,9)	2,89 ± 1,8 (3,5)	2,78 ± 1,76 (2,8)	-0,38 ± 1,62 (-1)	0,017*	0,017*	0,508
AW	32,72 ± 4,01 (32,2)	36,94 ± 3,69 (36,8)	35,26 ± 3,82 (35,4)	4,73 ± 1,96 (4,6)	2,95 ± 1,43 (2,9)	-1,69 ± 1,39 (-1,9)	0,012*	0,012*	0,017*
PAW	20,77 ± 2,54 (21,1)	22,12 ± 2,15 (22,2)	22,93 ± 2,43 (23,3)	1,35 ± 0,61 (1,3)	1,97 ± 0,55 (2,1)	0,88 ± 0,22 (0,9)	0,012*	0,028*	0,028*

Bold values denote statistically significant changes.

*p < 0.05.

^a Wilcoxon Sign Test.



Fig. 4. Frontal view of a patient in the hybrid SARME group at the three time points.



Fig. 5. Frontal view of a patient in the tooth-borne SARME group at the three time points.

Table 5
Intergroup comparison between the groups with tooth-borne (TB) and hybrid devices.

	T0-T1		¹ p	T0-T2		¹ p	T1-T2		¹ p
	Hybrid	TB		Hybrid	TB		Hybrid	TB	
	Mean ± SD (Median)	Mean ± SD (Median)		Mean ± SD (Median)	Mean ± SD (Median)		Mean ± SD (Median)	Mean ± SD (Median)	
AbW	2,19 ± 2,29 (2,3)	2,89 ± 1,8 (3,5)	0,674	3,08 ± 2,54 (3,2)	2,78 ± 1,76 (2,8)	0,753	1,17 ± 1,34 (1,2)	-0,38 ± 1,62 (-1)	0,049*
AW	3,74 ± 2,97 (4,2)	4,73 ± 1,96 (4,6)	0,462	2,82 ± 1,76 (3,3)	2,95 ± 1,43 (2,9)	0,916	-0,57 ± 1,64 (-0,4)	-1,69 ± 1,39 (-1,9)	0,143
PAW	1,16 ± 1 (1)	1,35 ± 0,61 (1,3)	0,418	2,46 ± 1,18 (2,4)	1,97 ± 0,55 (2,1)	0,522	1,16 ± 0,46 (0,9)	0,88 ± 0,22 (0,9)	0,435

Bold values denote statistically significant changes.

Mann Whitney U Test *p < 0.05.

Table 6
Skeletal and soft-tissue nasal changes in the overall study sample.

	T0	T1	T2	T0-T1	T0-T2	T1-T2	T0-T1	T0-T2	T1-T2
	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	Mean ± SD (Median)	^a p	^a p	^a p
AbW	21,33 ± 2,54 (21,5)	24,15 ± 2,72 (24,5)	24,19 ± 3,29 (23,9)	2,54 ± 2,02 (2,7)	2,93 ± 2,11 (2,8)	0,26 ± 1,67 (0,3)	0,002**	0,001**	0,554
AW	32,25 ± 3,54 (31,4)	36,45 ± 3,14 (36,4)	35,14 ± 3,38 (34,9)	4,23 ± 2,48 (4,3)	2,88 ± 1,55 (3)	-1,23 ± 1,56 (-1,1)	0,001**	0,001**	0,011*
PAW	21,26 ± 2,13 (21)	22,24 ± 1,81 (22,1)	23,5 ± 2,08 (23,5)	1,26 ± 0,79 (1,1)	2,17 ± 0,83 (2,2)	0,97 ± 0,32 (0,9)	0,001**	0,005**	0,008**

Bold values denote statistically significant changes.

*p < 0.05.

**p < 0.01.

^a Wilcoxon Sign Test.

Table 7
Correlation between skeletal (PAW) and soft tissue (AbW and AW) parameters.

Difference		T1-T0 PAW	T2-T0 PAW	T2-T1 PAW
T1-T0 AbW	r	0.046		
	p	0.869		
T2-T0 AbW	r		0.006	
	p		0.987	
T2-T1 AbW	r			0.345
	p			0.364
T1-T0 AW	r	0.189		
	p	0.499		
T2-T0 AW	r		0.636	
	p		0.048*	
T2-T1 AW	r			0.571
	p			0.108

Bold values denote statistically significant changes.

Spearman Correlation Analysis *p < 0.05.

