Original Article

Three-dimensional soft tissue evaluation after rapid maxillary expansion and mandibular midline distraction osteogenesis

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ABSTRACT

Objectives: To evaluate the effects of rapid maxillary expansion (RME) and mandibular midline distraction osteogenesis (MMDO) on facial soft tissues using three-dimensional (3D) images.

Materials and Methods: A total of 20 patients (average age 15.86 $\pm$ 2.17 years) were treated with RME and MMDO using tooth-borne distractors. Three-dimensional photographs of each patient were taken with a stereophotogrammetry system at baseline (T0), at the end of the distraction period (T1), and at the end of the consolidation period (T2). All data were analyzed using a dependent-samples *t*-test at a significance level of 5%.

Results: Total and lower face height increased after MMDO ($P < .05$). Nasal and mouth width increased after RME as compared with baseline ($P < .05$). The labiomental angle increased at T1 and decreased at T2 ($P < .05$). After MMDO, the convexity angle increased while the mandibular angle decreased ($P < .05$). Upper and lower lip angles increased after RME ($P < .05$). The distance from the lower lip to the E plane increased after MMDO and decreased after RME ($P < .05$).

Conclusions: The MMDO and RME procedures provide an efficient nonextraction treatment alternative for transverse maxillomandibular deficiency. MMDO may improve the facial soft tissue profile in the transverse and vertical axis of the mandibular region. (*Angle Orthod.* 2021;91:634–640.)

KEY WORDS: Mandibular midline distraction osteogenesis; Mandibular symphyseal distraction osteogenesis; Distraction osteogenesis; Three-dimensional imaging

INTRODUCTION

Mandibular and maxillary transverse deficiencies are common problems in orthodontic and oral maxillofacial patients.[1] Rapid maxillary expansion (RME) is a well-known approach to correcting maxillary transverse deficiency while providing an increase in arch width to resolve mild to moderate crowding.[2] Mandibular transverse deficiency causes dental crowding in anterior, unilateral, or bilateral crossbite in the posterior region, and traditional treatment modalities are usually inadequate in solving this problem. Expansion of the dental arches, tooth extraction, protrusion of the lower incisors, and interproximal reduction of tooth width can be used to treat mandibular transverse deficiencies.[3,4] In the mixed dentition, expansion of the mandibular arch with removable appliances and a lip bumper are used to treat dental crowding.[5,6] However, in the permanent dentition, increasing the intercanine distance with dental expansion tends to relapse toward the initial dimension.[7] In some cases, tooth extraction prolongs the treatment period, and the patient and parents may not want tooth extraction.[8] The alveolar bone limits protrusion of the lower incisors, which causes an unstable treatment result. In addition, this approach may cause periodontal problems and alve-

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olar bone loss.[9] Also, interproximal enamel reduction is limited in its applicability because of insufficient enamel thickness.[4]

Mandibular midline distraction osteogenesis (MMDO) was introduced as a treatment approach in 1990 to widen the mandible for transverse mandibular deficiencies.[10] It has been used to treat maxillomandibular transverse deficiencies, unilateral and bilateral posterior crossbite, the correction of a narrow mandibular arch, and mandibular anterior crowding.[11] Currently, different distraction devices, such as bone-borne, tooth-borne, and hybrid designs, are used for MMDO. The effects of MMDO have been investigated by several researchers, some of whom used tooth-borne distraction devices.[10,12–14] Tooth-borne distraction devices are easy to use, are supported by selected mandibular teeth, and provide patient comfort during treatment.

Maxillomandibular widening has mostly been investigated with dental models and posteroanterior radiographs. When evaluating the morphologic changes of soft tissue, the stereophotogrammetry technique was found to be more reliable and accurate than the two-dimensional and laser scanning methods.[15] Only a few clinical studies have evaluated soft tissue changes after treatment with maxillomandibular widening using three-dimensional (3D) imaging systems such as cone-beam computed tomography,[16,17] laser scanner,[17] and stereophotogrammetry.[18] To date, no study has evaluated MMDO with tooth-borne distraction to investigate the clinical outcomes on soft tissue using the 3D stereophotogrammetry technique. Accordingly, this study aimed to investigate the effects of MMDO with a tooth-borne distraction device on facial soft tissues using 3D images. The null hypothesis of the study was that there are no differences in the facial soft tissue profile after the MMDO and RME procedures.

