9-27-2019

Facial Tissue Changes with Microimplant Assisted Rapid Palatal Expanders

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Recommended Citation

Shimizu, Kevin, "Facial Tissue Changes with Microimplant Assisted Rapid Palatal Expanders" (2019). *Orthodontics and Endodontics Theses*. 1.
https://scholarlycommons.pacific.edu/dugoni_etd/1

FACIAL TISSUE CHANGES WITH MICROIMPLANT ASSISTED RAPID PALATAL EXPANDERS

by

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A Thesis submitted to the

Graduate School

In partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE IN

DENTISTRY

University of the Pacific

Arthur A. Dugoni School of Dentistry
San Francisco, California

2019

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ABSTRACT

Introduction: Skeletal expansion has been a treatment modality in orthodontics and orthopedics to correct skeletal transverse discrepancies with maxillary constriction. The utilization of microimplants in conjunction with these palatal expanders offers a higher degree of pure skeletal expansion and minimizes the dental side effects. The purpose of this study is to evaluate the changes of the hard and soft tissues of the face after skeletal expansion for orthodontics.

Methods: 36 patients who had received successful expansion with a microimplant assisted rapid palatal expander were compared to their pre-expansion records. All patients received CBCTs from which a 3-D analysis configuration was created to trace hard and soft tissue landmarks of the midface and nasal cavity regions. 3 judges analyzed each set of records and the average was used to calculate the amount of expansion experienced at each anatomical region. A paired T-test and Wilcoxon signed-rank test were used for statistical comparison between time points.

Results: Expansion can affect all of the midfacial hard tissues that support the overlying soft tissues. Increases in skeletal width from the Frontozygomatic suture down to the maxillary alveolar bone were all significant. The nasal cavity increased in width in all locations measured. Soft tissue changes were significant at the base of the ala suggesting a widening of the nose with expansion therapy.

Conclusion: Maxillary expansion with microimplant assisted expanders can have skeletal changes throughout the entire midface and may affect the width of the nasal cavity. Soft tissue changes were less pronounced, and though a widening of the base of the nose may be expected this may not be noticed by the patient.

INTRODUCTION

Expansion therapy in orthodontics aims to treat a transverse deficiency that expresses in a dental malocclusion. A narrow maxilla positions the upper molars in lingual crossbite with the lower molars and it may be necessary to expand the entire alveolar housing into the proper position over the bone of the mandible. Maxillary expansion by splitting the mid-palatal suture has been a common treatment modality to gain transverse width and correct dental crossbites.

Traditional palatal expanders successfully open the suture by exerting a strong force over a relatively short amount of time.[1-3] Many of these have a majority of the force application directed to the teeth, through which the force is transmitted to the alveolus and then to the suture. Side effects from tooth-borne expanders are common and are expressed as excessive buccal flaring of the maxillary posteriors, low hanging palatal cusps, backwards rotation of the mandible, and loss of total maxillary expansion.[4-6] Because the alveolus housing the teeth maintains a capacity to bend, much of the soft tissue tension achieved by initial expansion causes skeletal relapse during the retention phase of expansion.[5,7-9] This can result in about 50% loss of expansion of the palatal suture and will minimize the total amount of transverse correction after removal of the expander.[9]

Anatomical hurdles to skeletal expansion can limit the success, amount, and location of maxillary width gain. The midpalatal suture originally was thought to be the main obstacle due to the increasing interdigitation and rigidity that increases through the growing years. However other maxillary articulations were identified in the 60s to be major reinforcements that impede skeletal expansion.[3] The zygomatic and sphenoid articulations of the maxilla act as buttresses against expansion and create a center of resistance that is both superior and posterior to the site of force application on the dentition.[10] The resulting triangular shape of expansion results in the two maxillary halves swinging open both forwards and downwards.[11-13]

The development of skeletal anchorage with a Microimplant Assisted Rapid Palatal Expander (MARPE) improves on the ability for maxillary expansion to correct a skeletal problem. Direct force application into the maxilla mitigates dental side effects and can be used to maintain the skeletal expansion fully until the suture has time to fill in and stabilize.[14-16] Engagement of 2 layers of cortical bone has been shown to improve the parallelism of maxillary expansion in a coronal view due to increased microimplant stability and a closer proximity to the maxillary center of resistance.[10,17] Likewise, a distribution of microimplants in anterior and posterior positions improves the parallelism of the mid-palatal suture split and increases widening at the posterior nasal spine to up to 90% of the split at ANS.