Significant differences between the two groups were observed in the alar base width (ABW) during the retention period (T1–T2). However, soft-tissue measurements immediately after SARME (at T1) are liable to be affected by immediate postoperative swelling. To prevent this source of error, soft-tissue measurements should be evaluated at the end of treatment, at a mean of 6 months post-operatively (T0–T2) (Nooreyazdan et al., 2004).

When the groups were compared, it was found that the increases in the alar base width (ABW) were similar in the TB and hybrid SARME groups in the T0–T2 period, at 2.78 mm and

3.08 mm, respectively. Nada et al. (2013b) reported that the increase in nasal width was comparable with TB and bone-borne SARME procedures, limited to 1.2 mm and 1.4 mm in the two groups, respectively. The present findings are in agreement with those of previous studies reporting that the type of device used (TB, bone-borne, or hybrid) did not appear to significantly influence the extent of changes in the nasal soft tissues.

In the present study, significant increases of 2.78 mm in the alar base width (ABW) and 2.95 mm in the alar width (AW) were observed during the expansion and 6-month retention periods (T0–T2) in the whole study sample. Berger et al. (1999) reported a 2-mm increase in alar width, which was maintained 1 year after tooth-borne expansion. Filho et al. (2002) measured an increase in the nasal base width of up to 4.71 mm, while Ramieri et al. (2008) found a mean widening of 1.4 mm. de Assis et al. (2010) observed a mean increase of 1.6 mm in the alar base after SARME. The alar base also widened during the 3-year follow-up period, suggesting loosening or resorption of the alar base suture. In a CBCT analysis, Magnusson et al. (2013) reported an increase of 2.88 mm in the most lateral alar base. In addition, the study described overall inferior and anterior displacement of the nose. In a meta-analysis including very few studies, Lee and Perrino, 2017 found that there was a significant increase (1.7 mm) in the mean alar base width 6 months after tooth-borne SARME. Discrepancies in the extent of nasal soft-tissue changes with SARME reported in the literature may be attributable to factors such as variations in

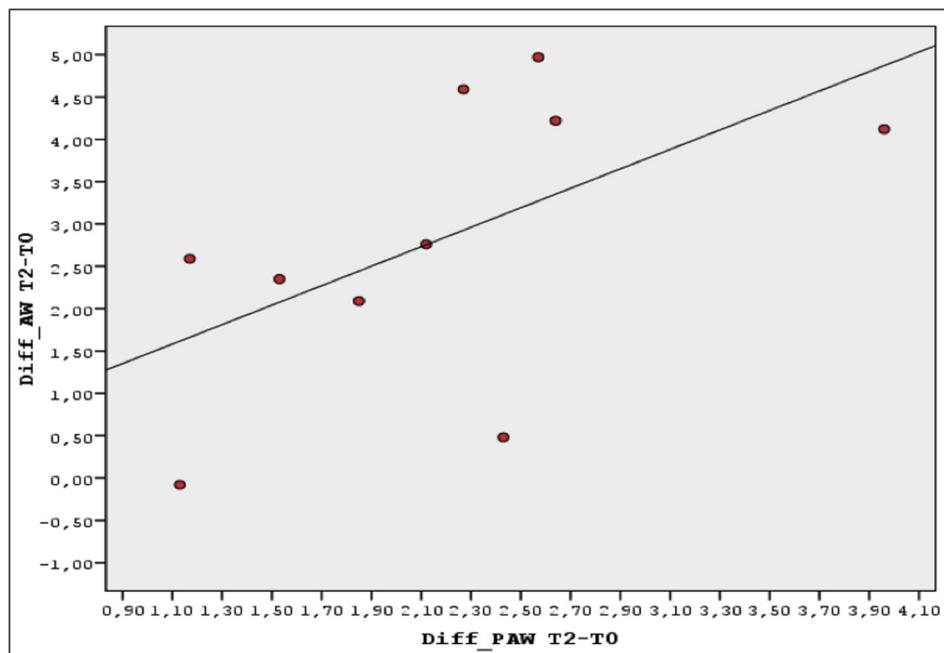


Fig. 6. Correlations between the PAW and AW parameters in the T0–T2 period.

surgical techniques, the amount of expansion, or differences in the accuracy and reliability of the measuring methods used in the studies. However, all of the earlier studies are in agreement with the present finding that skeletal or soft-tissue widening of nasal structures during SARME treatment is significant.

In soft tissue–based orthodontics, treatment results including nasal proportions are considered to have an important influence on patients' macro-aesthetic appearance (Sarver, 2015). From an aesthetic point of view, it is difficult to judge how this increase would be perceived by the patient. There are no established threshold values in the literature for assessing a layperson's perception of variations in nasal width (Nada et al., 2013b). Different results may be observed in different patients as a result of the same treatment, with deterioration in one case and improvements in another (Magnusson et al., 2013). Patients with narrow and constrained nasal structures may benefit from the nasal widening effects of SARME.