MATERIALS AND METHODS

Ethical approval was obtained from the human ethics committee of the University of İnönü. Written informed consent was obtained from the parents or guardians of all the participants. Based on a previous study,[19] a power calculation was performed using the *t* test family (G*Power 3.1 software; Heinrich Heine University, Dusseldorf, Germany), with $\alpha = 0.05$, $\beta = 0.95$, and an effect size of 0.89. The results indicated that the total sample size should be a minimum of 19, so we set the sample size at 20.

A total of 20 patients (8 boys and 12 girls; mean age: 15.86 $\pm$ 2.17 years; range: 13.1–21.5 years) who presented to the Department of Orthodontics, Faculty of Dentistry, İnönü University, were involved in this study. The inclusion criteria were narrow and V-shaped mandibular dental arch, moderate (4–6 mm) or severe (6–10 mm) mandibular anterior dental crowding, a transverse deficiency in the lower and upper jaw, dark corridors during smile, and single- or double-sided lingual crossbite closure in the lower jaw.[20] The exclusion criteria were skeletal or dental Class III features, orthognathic profile, systemic disease, previous orthodontic treatment, tooth deficiency, and craniofacial syndrome.

Figure 1. Tooth-borne distractor appliance.

Design of Intraoral Tooth-Borne Distractor

A custom-made tooth-borne distractor was prepared as described by Guerrero et al.,[21] consisting of two premolar bands (3M Unitek, Monrovia, Calif), two molar bands (3M Unitek), and one Hyrax (Leone, Florence, Italy) screw (Figure 1). The Hyrax screw was opened five turns and placed near the lingual of the lower incisors, and the lower arms of the screw were cut. The upper arms were welded to the premolar and molar teeth, and the screw was positioned 2 mm to the lingual of the lower incisors. Before surgery, the appliance was bonded using glass ionomer cement (Ketac Cem, 3M ESPE, Seefeld, Germany) and was left passive for 1 week.

Surgical Procedure

All operations were performed by the same surgeon (Dr Yolcu) using the technique described by Guerrero et al.[21] under local anesthesia. A horizontal incision of 4–6 mm was made in front of the vestibular fornix along the orbicularis oris muscle in the posterior part of the lower lip. Dissection of muscle attachments was performed along the bone at the tip of the chin. The upper part of the flap was dissected to the top of the alveolar bone, with attention paid to the gingival tissue.

During the osteotomy phase, the bone was completely cut from the lower edge of the symphysis under the apices of the incisors and vertically to the lingual cortical bone. The bone between the two incisors was gently divided into two with interdental osteotomies. Then, the previously placed distractor was opened 8–10 times (2 mm), and separation between the teeth was observed. Including the five previous turns, the screw was closed again to bring the osteotomy line closer to each two-bone surface. The dissected tissues and mental muscle were properly closed with resorbable suture material. Before the activation process, the RME appliance with acrylic splint was adapted to the mouth, but this appliance was not activated, and patients were instructed that it was to be removed only when brushing teeth after meals.

Distraction Protocol

The amount of activation for each patient was determined by considering the amount of crowding in the lower anterior arch, the position and inclination of the incisors and canines, the amount of maxillary expansion, and the alignment of the lower and upper teeth. The distractor was activated by the patient 1 mm/d (three times in the morning and two times in the evening) after a 7-day latent period. The distance between the screw threads was measured each day by a researcher (Dr Öztürk) until the desired distraction was achieved.

Orthodontic Treatment After Distraction

After the distraction period, the distractor screw was fixed and left in place for 7–10 days. The mandibular incisors were bonded and moved to the distraction region.[20] At the same time, the RME appliance with acrylic splint was activated once a day (0.2 mm).[2] After RME, the expansion appliances were retained for 3 months, and the consolidation time in the lower jaw was determined accordingly. The orthodontic treatment process was continued by removing the expansion appliances in the upper and lower jaws.

We obtained 3D facial images from the patients at the beginning of treatment (T0), at the end of the distraction period (T1), and at the end of the consolidation period (T2).