With the skeletal effects seen even in the posterior portions of the palate additional therapeutic goals may also be met with MARPE expansion.[14,15] Studies have shown that expansion therapy with traditional Rapid Palatal Expanders (RPEs) can help alleviate airway restriction on certain patients with Obstructive Sleep Apnea.[18,19,20] The volume of the nasal airway has been found to correlate with nasal airway resistance and may be a location for airway obstruction and lead to mouth breathing. Expansion with RPEs has shown to reduce some children's Apnea Hypopnea Index and improve polysomnography findings long term.[21] Other studies have shown that tissue tension in the upper pharyngeal airway can cause the lateral walls to collapse, thus obstructing the airway.[22-24] Expansion of the palatine bones and PNS may aide in maintaining tissue tone of the airway and alleviating OSA symptoms in patients with upper airway restrictions.

The purpose of this study is to evaluate the changes in both hard and soft tissues of the midface with MARPE treatment. Maximum skeletal expansion is achieved and maintained with bone-borne anchorage which is likely to affect the overlying soft tissue structures. The two aims are to 1) evaluate the extent of skeletal expansion using MARPEs and 2) to test the hypothesis that increasing the width of the supporting skeletal structure would have changes to the soft tissues of the face as well.

MATERIALS AND METHODS

In this retrospective study patient records were drawn from the University of the Pacific School of Dentistry graduate Orthodontic Residency clinic and from the private practice of one outside orthodontist. All patients had CBCTs as part of the routine diagnostic records taken before treatment (T1) and after completion of expansion (T2). The inclusion criteria were all patients who had received a MARPE for expansion and had available pre-treatment and post-expansion records. Patients were excluded from the study if they were under the age of 18 and more than 11 months elapsed between CBCTs, had received a facemask as part of their current treatment, had a history of craniofacial abnormalities, or did not have successful expansion from the MARPE.

The design of the MARPEs from the 2 different clinics were similar. Both housed a jackscrew appliance in the main body of the expander, with metal arm extensions to upper first molar bands which were soldered securely (Figure 1). In contrast to traditional RPEs, the arm metal is softer and more flexible and is not intended to provide force application to the teeth. Both sides of the MARPE body housings contained rigid microimplant guides - one on the anterior and one on the posterior - for a total of 4 microimplants to deliver the expansion force directly to the palate over a significant sagittal distance. The microimplants were placed with bicortical engagement into the palate when possible.

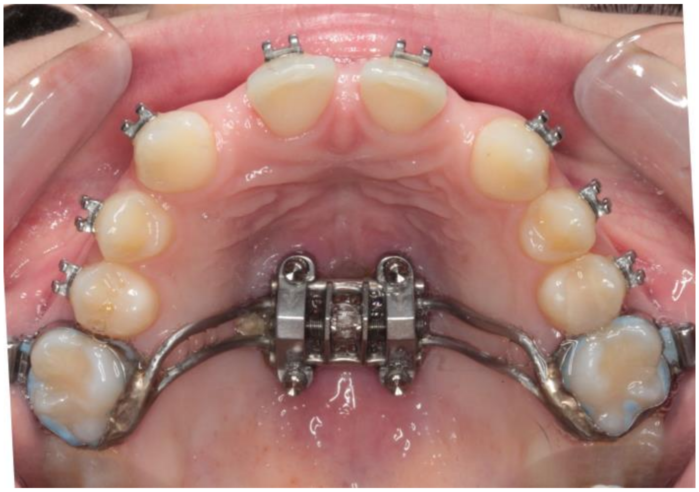

Figure 1. MARPE design consisting of 4 microimplants placed with significant anterior-posterior distance. The metal arms to the molar bands are not stiff and are not designed to apply force to the molars.

A total of 36 subjects (15 male, 21 female) met the necessary criteria and the acquired CBCTs were traced in Anatomage InVivo6® 3D Imaging Software. 3 judges were assigned to each scan and traced 18 hard tissue landmarks and 10 soft tissue landmarks at both T1 and T2 time points (Table 1). Left and right points were traced when structures existed bilaterally. Hard tissue landmarks were found by tracing points on a rendered 3D volume or in individual coronal slices (Figure 2). The nasal cavity points were identified in 2 sagittal locations: the anterior nasal cavity (ANC) was identified as the most anterior slice that the continuous outline of the lower piriform aperture could be seen and the posterior nasal cavity (PNC) point was determined to be at the level of PNS. Soft tissue landmarks were traced on 3D volumes on settings that displayed the soft tissue contours. Traced points were averaged between the 3 judges and distances were calculated between left and right points. A comparison between distances at T1 and T2 was then done.

