Original Article

Facial soft-tissue changes after rapid maxillary expansion analyzed with 3-dimensional stereophotogrammetry: *A randomized, controlled clinical trial*

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ABSTRACT

Objective: To evaluate three-dimensional (3-D) soft tissue facial changes following rapid maxillary expansion (RME) and to compare these changes with an untreated control group.

Materials and Methods: Patients who need RME as a part of their orthodontic treatment were randomly divided into two groups of 17 patients each. Eligibility criteria included having maxillary transverse deficiency with crossbite, and to be in the normal range according to body mass index. In the first group (mean age = 13.4 ± 1.2 years), expansion was performed. The second group received no treatment initially and served as untreated control (mean age = 12.8 ± 1.3 years). Skeletal and soft tissue changes were evaluated using posteroanterior cephalograms and 3-D facial images. The primary outcome of this study was to assess the soft tissue changes. The secondary outcomes were evaluation hard tissue and soft tissue relations. Randomization was done with preprepared random number tables. Blinding was applicable for outcome assessment only. MANOVA, *t*-test, and correlation analyses were used ($P = .05$).

Results: In both groups, there was a general trend of increase for the transverse skeletal measurements, but these increases were more limited in the control group. Alar base width was greater in the treatment group ($P = .002$). Pogonion soft tissue point ($P = .022$) was located more posteriorly in the expansion group compared with the control group.

Conclusions: Soft tissue changes between groups were similar, except for the alar base, which became wider in the treatment group. Weak correlations were found between the skeletal and soft tissue changes. (*Angle Orthod.* 2016;86:934–942.)

KEY WORDS: Rapid maxillary expansion; Stereophotogrammetry

INTRODUCTION

The goals of orthodontic treatment are to improve esthetics and correct the occlusion. The primary concern of patients has been improvement in facial appearance, which is considered an important factor of well-being and social success.[1] Recently, a paradigm shift has occurred from hard tissue to soft tissue known as the soft tissue paradigm.[1] According to this reverse approach, the key determinant is soft tissue positions, necessitating evaluating the effects of various orthodontic treatments and their effect on the face.

The maxilla is a large facial bone that articulates with 10 facial and cranial bones.[2] The maxilla moves downward and forward after rapid maxillary expansion (RME) and, except for the sphenoid bone, all craniofacial bones articulating with the maxilla also displace.[3] Nasal cavity width increases, particularly at the floor of the nose.[4] Thus, treatment effects of RME are not only limited to oral structures but are also related to changes in the circummaxillary region. There has been copious literature about the skeletal and dental effects of RME, whereas only scarce information and nonconsensus exist about soft tissue changes.

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Table 1. Inclusion and Exclusion Criteria Used in the Present Study

Inclusion criteria
Maxillary transverse deficiency, assessed both clinically and radiographically, with posterior crossbite
Willingness of patient and parents to participate in the study
To be within normal range according to body mass index
Exclusion criteria
Congenitally missing or extracted permanent tooth (except third molars)
Severe facial asymmetry determined by clinical examination
Craniofacial syndrome
Neuromuscular deformities
History of trauma
History of orthodontic treatment
Poor oral hygiene
Systemic diseases that might affect treatment results

According to the findings of cephalometric studies, nose tip and soft tissue A-point move forward[5] and H angle and profile convexity increase after this treatment.[3] Nasal width increase was reported in studies using serial frontal photographs[6] and anthropometric measurements.[7] Three-dimensional (3-D) evaluation of widths of the nasal base,[8,9] mouth,[8] and columella[9] increased with flattening of the nose[9] and upper lip elongation and thinning.[10]

3-D stereophotogrammetry is a method of acquiring images using one or more pairs of simultaneously taken photographs. Soft tissue records are easy to capture using optical scanners with short shutter speeds. Erratic movement of the patient is not a matter discussion with fast scanning speed.[11] Inclusion of surface texture is another advantage of the system. The reproducibility and accuracy of the technique, has been stated to be “more than sufficient for clinical needs” and has greater accuracy compared with direct anthropometry and 2-D photography.[12]

The aim of this prospective clinical trial was to quantify the soft tissue facial changes following RME and to compare these changes with an untreated control group using 3-D facial images. To our knowledge, this study was the first to include a control group to distinguish the changes after RME treatment with those resulting from normal growth and development. The null hypothesis was that soft tissue changes are not significantly different between treatment and control group. Also, the soft tissue adaptability to the dento-skeletal changes associated with expansion of the maxilla will be evaluated. In this study, the following hypotheses were tested: (1) there is no difference between RME-treated and untreated subjects regarding soft tissue changes and (2) there is no relation between hard and soft tissue changes.