The skeletal nasal widening observed in the present study (piriform aperture width, PAW) was significant and comparable between the hybrid device group at 2.4 mm and the TB device group at 2.1 mm 6 months after SARME (T0–T2) (Table 5). These findings are comparable with those of Günyüz Toklu et al. (2015), who reported that the change in skeletal nasal width was approximately 2.5 mm with both hybrid and TB devices during nonsurgical RME treatment of growing patients. Zandi et al. (2014) compared the effects of TB and bone-borne distraction devices in 4 months after SARME. They found that the increases in skeletal nasal width observed were comparable with TB and bone-borne SARME, at 1.61 mm and 1.47 mm in the two groups, respectively. However, Seeberger et al. (2015) found that skeletal nasal widening was significantly greater in the bone-borne device group at 3.0 mm than in the TB device group at 0.98 mm 3 months after SARME. The differences between the studies may be due to shorter observation periods, different expansion devices, and the amount of screw activation carried out.

In the present study, the findings showed that the skeletal nasal width increased by 1.3 mm during the active expansion period (T0–T1) and increased further by 0.9 mm during the 6-month retention period (T1–T2) in TB device group (Table 4). Berger et al. (1998) noted an increase in nasal width after retention following SARME. Buck et al. (2016) observed that short-term increases in volume in the nasal cavity during SARME were still maintained for at least 63 months. In a study by Zambon et al. (2012), the nasal cavity was found to maintain a small nonsignificant increase during retention. Significant increases above baseline values were observed by Aras et al. (2010) over the longer term, 12 months after removal of the appliance. This positive change from T1 to T2 might be explained by a delayed remodeling process in the skeletal nasal structures and might be the reason why SARME patients are not highly susceptible to relapses after respiratory improvements.

Over the whole study period, significant positive correlations, at a level of 63.6%, were found between changes in the piriform aperture width (PAW) and changes in alar width (AW) (Table 7, Fig. 6). As in the present study, Hoffman et al. (1991) also noted statistically significant correlations between alar width and piriform aperture. Strapasson et al. (2017) observed a significant and direct correlation between the piriform aperture width and external nose width, corroborating previous claims that the structure of the nasal cavity may be predictive for nasal morphology. Gerasimov (1971) stated that the soft part of the nose is an “organic continuation of the nasal bones.” The present study indicates that the increase in the width of the nasal soft tissue has a 63.6% level of correlation with the increase in the width of the piriform aperture.

This study was limited to an investigation of expansion and post-retention changes after SARME, without evaluating long-term

stability and relapse, and was based on a relatively small sample size. The study has the following strengths: a randomized clinical trial study design; treatment of all patients by the same surgeons using the same surgical technique, expansion protocol, and expansion device (in each group); and use of an advanced imaging technique (CBCT) for assessment of the treatment outcomes.

The generalizability of these results may be limited, as the investigation was performed in a single center and with a small group of participants. The hybrid devices showed similar effects in comparison with conventional devices in the study. However, randomized controlled clinical trials based on larger study groups and with longer-term follow-up will be needed in the future in order to confirm these findings.

5. Conclusion

Both tooth-borne and hybrid devices led to significant widening of the nasal soft and hard tissues, both in the short term and 6 months after SARME. Skeletal nasal widening increased further during the retention phase. The amount of widening did not differ significantly between tooth-borne and hybrid SARME. There was a significant relationship between changes in the hard tissue (piriform aperture) and soft tissue (alar width) in a positive direction, at a level of 63.6%. Patients with a narrow and constrained nose may benefit from the soft-tissue changes provided by SARME, and skeletal nasal widening may promote respiratory improvements.

Registration

This trial was not registered.

Protocol

The protocol was approved by the Clinical Research Ethics Committee of Istanbul University Medical Faculty (2012/641-1044).

Funding

Research for the study was supported by the Research Fund of Istanbul University (25477).

Conflicts of interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcms.2019.01.005>.