Figure 2. A) 3D volume hard tissue landmark identification. B) 3D volume soft tissue landmark identification. C) CBCT slice of inner nasal cavity structure landmarks.

Table 1. Landmarks traced on the CBCT

Hard Tissue	**Soft tissue**
Porion	Endocanthion
Frontozygomatic Suture	Exocanthion
Nasofrontal Suture	Soft tissue nasion
Key Ridge	Ala
ANC Lateral Piriform	Ala-Cheek (AC)
ANC Inferior Turbinate	Pronasale
ANC Inferior Piriform	Subnasale
PNC Superior Turbinate	Subalare
PNC Inferior Turbinate	Chelion
PNC Nasal floor	Philtrum
Jugum	
ANS	
PNS	
A point	
U6 MB Cusp	
U6 Apex	
U1 Mesial-Incisal	
U1 Apex	

STATISTICAL ANALYSIS

The statistics generated report the mean of the 3 judges' tracings as well as standard deviation. Intraclass correlation coefficient (ICC) was used to evaluate the inter-judge reliability for all measurements. For statistical analyses, we used paired t-test or Wilcoxon signed-rank test according to the normality of the data. Significance was set at 0.05. To compare the soft tissue changes to hard tissue changes, a stepwise regression was used to build the best regression model.

RESULTS

The inter-rater reliability was good with an ICC > 0.71 for all points except T2 of the philtrum width measurement (Table 2).

The sample had an average age of 17 years 4 months at the pre-treatment T1 records with a range between 10 and 28 years of age. T2 record age was averaged at 17 years 9 months and the average amount of time between T1 and T2 was 5.97 months. The shortest time interval before the post-expansion records was 1 month and the longest was 19 months.

Table 2. ICC of the traced hard and soft tissue measurements.

	Skeletal T1	Skeletal T2		Soft tissue T1	Soft tissue T2
Po-Po	0.931	0.981	en-Na'-en	0.996	0.713
Fz-Fz	0.992	0.993	al-al	0.991	0.994
NaFrSu-NaFrSu	0.837	0.856	ac-ac	0.946	0.918
KRG-KRG	0.748	0.894	al-PrN-al	0.973	0.977
Ju-Ju	0.828	0.821	ac-PrN-ac	0.947	0.953
ANS_Di		0.88	al-Na'-al	0.945	0.899
PNS_Di		0.799	Chelion width	0.941	0.812
A point		0.887	Philtrum width	0.738	0.525
Lat_Pirif-Lat_Pirif	0.882	0.904			
Inf_Pirif-Inf_Pirif	0.919	0.885			
ANC IT-IT	0.855	0.922			
PNC IT-IT	0.962	0.937			
PNC ST-ST	0.796	0.79			
PNC NF-NF	0.913	0.933			
U6 MB CUSP	0.979	0.919			
U6 APEX	0.962	0.916			
U1 MI	0.696	0.941			
U1 APEX	0.911	0.883			

Hard tissue results

Of the hard tissue landmarks, all points associated with the maxilla showed statistically significant width increase from expansion. 16 out of 18 hard tissue measurements showed a significant difference, with the exceptions being the width between left and right Porions and the left and right Nasofrontal suture points (Table 3). Measurements of the nasal cavity in both the anterior and posterior limits as well as lower and upper boundaries showed an increase in width after expansion. Expansion of the maxillary bones resulted in A point increasing in width by 3.92 ± 1.75 mm, ANS widening by 4.48 ± 1.69mm, and PNS widening by 3.27 ± 1.43mm. Inter-molar and inter-incisor widths increased as well when measured from both the cusp/incisal edge and the apices.

Table 3. Hard tissue measurement data between pre-treatment (T1) and post-expansion (T2). Values are presented as a mean ± standard deviation. $P < 0.05$.