Specific Objectives or Hypotheses

In this study following hypotheses were tested (1) there is no difference between RME-treated and untreated subjects regarding the soft tissue changes (2); there is no relation between hard and soft tissue changes.

MATERIALS AND METHODS

This was a parallel-group, randomized, controlled trial with a 1:1 allocation ratio.

Sample Size Calculation

The optimal sample size determination prior to the statistical analyses was performed based on the effect size (Cohen’s d = 0.99) reported by Johnson et al.,[7] which indicated that group sizes of 17 (total 34) would provide at least 80% statistical power.

Participants, Eligibility Criteria, and Settings

Ethical approval was obtained from the Izmir Katip Celebi University, Clinical Research Ethics Committee (No. 54). Informed consent for the study was obtained from all the parents.

Patients requiring RME as a part of their individual treatment plan in the initial examination were selected from the patient waiting list of the Orthodontic Department Clinics. Inclusion and exclusion criteria are given in Table 1. Among these patients, patients who fulfilled the inclusion criteria were informed about the study and invited to participate.

Randomization

If the child and parent consented, initial records are taken and each patient was randomized to receive treatment or to have treatment delayed for at least 6 months. The randomization was made at the start of the study with preprepared random number tables. One researcher evaluated the patients and the other author did the enrolling. Thirty-four subjects were randomized into two groups of 17 patients each. Mean ages of the treatment and control subjects were 13.4 ± 1.2 years and 12.8 ± 1.3 years, respectively. A patient flowchart is shown in Figure 1.

Interventions

All patients were submitted to the RME protocol established by a bonded acrylic splint expander (Figure 2). The screw was activated a quarter turn twice per day (0.5 mm) for the first week, then a quarter turn per day (0.25 mm), until the palatal cusps of the maxillary molar contacted the buccal cusps of the mandibular molar.[13] Mean maxillary

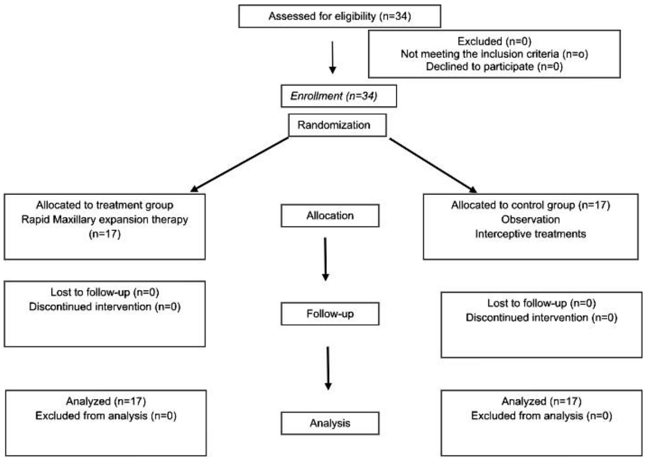

Figure 1. Flow diagram.

expansion achieved was 6.25 ± 2.9 mm, with a mean number of activations of 25 ± 11.6 turns. After the expansion completed, the appliance was kept in the mouth passively for the first month. The mean active expansion period was 0.7 ± 0.4 month in the treatment group. A Hawley retainer was delivered to all patients for the rest of the retention period. After 6 months, T1 records were taken of the participants. Mean observation time was 6.1 ± 0.6 months. Three-dimensional facial surface images and posteroanterior cephalograms (PACs) were taken before treatment (T0) and immediately after the retention/observation period (T1).

Soft tissue changes were evaluated using 3-D facial images, which were captured in the natural head position using the 3dMD imaging system (3dMD, Atlanta, Ga) in less than 1.5 milliseconds. Each patient was positioned on an adjustable stool and instructed to look into his or her eyes in a mirror placed between the cameras with eyes open and facial musculature relaxed.[14] All images were saved as TSB files and

Figure 2. The expander.