Image Acquisition by 3D Stereophotogrammetry

The 3D images of all the patients were taken using the 3dMD Face system (3dMd, Atlanta, Ga) at T0, T1, and T2 by one examiner (Dr Öztürk). The 3dMD system includes high-speed, precision stereoscopic cameras to produce 3D polygonal models and texture images that capture the human face and head surface accurately. It features 180° face capture speeds (ear to ear) at 1.5 ms, two modular units consisting of six machine vision cameras, an industrial-grade flash system, and less than 0.2 mm root mean square or better geometric accuracy. The 3dMD system automatically creates a continuous 3D polygon surface network from all synchronized stereo pairs with a single xyz coordinate system. All images were taken with the head in the natural head position, teeth in centric occlusion, and lips in repose. The 3dMD software automatically matched all color information in the mesh, and no stretching of images was required. The images were obtained in .tsb format, and software (3dMD, Vultus, Atlanta, Ga) was used to evaluate 3D facial images. The program has the ability to move images in three directions of space and to mark soft tissue landmarks. Those points marked as defined by Farkas[22] were selected, the analysis template used in the current study was created, and the desired angular and linear measurements were defined (Figure 2a,b; Figure 3a,b; Table 1). The analyses were performed automatically according to the analysis template prepared specifically for this study using the program's "custom analysis template" feature.

The point marking and measurement procedures of 10 randomly selected patients were repeated after 4 weeks by the same investigator (Dr Öztürk). For all measurements, the intraclass correlation coefficient was 0.908–0.990, meaning that acceptable reliability and reproducibility of all measurements were observed.

Statistical Analysis

The normal distribution of the data, expressed as the mean $\pm$ standard deviation, was determined through the Kolmogorov–Smirnov test. Comparisons of the T0, T1, and T2 values were conducted using the dependent-sample *t*-test. Data were analyzed using SPSS 22.0 software (IBM-SPSS Inc., Chicago, Ill). The statistical significance level was set at 5%.

RESULTS

The RME and MMDO were successfully performed, and no loss or failure of the devices or side effects was noted. The activation period lasted 9.19 $\pm$ 0.81 days, and the activation amount was an average of 8.12 $\pm$ 1.78 mm. The average consolidation period after the activation period was 165.85 $\pm$ 10.42 days.

Evaluation of the linear measurements showed that bizygomatic width, bigonial width, biphiltrum width, upper vermillion height, and lower vermillion height did not change at any time point ($P > .05$). Lower and total face height increased at T1 ($P < .05$), and nasal and mouth width increased at T2 ($P < .05$; Table 2).

In the analysis of angular measurements, the labiomental angle was found to have increased at T1