	T1	T2	T2-T1	p-value
Upper Face skeletal				
Po-Po	118.22±6.54	116.00±6.77	-2.22±5.26	0.016
Fz-Fz	93.97±5.17	94.65±5.25	0.70±1.14	<0.05
NaFr-NaFr	11.20±1.92	11.61±1.99	0.37±1.07	0.05151
KRG-KRG	87.56±5.25	90.39±5.58	2.83±2.72	<0.05
Nasal Cavity				
Lat_Pirif-Lat_Pirif	18.54±2.92	20.00±2.92	1.45±1.69	<0.05
Inf_Pirif-Inf_Pirif	17.92±2.65	20.50±3.07	2.59±1.51	<0.05
ANC IT-IT	20.86±2.61	23.12±3.05	2.26±1.53	<0.05
PNC ST-ST	25.82±2.02	27.04±2.18	1.22±1.27	<0.05
PNC IT-IT	22.14±3.06	22.75±3.33	0.61±1.72	<0.05
PNC NF-NF	25.00±2.10	27.03±2.58	2.04±1.77	<0.05
Maxilla				
Ju-Ju	66.57±5.10	69.60±5.58	3.03±2.20	<0.05
ANS_Di	0	4.48±1.69	4.48±1.69	<0.05
PNS_Di	0	3.27±1.43	3.27±1.43	<0.05
A point	0	3.92±1.75	3.92±1.75	<0.05
Dental				
U6 MB CUSP	50.42±3.68	56.99±3.92	6.57±2.22	<0.05
U6 APEX	48.82±3.63	53.07±4.77	4.25±2.18	<0.05
U1 MI	1.62±0.59	3.61±2.10	1.99±2.05	<0.05
U1 APEX	6.80±1.28	10.56±2.47	3.76±2.19	<0.05

Soft tissue results

The soft tissues around the nose did not experience the same amount of change that the hard tissue did. The outer prominences of the nostrils (ala), the commissures of the lips (chelion), and the philtrum did not widen following expansion. The two significant increases in soft tissue were the alar base width and the alar base angle measurement (Table 4). The base of the ala (AC point) realized an expansion of 1.29 ±2.64mm and the angle measurement increased by 2.24 ± 6.35 degrees.

Between the hard and soft tissue, a correlation was found between the alar base angle and amount of expansion at the anterior nasal spine. A linear regression model identified the relationship as: ac-Prn-ac = 1.90* (ANS) – 4.46 (R value 0.7) (Figure 3).

Table 4. Soft tissue measurement data between pre-treatment (T1) and post-expansion (T2). Values are presented as a mean ± standard deviation. $P < 0.05$.

	T1	T2	T2-T1	p-value
en-Na'-en(°)	120.92±19.7	118.19±17.4	-1.71±10.6	0.3603
al-al	36.23±3.72	36.83±3.97	0.60±2.40	0.1445
ac-ac	32.76±3.85	34.05±4.33	1.29±2.64	<0.05
al-PrN-al (°)	94.12±11.10	93.79±10.58	-0.32±7.94	0.8122
ac-PrN-ac (°)	75.22±10.18	77.46±10.46	2.24±6.35	<0.05
al-Na'-al (°)	46.74±5.17	46.28±4.91	-0.47±4.43	0.5501
Chelion width	45.10±3.79	43.59±5.38	-1.51±4.71	0.06604
Philtrum width	12.27±1.62	12.26±1.87	-0.01±1.89	0.9774

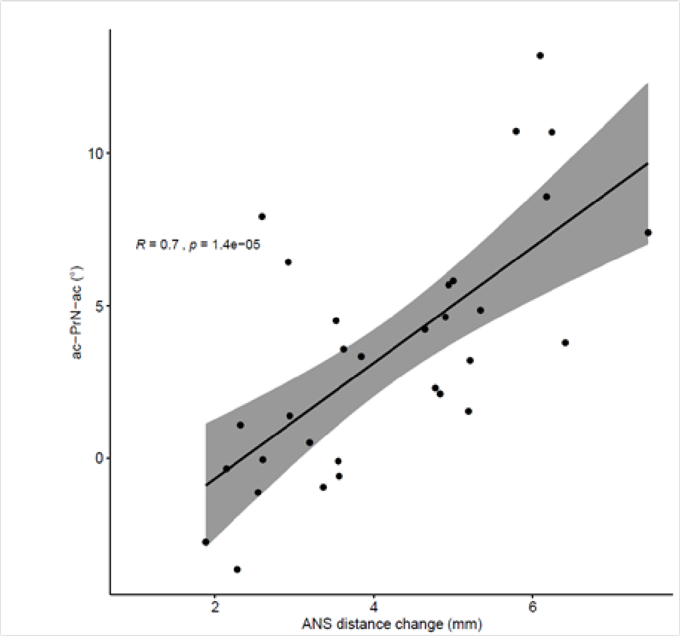

Figure 3. Regression model of the relationship between expansion at ANS and the nasal base angle of ac-PrN-ac.