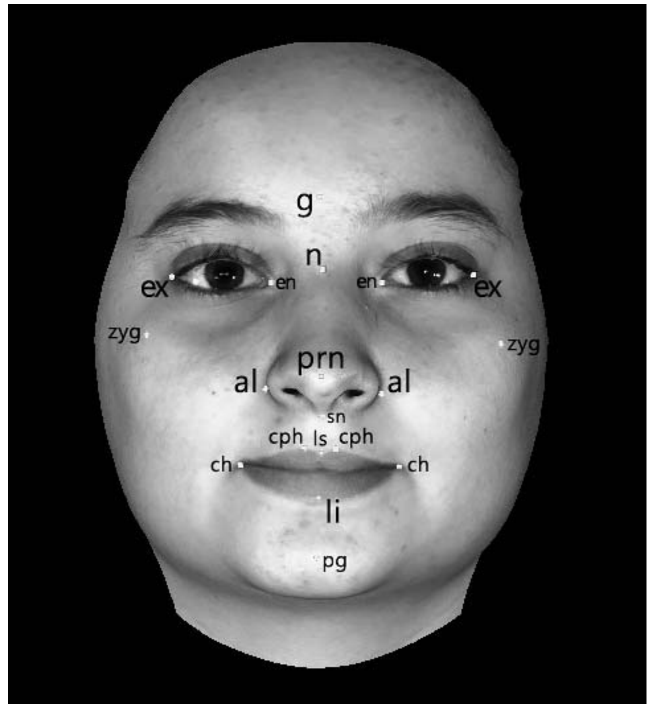

Figure 3. Soft tissue landmarks.

manipulated using the 3dMD Vultus software (3dMD). Each 3-D facial image was cleaned to exclude confounding regions by removing the extraneous surface data from the neck, ears, and scalp hair.

PACs were used to assess transverse changes on the skeletal, dental, and nasal structures. The standard scan takes only 10 seconds with 2.3 seconds exposure time and optimized patient dose (Orthopantomograph OP300, Instrumentarium, Tuusula, Finland).

The landmarks and measurements are given in Figures 3 and 4 and Tables 3 and 4.

Individual changes of the soft tissue landmarks were recorded using superimposed images. In order to accurately superimpose the two 3-D facial images, the registration protocol was performed on the forehead, upper nasal dorsum, and zygoma. These were defined as the most stable regions over time.[15] The 3-D facial images were then landmarked by a single trained investigator. The software was designed to automatically calculate the Euclidean distance of the landmark positions (Figure 5). Positive values indicated forward movement of the specific landmark in three planes of space according to Euclidean distance matrix analysis,[16] while negative values indicated posterior movement.

Interim Analyses and Stopping Guidelines

Not applicable.

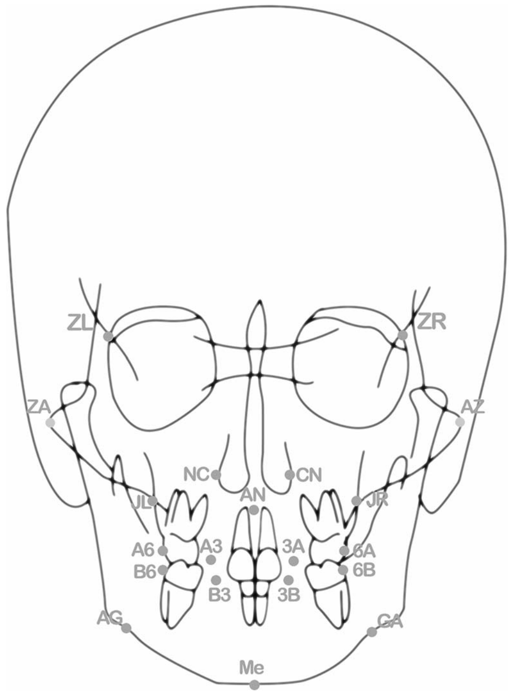

Figure 4. Hard tissue landmarks.

Outcomes and Changes After Trial Commencement

The primary outcome of this study was to assess soft tissue changes. Secondary outcomes were to evaluate hard and soft tissue relations. No changes in methodology or outcome changes occurred after trial commencement. Blinding of neither patient nor operator was possible but was feasible during evaluation and outcome assessment.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, Version 20.0 (SPSS Inc, Chicago, Ill). The normality test of Shapiro-Wilks and Levene's variance homogeneity tests were applied to the data. Intragroup comparisons were determined with paired-samples *t*-tests (Bonferroni correction) and intergroup comparisons were determined with MANOVA. Pearson correlation analyses were used to assess the degree of correlation between soft and hard tissue changes.