References

- Altug-Atac AT, Atac MS, Kurt G, Karasud HA: Changes in nasal structures following orthopaedic and surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg* 39: 129–135, 2010
- Alves N, Oliveira TFM, Pereira-Filho VA, Goncales ES, Gabrielli MAC, Passeri LA: Nasolabial changes after two different approaches for surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg* 46: 1088–1093, 2017
- Aras A, Akay MC, Cukurova I, Gunbay T, Isiksal E, Aras I: Dimensional changes of the nasal cavity after transpalatal distraction using bone-borne distractor: an acoustic rhinometry and computed tomography evaluation. *J Oral Maxillofac Surg* 68: 1487–1497, 2010
- Ballanti F, Lione R, Fanucci E, Franchi L, Baccetti T, Cozza P: Immediate and post-retention effects of rapid maxillary expansion investigated by computed tomography in growing patients. *Angle Orthod* 79: 24–29, 2009
- Bell WH, Epker BN: Surgical-orthodontic expansion of the maxilla. *Am J Orthod* 70: 517–528, 1976
- Berger JL, Pangrazio-Kulbersh V, Borgula T, Kaczynski R: Stability of orthopedic and surgically assisted rapid palatal expansion over time. *Am J Orthod Dentofacial Orthop* 114: 638–645, 1998