DISCUSSION

Expansion using MARPEs offers the benefit of maximizing the amount of skeletal expansion and maintaining it until the mid-palatal suture fills in with new bone. Rather than use teeth as abutments to expand the maxilla direct force application into the bone via micro-implants mitigates side effects like dental tipping and mandibular plane autorotation and allows further bony anchorage for tooth movements. Force is directed closer to the maxillary center of resistance and even though in this study it was found to be not statistically significant, sutural opening at the Nasofrontal suture is visible from CBCT imaging (Figure 4). With MARPE expansion the centers of rotation have been found to be high around the Frontozygomatic suture, causing significant lateral expansion throughout the zygomatic buttresses.[25] Though the pattern is still triangular in nature with the base towards the dentition, the skeletal anchorage shows that the entire midface can widen with disarticulation of the circummaxillary sutures and bending of adjacent bones (Figure 5).

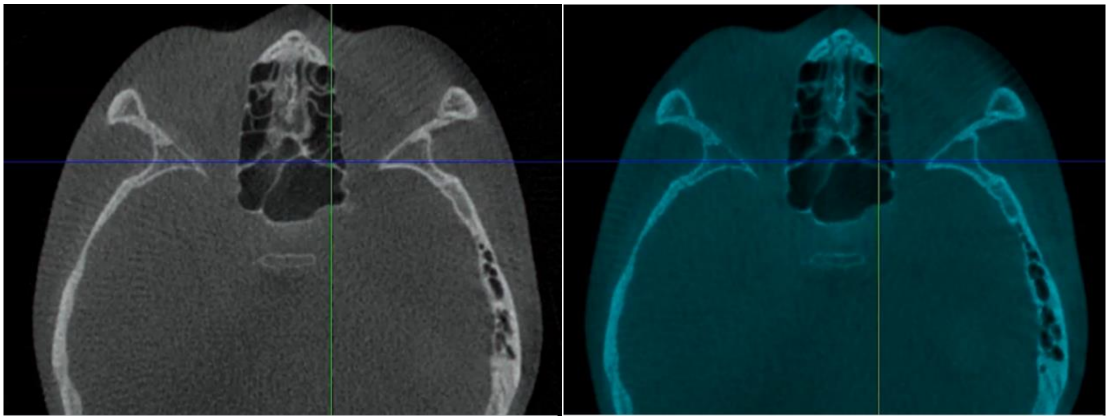

Figure 4. Coronal slices of the Nasofrontal suture taken at A) pre-treatment T1 and B) post-expansion T2

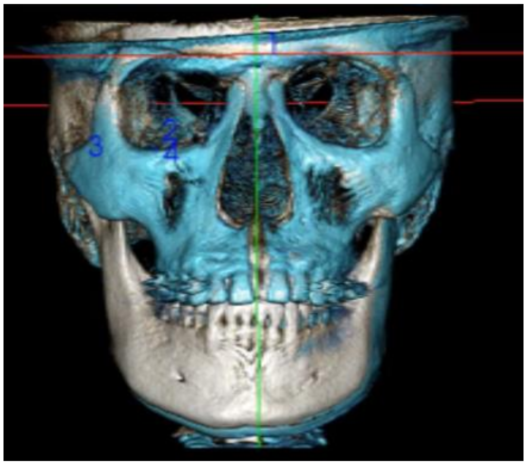

Figure 5. 3D superimposition of pre-treatment T1 (white) and post-expansion (blue). MARPE expansion shows effects on the entire midface region

Our study reports that 16 out of 18 hard tissue points experienced statistically significant expansion from MARPE treatment. The two locations that did not, the inter-porion width and the Frontozygomatic suture, are likely to have had minimal expansion due to the superior anatomic positioning which is located closely to the vertical position of the maxillary centers of rotation. Porion also is a traced structure of the Parietal bone and is a structure that likely receives mitigated force due to the flexibility of the Zygomatic process of the Parietal bone.

All other locations of the maxillary base, nasal cavity, and dentition increased in width. More superior points like the Frontozygomatic suture experienced a change of 0.70 ± 1.14 mm in width gain. Points traced in the middle of the Maxilla such as Jugum increased 3.03 ± 2.20 mm, and the dentition at the base of the expansion triangle expanded the most with 6.57 ± 2.22 mm width gain. Clinically, this will allow the patient to achieve more dental expansion than what is activated in the expander because of the lower positioning of the teeth. Overcoming this triangular shape of expansion without surgery is unlikely due to requiring complete disarticulation of the circummaxillary sutures, although studies show that with micro-implants we achieve more expansion in higher points of the maxilla[14,25].