Table 2. Demographic and Clinical Characteristics of Groups

	Treatment Group	Control Group	Total
Age (y)	13.4 ± 1.2	12.8 ± 1.3	13.1 ± 1.2
Boys (n)	9	9	17
Girls (n)	8	8	17
Malocclusion			
Class I	4	4	8
Class II	10	10	20
Class III	3	3	6

RESULTS

Method Error

The same author repeated the measurements 1 month after the first measurements on 20 3-D images and 20 PACs randomly selected from 10 patients. Intraclass correlation coefficients (r) ranged from 0.94 (6A-6B) to 1.00 (AG-GA). No significant errors were found when repeat measurements were evaluated with paired *t*-tests.

Baseline demographic and clinical characteristics of the patients are given in Table 2. Patient treatment and observation were completed without dropouts from either group. The follow-up period for both groups was 6 months.

Transverse Measurements

A comparison of starting forms of treated and control subjects is given in Table 5. Only face widths (ZA-AZ, $P = .042$) and maxillary intermolar distances ($P = .008$) were different between groups. Initial soft tissue cephalometric values were comparable between groups.

Table 6 shows the intra- and intergroup comparisons of the mean changes between T0 and T1. In both groups, there was a general trend of increase for the transverse skeletal measurements, especially in the expansion group, but these increases were not as great in the control group. Maxillary and mandibular midlines, mandibular intercanine width, ZL-ZR, AG-GA, and occlusal difference changes were not statistically significant between groups. Average molar relation was increased and average maxillomandibular relation was decreased in the expansion group; these changes were the opposite in the control group.

Similar to transverse skeletal measurements, increases in soft tissue measurements were found. Except for alar base width ($P = .002$), soft tissue differences were comparable between groups.

Soft Tissue Point Measurements

To determine soft tissue point changes, the distance between locations of the same point was calculated after superimposition of pre- and posttreatment stereophotogrammetric images (Table 7). No statistically significant differences were found between groups, except for pogonion ($P = .022$), which was found to be posteriorly located in the expansion group

Table 3. Definitions of Soft and Hard Tissue Landmarks

	Definition
Soft tissue landmarks	
Labiale Superius (ls)	Midpoint of the upper vermillion line
Crista Philtri (cph)	Point on left and right elevated margins of philtrum just above VL (L/R)
Labiale Inferius (li)	Midpoint of the lower vermillion line
Subnasale (sn)	Midpoint of angle at columella base
Pronasale (prn)	Most protruded point of apex nasi
Cheilion (ch)	Point located at left and right labial commissure (L/R)
Endocanthion (en)	Inner commissure of left and right eye fissure (L/R)
Pogonion (pog)	Most anterior point on bony chin
Alare (al)	Most lateral point on left and right alar contour (L/R)
Zygion (zyg)	Most lateral point of zygomatic arch (L/R)
Hard tissue landmarks	
ZL-ZR	Intersection of left/right zygomaticofrontal suture and orbit
ZA-AZ	Intersection of lateral borders of left/right zygomatic arch
NC-CN	Widest part of left/right nasal cavity
Me	Most inferior point of mandibular symphisis, in midsagittal plane
AN	Anterior nasal spine
JL-JR	Intersection of processus zygomaticus and processus alveolaris maxillae
A6-6A	Outermost point of maxillary left/right first permanent molar, determined perpendicularly to occlusal plane
B6-6B	Outermost points of mandibular left/right first permanent molar, determined perpendicularly to occlusalplane
A3-3A	Cusp tip of maxillary left/right permanent canine
B3-3B	Cusp tip of mandibular left/right permanent canine
AG-GA	Lateral and inferior border of left/right antegonial notch

(−1.33 mm), but forward movement (0.11 mm) was recorded in the control group.

Hard and Soft Tissue Relations

Correlation coefficients were calculated; the only statistically significant correlation was found between the amount of expansion and maxillary intermolar distance ($r = 1.000$, $P = .001$). The regression model was not used, as weak or no correlation existed between soft and hard tissue changes.

No serious harm was observed in the treatment group other than gingivitis associated with the difficulty of plaque removal.

DISCUSSION

The aim of orthodontic treatment is to achieve facial harmony as well as ideal occlusion. From this point of view, orthodontic procedures should be evaluated to clarify whether—and how—these procedures affect the appearance of soft tissues. In the present study,

Figure 5. Superimposition and soft tissue point measurement using the software.