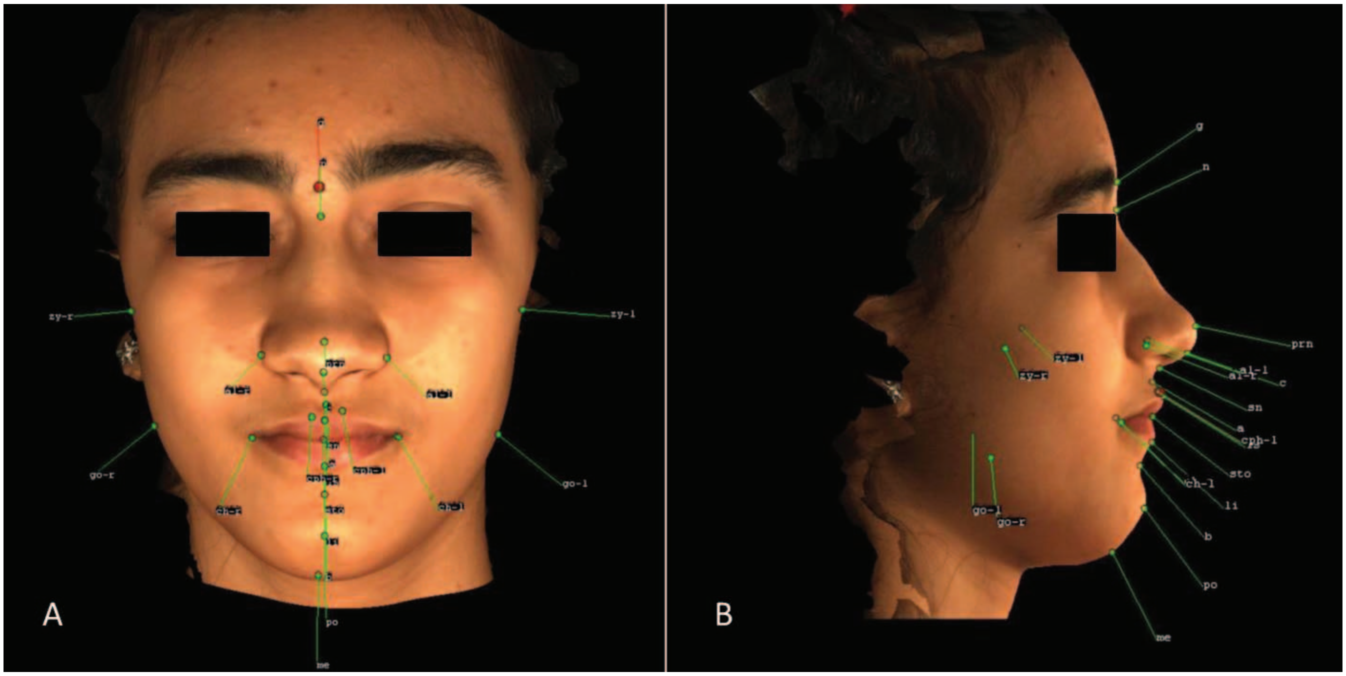

Figure 2. (a, b) Anthropometric landmarks of soft tissue. n indicates nasion; prn, pronasale; sn, subnasale; all-alr, left and right alare; c, columella; ls, labiale superius; sto, stomion; li, labiale inferius; cphr-cphl, right and left philtrum; chr-chl, left and right cheilion; sl, sublabiale; me, menton; gn, gnathion; zyr-zyl, right and left zygoma; trr-trl, right and left tragion; gor-gol, right and left gonion.

and decreased at T2 ($P < .05$). There was an increase in the convexity angle at T1 ($P < .05$) and a decrease in the mandibular angle at T1 ($P < .05$). The upper and lower lip angles were increased at T2 ($P < .05$). There were no changes in the nasolabial angle at any time point ($P > .05$; Table 2).

DISCUSSION

Recent studies have suggested MMDO as an alternative to traditional approaches to widen the mandible in terms of periodontal health and esthetic results.[11] Few clinical studies[17,18] have evaluated the

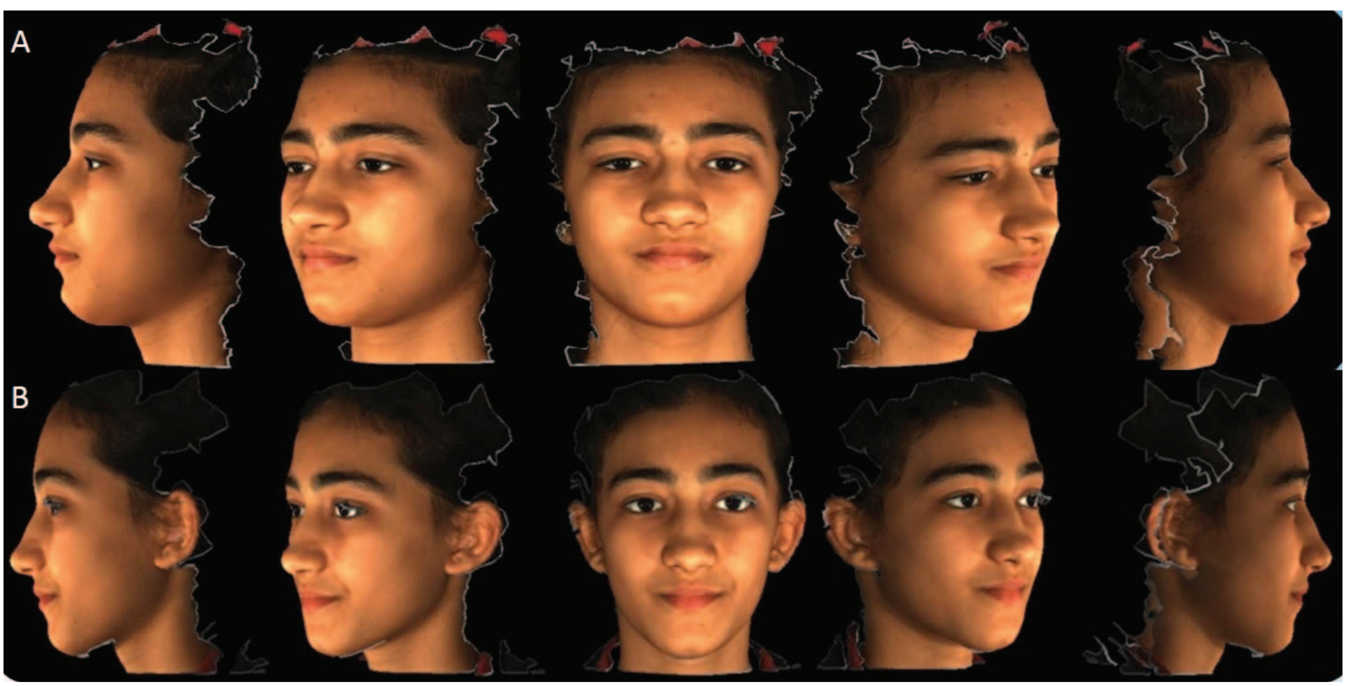

Figure 3. (a, b) Frontal section of facial photographs at T0 and T2.