- Berger JL, Pangrazio-Kulbersh V, Thomas BW, Kaczynski R: Photographic analysis of facial changes associated with maxillary expansion. *Am J Orthod Dentofacial Orthop* 116: 563–571, 1999
- Bianchi FA, Gerbino G, Corsico M, Schellino E, Barla N, Verze L, Ramieri G: Soft, hard-tissues and pharyngeal airway volume changes following maxillomandibular transverse osteodistraction: computed tomography and three-dimensional laser scanner evaluation. *J Craniomaxillofac Surg* 45: 47–55, 2017
- Buck LM, Dalci O, Darendeliler MA, Papadopoulou AK: Effect of surgically assisted rapid maxillary expansion on upper airway volume: a systematic review. *J Oral Maxillofac Surg* 74: 1025–1043, 2016
- de Assis DS, Duarte MA, Goncalves ES: Clinical evaluation of the alar base width of patients submitted to surgically assisted maxillary expansion. *Oral Maxillofac Surg* 14: 149–154, 2010
- Filho HN, Goncalves 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 Orthod Orthognath Surg* 17: 89–97, 2002
- Garib DG, Henriques JF, Janson G, de Freitas MR, Fernandes AY: Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. *Am J Orthod Dentofacial Orthop* 129: 749–758, 2006
- Gerasimov MM: *The face finder*. Philadelphia: J. B. Lippincott, 1971
- Glassman AS, Nahigian SJ, Medway JM, Aronowitz HI: Conservative surgical orthodontic adult rapid palatal expansion: sixteen cases. *Am J Orthod* 86: 207–213, 1984
- Günyüz Toklu M, Germeç-Çakan D, Tozlu M: Periodontal, dentoalveolar, and skeletal effects of tooth-borne and tooth-bone-borne expansion appliances. *Am J Orthod Dentofacial Orthop* 148: 97–109, 2015
- Hellak AF, Kirsten B, Schauseil M, Davids R, Kater WM, Korbmacher-Steiner HM: Influence of maxillary advancement surgery on skeletal and soft-tissue changes in the nose - a retrospective cone-beam computed tomography study. *Head Face Med* 11: 23, 2015
- Hoffman BE, McConathy DA, Coward M, Saddler L: Relationship between the piriform aperture and interalar nasal widths in adult males. *J Forensic Sci* 36: 1152–1161, 1991
- Houston WJ: The analysis of errors in orthodontic measurements. *Am J Orthod* 83: 382–390, 1983
- Kayalar E, Schauseil M, Kuvat SV, Emekli U, Firatlı S: Comparison of tooth-borne and hybrid devices in surgically assisted rapid maxillary expansion: a randomized clinical cone-beam computed tomography study. *J Craniomaxillofac Surg* 44: 285–293, 2016
- Lagravere MO, Carey J, Heo G, Toogood RW, Major PW: Transverse, vertical, and anteroposterior changes from bone-anchored maxillary expansion vs traditional rapid maxillary expansion: a randomized clinical trial. *Am J Orthod Dentofacial Orthop* 137, 2010 304 e301-312
- Lagravere MO, Heo G, Major PW, Flores-Mir C: Meta-analysis of immediate changes with rapid maxillary expansion treatment. *J Am Dental Assoc* 137: 44–53, 2006
- Landes CA, Laudemann K, Schubel F, Petruchin O, Mack M, Kopp S, Sader RA: Comparison of tooth- and bone-borne devices in surgically assisted rapid maxillary expansion by three-dimensional computed tomography monitoring: transverse dental and skeletal maxillary expansion, segmental inclination, dental tipping, and vestibular bone resorption. *J Craniofac Surg* 20: 1132–1141, 2009
- Lee K, Perrino M: Alar width changes due to surgically-assisted rapid palatal expansion: a meta-analysis. *J Orthod Sci* 6: 115–122, 2017
- Ludwig B, Glas B, Bowman SJ, Drescher D, Wilmes B: Miniscrew-supported class III treatment with the hybrid RPE advancer. *J Clin Orthod* 44: 533–539, 2010
- Ludwig B, Glasl B, Bowman SJ, Wilmes B, Kinzinger GS, Lisson JA: Anatomical guidelines for miniscrew insertion: palatal sites. *J Clin Orthod* 45: 433–441, 2011
- 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* 144: 404–413, 2013
- Metzler P, Geiger EJ, Chang CC, Steinbacher DM: Surgically assisted maxillary expansion imparts three-dimensional nasal change. *J Oral Maxillofac Surg* 72: 2005–2014, 2014
- Mommaerts MY: Transpalatal distraction as a method of maxillary expansion. *Br J Oral Maxillofac Surg* 37: 268–272, 1999
- 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* 40: 757–762, 2012
- 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 Invest* 17: 2017–2024, 2013a
- Nada RM, van Loon B, Schols JG, Maal TJ, de Koning MJ, Mostafa YA, Kuijpers-Jagtman AM: Volumetric changes of the nose and nasal airway 2 years after tooth-borne and bone-borne surgically assisted rapid maxillary expansion. *Eur J Oral Sci* 121: 450–456, 2013b
- Nooreyazdan M, Trotman CA, Faraway JJ: Modeling facial movement: II. A dynamic analysis of differences caused by orthognathic surgery. *J Oral Maxillofac Surg* 62: 1380–1386, 2004
- O’Ryan F, Schendel S: Nasal anatomy and maxillary surgery. I. Esthetic and anatomic principles. *Int J Adult Orthod Orthognath Surg* 4: 27–37, 1989
- 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* 37: 810–818, 2008
- 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* 34: 357–363, 2005
- Sarver DM: Interactions of hard tissues, soft tissues, and growth over time, and their impact on orthodontic diagnosis and treatment planning. *Am J Orthod Dentofacial Orthop* 148: 380–386, 2015
- Schimming R, Feller KU, Herzmann K, Eckelt U: Surgical and orthodontic rapid palatal expansion in adults using Glassman’s technique: retrospective study. *Br J Oral Maxillofac Surg* 38: 66–69, 2000
- Seeberger R, Abe-Nickler D, Hoffmann J, Kunzmann K, Zingler S: One-stage tooth-borne distraction versus two stage bone-borne distraction in surgically assisted maxillary expansion (SARME). *Oral Surg Oral Med Oral Pathol Oral Radiol* 120: 693–698, 2015
- Strapasson RAP, Herrera LM, Melani RFH: Forensic facial reconstruction: relationship between the alar cartilage and piriform aperture. *J Forensic Sci* 62: 1460–1465, 2017
- Timms DJ, Moss JP: An histological investigation into the effects of rapid maxillary expansion on the teeth and their supporting tissues. *Trans Eur Orthod Soc* 263–271, 1971
- Torun GS: Soft tissue changes in the orofacial region after rapid maxillary expansion: a cone beam computed tomography study. *J Orofac Orthop* 78: 193–200, 2017
- Verlinden CR, Gooris PG, Becking AG: Complications in transpalatal distraction osteogenesis: a retrospective clinical study. *J Oral Maxillofac Surg* 69: 899–905, 2011
- Wilmes B, Nienkemper M, Drescher D: Application and effectiveness of a mini-implant- and tooth-borne rapid palatal expansion device: the hybrid hyrax. *World J Orthod* 11: 323–330, 2010
- Yuzbasioglu N, Yilmaz MT, Cicekcibasi AE, Seker M, Sakarya ME: The evaluation of morphometry of nasal bone and pyriform aperture using multidetector computed tomography. *J Craniofac Surg* 25: 2214–2219, 2014
- Zambon CE, Cecchetti MM, Utumi ER, Pinna FR, Machado GG, Peres MP, Voegels RL: Orthodontic measurements and nasal respiratory function after surgically assisted rapid maxillary expansion: an acoustic rhinometry and rhinomanometry study. *Int J oral maxillofac surg* 41: 1120–1126, 2012
- Zandi M, Miresmaeili A, Heidari A: Short-term skeletal and dental changes following bone-borne versus tooth-borne surgically assisted rapid maxillary expansion: a randomized clinical trial study. *J Craniomaxillofac Surg* 42: 1190–1195, 2014