Table 4. Definition of Linear Transverse Measurements

Hard tissue linear measurements	
ZL-ZR	Distance between right and left zigion (Z plane) points
ZA-AZ	Width of zygomatic arch at its most lateral aspect
NC-CN	Nasal width, width between the NC and CN points
Maxillary width (JL-JR)	Width between the left and right jugulare points
Mandibular width (bigonial width)	Width between the AG and GA points
A6-B6 difference (average molar relation)	Difference between outermost points of the maxillary and mandibular left permanent molars, determined perpendicularly to the occlusal plane
6A-6B difference (average molar relation)	Difference between outermost points of the maxillary and mandibular right permanent molars, determined perpendicularly to the occlusal plane
JL-FFP distance (average maxillomandibular relation)	Distance between left jugulare point and frontal face plane, determined perpendicularly to the occlusal plane
JR-FFP distance (average maxillomandibular relation)	Distance between right jugulare point and frontal face plane, determined perpendicularly to the occlusal plane
6B-FTP (frontal tooth plane) distance	Distance between outermost point of mandibular left permanent molar and frontal tooth plane, determined perpendicularly to the occlusal plane
B6-FTP (frontal tooth plane) distance	Distance between outermost point of mandibular right permanent molar and frontal tooth plane, determined perpendicularly to the occlusal plane
Oclusal plane inclination	Difference between the right and left occlusal plane distances to the Z-plane.
Maxillary midline deviation	Distance between contact point of the maxillary cental incisors and the midsagittal plane (AN-Me)
Mandibular midline deviation	Distance between contact point of the mandibular central incisors and the midsagittal plane (AN-Me)
Maxillary intermolar width	Distance between A6 point and 6A point
Mandibular intermolar width	Distance between B6 point and 6B point
Mandibular intercanine width	Distance between U3 point and 3U point
Mandibular intercanine width	Distance between L3 point and 3L point
Soft tissue linear measurements	
EndR-EndL	Distance between left and right endocanthion
ZigR-ZigL	Distance between left and right zygion
AlR-AlL	Distance between left and right alare
ChR-ChL	Distance between left and right chelion
PhR-PhL	Distance between left and right christa philtri
Subn-Pron	Distance between pronasale and subnasale
Upper lip length (Subn_Labsub)	Distance between labrale superior and subnasale
Lower lip length (Pog_Labinf)	Distance between labrale inferior and pogonion
Lower face height (Subn_Pog)	Distance between subnasale and pogonion

the soft tissue effects of RME were examined using 3-D stereophotogrammetric images.

The only statistically significant difference in soft tissue linear changes between groups was found for alar base width. In the treatment group, the difference was 1.41 ± 0.95 mm, which was approximately 1 mm greater than in the control group. Widening of the alar base is a common finding that does not exceed 2 mm.[6–10] Also, statistically significant differences were reported, whose clinical significance is open to question.

An increase in hard tissue nasal width (2.42 ± 1.28 mm) was also found. Widening of the alar base after RME has been shown in studies using metallic markers.[17] Berger et al.[6] advocated that the soft tissue findings correlated well with the skeletal effects (1 to 1 ratio) and even the expansion was 4-5 mm, this amount lead to significant soft tissue changes. But weak correlation was found in our study.

Kim et al.[10] found that the nose apex and the distance between zygion points increased immediately after RME. Berger et al.[6] reported statistically significant increases in eye width (0.2 mm) and intercanthal distance (0.3 mm). In the current study, statistically significant increases were also found between the intercanthal distance and zygoma points in both groups. But the difference did not reach a statistically significant level, thus the increases were thought to be the result of normal growth and development.

Elongation of the upper lip,[6,10] thinning of both lips,[10] and increase in lower vermilion height[8] were reported after RME. In this study, no statistically significant change was found for the lips in either group.

Records were taken after appliance removal and retention to eliminate the immediate positional changes of the lips, cheeks, chin, and mandible caused by adapting to the bulk of the expander.[6] Changes in occlusion could also be a confounding factor that leads to soft tissue changes not related to expansion.[10] The postretention records were therefore taken to account for occlusal settling and to obtain a stable mandibular position.