Table 1. Description of Measurements[a]

Variable	Definition
Stereophotogrammetry analysis, linear, mm	
Nasal width (alr-all)	Distance from alare right to alare left
Bizygomatic width (zygr-zygl)	Distance from zygion right to zygion left
Bigonial width (gor-gol)	Distance from gonion right to gonion left
Biphiltrum width (cphr-cphl)	Distance from crista philtri right to left
Mouth width (chr-chl)	Distance from cheilion right to cheilion left
Upper vermillion height (ls-sto)	Distance from labium superioris to stomion
Lower vermillion height (sto-li)	Distance from stomion to labium inferious
Total face height (n-me)	Distance from nasion to menton
Lower face height (sn-me)	Distance from subnasale to menton
Angular measurements (u)	
Nasolabial angle (c-sn-ls)	Angle subtended by the nasal tip, subnasale, and labrale superioris
Labiomental angle (li-b-pog)	Angle subtended by the labrale inferioris, soft tissue b point, and soft tissue pogonion
Convexity angle (n-sn-pog)	Angle subtended by nasion, subnasale, and soft tissue pogonion
Mandibular angle (gor-me-gol)	Angle subtended by gonion right, menton, and gonion left
Upper lip angle (chr-ls-chl)	Angle subtended by chelion right, labrale superioris, and chelion left
Lower lip angle (chr-li-chl)	Angle subtended by chelion right, labrale inferioris, and chelion left

[a] alr-all indicates right and left alare; zygr-zygl, right and left zygoma; gor-gol, right and left gonion; cphr-cphl, right and left philtrum; chr-chl, right and left cheilion; ls, labiale superius; sto, stomion; li, labiale inferius; n, nasion; me, menton; sn, subnasale; c, columella; b:soft tissue b point; pog, pogonion.

soft tissue changes of maxillomandibular widening with 3D imaging systems. No study has yet evaluated MMDO with tooth-borne distraction in terms of the clinical outcomes on soft tissue using the 3D stereophotogrammetry technique. Thus, this study aimed to evaluate the effects of RME and MMDO with tooth-borne distraction on facial soft tissues using 3D images. The results of this study showed that RME and MMDO with tooth-borne distraction enhanced the facial soft tissues, and maxillomandibular widening is an acceptable nonextraction treatment option. Therefore, the null hypothesis was rejected.

RME was performed in the current study after the distraction procedure as in previous studies.[20,23] This was because it is necessary to prevent the patient from confusing two different expansion procedures and to determine the amount of maxillary expansion after lower jaw expansion is accomplished.

Using 3D imaging, Gül et al.[18] evaluated the soft tissue effects of mandibular midline distraction with a bone-borne distractor and surgically assisted RME by a stereophotogrammetry analysis. After MMDO, the current results showed no change in bigonial width, mouth width, bizygomatic width, and lower vermillion height, and this was consistent with the findings of the

Table 2. Comparison of Pretreatment (T0), Postdistraction (T1), and Postconsolidation (T2) Values[a,b]