Transverse measurements along the palate show that MARPE expansion affects sutural splitting in the posterior, with PNS widening an average of 73% of the ANS split. The hard palate roof of the mouth also acts as the floor of the nose, so width increase in the mouth affect the nasal airway as well. The nasal cavity expansion was significant in all measured locations, and of particular importance is the posterior superior dimension. This region is supported by the most buttressing and has the most resistance to expansion. However, this study confirms that we can increase the cross sectional area at any point in the nasal cavity and increase the nasal volume. The additional volume allows a drop in nasal airway resistance and can alleviate some of the symptoms of OSA for the properly identified patient.[19] Patients who initially had nasal airway constriction in our clinic reported an increased ability to breathe through their nose and even a cessation of snoring.

Soft tissue changes were highly variable and did not follow the same magnitude of changes that hard tissue did. The base of the ala where it connects to the cheek was found to expand laterally with expansion. This made the alar base dimension (AC-AC) increase by 1.29 ± 2.64 mm after expansion, though the cartilaginous ala projections did not undergo significant expansion. The ability of the nasal cartilages to remain flexible and maintain their original form mask the changes of the underlying skeletal foundation.[26] The alar base points are close to the maxillary bone, and the intimate relation translated to more soft tissue change. For soft tissues supported by muscles and cartilage, the elastic nature likely distributes tension and stretching across large areas of the face and skin. Another study utilizing dedicated 3D facial scanners realized that MARPE expansion has some effect on the nasal tissues but a more significant effect on widening of soft tissues overlaying the cheeks.[27]

Our alar base angle (AC- PrN-AC) using Pronasale increased significantly by 2.24 ± 6.35°. Both this and the alar base width indicate that there is soft tissue widening of the nose with expansion. The regression equation of ac-Prn-ac = 1.90* (ANS) – 4.46 allows us to make a correlation between skeletal expansion and widening of the nasal soft tissues with respect to ANS and the alar base. We expect that 5mm of ANS expansion will widen the nose 5.04 degrees and 10 mm of ANS expansion will show 14.54 degrees of change at the alar base angle. However, though this is a statistically significant finding, it may not be clinically significant. The wide variety of patient phenotypes and tissue thicknesses may minimize or completely mask any soft tissue changes unless expansion is excessive. Many patients are likely to not notice a change in facial tissues, unlike patients who undergo large surgical movements. Furthermore, the dynamic changes of facial soft tissues with normal growth, weight change, or facial expressions may distract the patient from any changes that occur over the course of treatment.

The limitations of the study may have confounded the results due to the heterogeneity of the sample. The sample was of adequate size under the current inclusion criteria, although it would have been more ideal to limit the demographics to non-growing patients over the age of 18. However, lack of available records limited the number of adult patients in our sample. Also, the two different clinics had different T2 record protocols. The resident clinic at the dental school had a 6 month post-expansion progress image protocol, though for reasons such as delayed treatment start, failed MARPEs, or scheduling issues this was sometimes over a year after the initial T1 records. Growth may still have played a part in the changes seen. Another variable was that expansion protocols were not all the same. Some patients were under a strict rapid expansion protocol throughout correction, while others were told to decrease the rate of activation turns after an initial diastema appeared between the upper centrals. There was also no collected record of the amount of MARPE activation so no correlation could be made between amount of expansion in the MARPE and the amount realized by the hard tissues or soft tissues. This study did not have a quantified compared sample of expansion achieved from traditional tooth or tissue-borne RPEs, which would support the idea that bone-borne anchorage results in more skeletal expansion. The study also did not have available post-treatment records to look at whether or not these changes to expansion in the soft tissue persist or if they are attributed to temporary soft tissue swelling from orthodontic treatment.

CONCLUSIONS

We found that expansion using MARPEs results in an increase in width between left and right side skeletal structures. All of the landmarks placed on the maxilla and in the nasal cavity indicated expansion and suture disarticulation was seen up to the Nasofrontal suture. Widening of the midface does affect the overlying soft tissues, and the nose widened at the base of the ala with expansion. These results indicate that in addition to successfully gaining transverse with in the maxillary dentition, the nasal cavity volume increased and may help alleviate nasal airway resistance in some OSA patients. They also show that large amounts of expansion are likely to change the width of the nose, although it is possible that they are to a small enough degree to go unnoticed by the patient.

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