Table 5. Comparison of Baseline Measurements of Treated and Control Subjects (mm)

	RME(E) ($n^a = 17$)		Control (C) (n = 17)		MANOVA		
	Mean	SD	Mean	SD	Mean Difference (E−C)	***P***	Sig
Hard tissue linear measurements							
ZL-ZR	85.311	5.646	86.176	3.326	−.865	.590	NS
ZA-AZ	123.412	7.042	118.376	6.826	5.035*	.042	<.05
NC-CN	29.118	1.470	28.729	2.104	.388	.537	NS
JL-JR	59.465	2.163	59.288	5.554	.176	.904	NS
AG-GA	80.388	4.692	78.376	4.706	2.012	.221	NS
A6-B6	−1.376	1.965	−0.712	1.468	−.665	.272	NS
6A-6B	−1.806	1.567	−0.806	1.396	−1.000	.058	NS
JL-FFP	11.547	2.123	11.224	1.653	.324	.623	NS
JR-FFP	11.235	2.632	11.118	1.770	.118	.879	NS
B6-FTP	11.629	2.418	11.106	2.525	.524	.541	NS
6B-FTP	9.688	2.440	8.424	3.261	1.265	.210	NS
Occlusal difference	−0.647	1.601	−0.900	2.161	.253	.701	NS
Maxillary midline	0.482	1.027	0.765	0.803	−.282	.379	NS
Mandibular midline	−0.012	1.765	−0.135	0.974	.124	.802	NS
Maxillary intermolar width	31.249	2.747	33.447	1.636	−2.198*	.008	<.05
Mandibular intermolar width	34.148	2.270	34.555	1.842	−.408	.569	NS
Maxillary intercanine width	24.512	2.658	24.082	1.670	.429	.577	NS
Mandibular intercanine width	23.765	2.653	23.559	1.772	.206	.792	NS
Soft tissue linear measurements							
EndR-EndL	32.526	3.125	32.386	3.695	.140	.906	NS
ZigR-ZigL	103.945	6.927	100.523	5.432	3.422	.119	NS
AlR-AlL	29.668	2.953	27.648	2.408	2.020	.056	NS
ChR-ChL	46.825	4.017	44.283	2.849	2.542	.066	NS
PhR-PhL	12.803	1.875	13.171	2.190	−.368	.603	NS
Subn-Pron	16.644	1.763	15.672	1.983	.972	.141	NS
Subn-Labsup	16.226	2.509	16.201	3.173	.025	.980	NS
Pog-Labinf	26.441	3.365	24.899	2.498	1.542	.139	NS
Subn-Pog	57.525	4.575	54.812	4.249	2.713	.083	NS

[a] n indicates sample size; SD, standard deviation; *$P < .05$.

Soft tissue pogonion was positioned backward in the treatment group. The difference was approximately 1.5 mm; this change may be assumed to be clinically important. One explanation is rotation of the mandible, which has been stated to be the result of either extrusion of posterior teeth or downward displacement of the maxilla.[18] We used bonded expanders to prevent the bite opening effect[8,19] but found an approximately 1-mm increase in both groups. The other factor might be the result of a decrease in soft tissue chin thickness. Unfortunately, as stereophotogrammetric images do not provide information about subsurface structures, assessment of soft tissue chin thickness was not possible. Kilic et al.[2] found no change in the soft tissue chin thickness after rapid maxillary expansion.

The change in the nasal prominence was nonsignificant. Similar[2,9] and contrary[5] results were reported.

The relation between the dentoskeletal changes and accompanying soft tissue changes was evaluated using correlation analysis. Weak correlation was found between the hard and soft tissues. These results bring us to conclude that the soft tissue effects of RME is hard predict before treatments just taking into account the dentoskeletal changes.

Advances in computer technology have enabled us to capture and superimpose 3-D images in order to evaluate soft tissue changes and prevent the information loss inherent in the use of 2-D imaging. In a recent study,[12] reliability of the system was reported to be high, with a mean error of only 0.2 mm. Weinberg et al.[20] compared two digital photogrammetry systems with direct physical measurements and found high intraobserver precision across the three methods. Similarly, we found no significant errors when repeat measurements were evaluated, showing high reliability of the measurements.

The best approach to evaluate treatment changes is to compare the treated samples with an untreated control group. To our knowledge, this is the first study to include a control group to distinguish the changes accompanying normal growth and development.

Table 6. Comparison of Mean Differences Between Treated and Control Subjects (mm)

	RME(E) (n = 17)			Control (C) (n = 17)			MANOVA		
	Mean	SD	*t*-test	Mean	SD	*t*-test	Mean Difference (E−C)	***P***	Sig
Hard tissue linear measurements									
ZL-ZR	1.629	1.514	0.000	0.947	1.475	NS	.682	.193	NS
ZA-AZ	2.124	1.127	0.000	1.218	0.997	0.000	.906*	.019	<0.05
NC-CN	2.429	1.281	0.000	0.347	0.741	NS	2.082*	.000	<0.001
JL-JR	3.165	2.046	0.000	0.729	0.877	NS	2.435*	.000	<0.001
AG-GA	1.482	1.431	0.001	0.847	0.923	0.002	.635	.134	NS
A6-B6	3.241	1.367	0.000	−0.229	0.421	NS	3.471*	.000	<0.001
6A-6B	3.429	1.994	0.000	−0.182	0.425	NS	3.612*	.000	<0.001
JL-FFP	−1.741	1.739	0.001	0.259	0.587	NS	−2.000*	.000	<0.001
JR-FFP	−1.865	1.612	0.000	0.253	0.312	NS	−2.118*	.000	<0.001
B6-FTP	1.112	0.803	0.000	−0.212	1.056	NS	1.324*	.000	<0.001
6B-FTP	1.318	1.141	0.000	0.300	0.699	NS	1.018*	.004	<0.05
Occlusal difference	0.276	1.865	NS	0.071	0.202	NS	.206	.654	NS
Maxillary midline	0.312	1.104	NS	0.000	0.194	NS	.312	.260	NS
Mandibular midline	0.124	1.613	NS	0.018	0.198	NS	.106	.790	NS
Maxillary intermolar width	6.443	1.023	0.000	0.178	0.155	0.000	6.265*	.000	<0.001
Mandibular intermolar width	0.943	0.466	0.000	0.070	0.074	0.001	.873*	.000	<0.001
Maxillary intercanine width	2.465	0.857	0.000	0.176	0.199	0.002	2.288*	.000	<0.001
Mandibular intercanine width	0.665	0.357	0.000	0.118	0.159	NS	.547*	.000	NS
Soft tissue linear measurements									
EndR-EndL	0.649	0.693	0.001	0.284	0.437	NS	.365	.075	NS
ZigR-ZigL	0.740	1.053	NS	1.012	0.833	0.000	−.272	.409	NS
AlR-AlL	1.419	0.956	0.000	0.427	0.794	NS	.992*	.002	<0.05
ChR-ChL	1.856	1.349	0.000	1.227	1.031	0.000	.629	.137	NS
PhR-PhL	0.689	0.950	NS	0.558	0.521	0.000	.131	.623	NS
Subn-Pron	0.171	1.537	NS	0.555	0.816	NS	−.385	.369	NS
Subn-Labsup	0.225	0.923	NS	0.332	1.560	NS	−.106	.810	NS
Pog-Labinf	0.392	1.906	NS	−0.042	1.196	NS	.434	.432	NS
Subn-Pog	1.135	1.564	NS	1.261	1.171	0.000	−.125	.793	NS

[a] n indicates sample size; SD, standard deviation; $P = .05$ for MANOVA; adjusted alpha level = .0025 for hard tissue; adjusted alpha level = .006 for soft tissue measurements.

The patients in the control group were called from the waiting list of the clinic. During the 6-month observation period, they underwent interceptive procedures (fissure sealants, space maintainers, fillings, extractions) if necessary. Immediately after 6 months of observation, all patients in the control group received orthodontic treatment including RME and fixed appliance therapy.

Table 7. Comparison of Mean Differences Between Treated and Control Subjects

	RME(E) (n = 17)		Control (C) (n = 17)				
	Mean	SD	Mean	SD	Mean Difference (E−C)	***P***	Sig
Labsup	−0.550	1.071	−0.204	1.469	−.346	.438	NS
Lapinf	0.038	1.287	0.098	1.414	−.060	.898	NS
CrissFiltR	−0.478	1.074	−0.308	1.331	−.170	.685	NS
CrissFiltL	−0.446	0.815	−0.177	1.107	−.269	.425	NS
Subnasale	0.155	0.670	0.524	0.757	−.369	.142	NS
Pronasale	−0.147	0.683	0.296	0.614	−.443	.055	NS
ChelionR	−0.361	1.493	−1.213	1.503	.852	.107	NS
ChelionL	−0.166	1.672	−0.812	1.297	.645	.218	NS
Pogonion	−1.332	1.718	0.118	1.797	−1.450*	.022	<0.05
EndR	−0.209	0.417	−0.125	0.644	−.084	.654	NS
EndL	−0.079	0.490	−0.066	0.507	−.014	.937	NS
AlareR	0.064	0.745	−0.105	0.562	−169	.461	NS
AlareL	0.021	0.535	0.056	0.532	−.035	.848	NS
ZigionR	−0.228	0.739	−0.719	0.800	.491	.072	NS
ZigionL	−0.399	0.643	−0.468	0.653	−.069	.759	NS

[a] n indicates sample size; SD, standard deviation; $^*P < .05$.

Within the limitations of this study, it can be concluded that alar base enlargement and backward movement of pogonion is a consequence of RME. But these minor changes were not clinically significant and their importance is questionable. Generalizability is limited because it was a single-center study with limited sample size.

CONCLUSIONS

- After RME therapy, statistically significant hard tissue changes were observed compared with the untreated control group.
- Soft tissue changes were similar in both groups, except the alar base, which became wider in the RME treatment group.
- Soft tissue pogonion point was positioned backward in the treatment group.
- Weak correlations were found between skeletal and soft tissue changes after RME therapy.

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REFERENCES

1. Ackerman JL, Proffit WR, Sarver DM. The emerging soft tissue paradigm in orthodontic diagnosis and treatment planning. *Clin Orthod Res*. 1999;2:49–52.
2. Kilic N, Kiki A, Oktay H, Erdem A. Effects of rapid maxillary expansion on Holdaway soft tissue measurements. *Eur J Orthod*. 2008;30:239–243.
3. Kudlick EM. A study utilizing dried human skulls as models to determine how bones of the craniofacial complex are displaced under the influence of midpalatal expansion [Master's thesis]. Teaneck, NJ: Fairleigh Dickinson University; 1973.
4. Wertz RA. Changes in nasal air flow incident to rapid maxillary expansion. *Am J Orthod*. 1967;53:705–706.
5. Karaman AI, Gelgör I, Demir A. Examination of soft tissue changes after rapid maxillary expansion. *World J Orthod*. 2002;3:217–222.
6. Berger JL, Pangrazio-Kulbersh V, Thomas BW, Kaczynski R. Photographic analysis of facial changes associated with maxillary expansion. *Am J Orthod Dentofacial Orthop*. 1999;116:563–571.
7. 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;80:995–1001.
8. Altındis S, Toy E, Basciftci FA. Assessment of the effects of different rapid maxillary expansion appliances on facial soft tissues using three-dimensional imaging. *Angle Orthod*. doi:10.2319/051115-319.1[Epub].
9. 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. *The Surgeon*. 2014. doi:10.1016/j.surge.2014.04.005.
10. Kim KB, Adams D, Araújo EA, Behrents RG. Evaluation of immediate soft tissue changes after rapid maxillary expansion. *Dental Press J Orthod*. 2012;17:157–164.
11. Germec-Cakan D, Canter HI, Nur B, Arun T. Comparison of facial soft tissue measurements on three-dimensional images and models obtained with different methods. *J Craniofac Surg*. 2010;21:1393–1399.
12. Lübbers HT, Medinger L, Kruse A, Gratz KW, Matthews F. Precision and accuracy of the 3dMD photogrammetric system in craniomaxillofacial application. *J Craniofac Surg*. 2010;21:763–767.
13. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion: 3. Forces present during retention. *Angle Orthod*. 1965;35:178–186.
14. Chiu CS, Clark RK. Reproducibility of natural head position. *J Dent*. 1991;19:130–131.
15. Djordjevic J, Jadallah M, Zhurov A, Toma A, Richmond S. Three dimensional analysis of facial shape and symmetry in twins using laser surface scanning. *Orthod Craniofac Res*. 2013;16:146–160.
16. O'Grady KF, Antonyshyn OM. Facial asymmetry: three-dimensional analysis using laser surface scanning. *Plast Reconstr Surg*. 1999;104:928–937.
17. Skeiller V. Expansion of the midpalatal suture by removable plates analyzed by the implant method. *Trans Eur Orthod Soc*. 1964;40:143.
18. McNamara JA Jr. The role of the transverse dimension in orthodontic diagnosis and treatment planning. In: *Craniofacial Growth Series*. Monograph 36. Ann Arbor, Mich: University of Michigan Center for Human Growth and Development; 1999.
19. McNamara JA Jr, Brudon WL. *Orthodontic and Orthopedic Treatment in the Mixed Dentition*. Ann Arbor, MI: Needham Press; 1993.
20. Weinberg SM, Naidoo S, Govier DP, Martin RA, Kane AA, Marazita ML. Anthropometric precision and accuracy of digital three-dimensional photogrammetry: comparing the Genex and 3dMD imaging systems with one another and with direct anthropometry. *J Craniofac Surg*. 2006;17:477–483.