Stereophotogrammetry Analysis	T_0, M ± SD	T_1, M ± SD	T_2, M ± SD	P_1, T_0–T_1	P_2, T_0–T_2	P_3, T_1–T_2
Linear measurements (mm)						
Nasal width (alr-all)	32.81 ± 2.38	32.42 ± 2.94	33.70 ± 2.96	.165	.045*	.005*
Bizygomatic width (zygr-zygl)	126.81 ± 5.84	126.92 ± 5.34	127.76 ± 6.19	.637	.218	.222
Bigonial width (gor-gol)	117.62 ± 6.14	115.24 ± 6.66	115.94 ± 6.66	.130	.112	.618
Biphiltrum width (cphr-cphl)	12.00 ± 1.67	11.89 ± 1.63	11.98 ± 1.93	.698	.937	.770
Mouth width (chr-chl)	46.31 ± 3.26	46.77 ± 3.45	47.82 ± 2.86	.381	.002*	.081
Upper vermillion height (ls-sto)	7.80 ± 1.89	8.27 ± 1.53	7.77 ± 1.63	.248	.934	.159
Lower vermillion height (sto-li)	7.97 ± 1.79	7.38 ± 1.93	8.29 ± 1.97	.127	.350	.053
Total face height (n-me)	113.75 ± 5.19	115.69 ± 5.00	115.99 ± 5.75	.005*	.019*	.694
Lower face height (sn-me)	65.32 ± 4.25	66.60 ± 3.83	66.08 ± 3.74	.021*	.310	.384
Angular measurements (u)						
Nasolabial angle (c-sn-ls)	115.95 ± 12.12	116.50 ± 9.98	115.89 ± 9.39	.848	.967	.653
Labiomental angle (li-b-pog)	136.51 ± 11.82	150.96 ± 8.38	144.25 ± 9.92	.000*	.002*	.002*
Convexity angle (n-sn-pog)	158.53 ± 7.80	160.46 ± 7.61	159.95 ± 7.53	.000*	.008*	.209
Mandibular angle (gor-me-gol)	88.80 ± 4.72	84.55 ± 5.94	86.07 ± 3.94	.001*	.000*	.219
Upper lip angle (chr-ls-chl)	106.24 ± 5.61	106.87 ± 6.52	110.88 ± 6.92	.333	.000*	.000*
Lower lip angle (chr-li-chl)	118.75 ± 4.36	119.70 ± 5.10	122.30 ± 4.65	.097	.001*	.002*

[a] Dependent-samples *t* test: * $P < .05$.

[b] alr-all indicates right and left alare; zygr-zygl, right and left zygoma; gor-gol, right and left gonion; cphr-cphl, right and left philtrum; chr-chl, right and left cheilion; ls, labiale superius; sto, stomion; li, labiale inferius; n, nasion; me, menton; sn, subnasale; c, columella; b:soft tissue b point; pog, pogonion.

previous authors.[18] After RME, Gül et al.[18] found that bizygomatic width, biphiltrum width, and upper vermillion height did not change, and nasal width increased. Those findings were similar to the current results. They also reported that the mouth width did not change, but we did find an increase in the current study.

Facial changes can be largely explained by the underlying skeletal movements, which were transverse increases of both the maxilla and mandible. In a study on facial changes, Bianchi et al.[17] investigated soft and hard tissue changes in 19 patients treated with bone-borne distraction devices using computed tomography and a 3D laser scanner. Bianchi et al.[17] noted that the lower and total facial height did not change. In the present study, total and lower facial height increased after MMDO, but there was no change after RME as compared with baseline records. In addition, Bianchi et al.[17] found an increase in total vermillion height (ls-li), but it was not significant. In the present study, no significant changes in the upper (ls-sto) or lower vermillion heights (sto-li) were observed. Bianchi et al.[17] also reported that nasal width did not change; however, contrary to their findings, it increased in the current study. While the bizygomatic width increased in their study,[17] no significant change in the bizygomatic width was observed in the present study. However, similar to the current findings, Bianchi et al.[17] found an increase in mouth width. The findings indicated that maxillomandibular transverse osteodistraction produced facial changes in the cheek, paranasal areas, nasal base, and chin.

This was the first study to examine profile changes of facial soft tissues with 3D imaging after maxillomandibular transverse osteodistraction; those were not evaluated in previous studies.[17,18] Labiomental and convexity angles increased after the distraction period in the present study. Expansion of the mandibular region caused flattening of this region because of lower lip stretch, and the labiomental angle may have increased as a result. The reduction of bigonial distance and dental arch enlargement toward the posterior with expansion may have caused a decrease in the mandibular angle after distraction. In addition, the mouth width increased after RME. The upper and lower lip angles were found to have increased with the increase in mouth width.

Different distractors are available for mandibular widening, and each device has its advantages and disadvantages.[16] In this study, tooth-borne distractors were applied to evaluate the effects on facial soft tissue changes using stereophotogrammetry. It has been reported that mandibular widening obtained with bone-borne distractors prevents further enlargement of the dentoalveolar area than basal bone, thereby reducing the likelihood of relapse.[23] However, bone-borne devices have the disadvantages of prolonged surgery time, higher costs, and the need for a second operation to remove the distractor.[16] In a related study, de Gijt et al.[24] concluded that bone-borne distractors had a higher incidence of irritation and gingivitis as compared with tooth-borne distractors. For these reasons, the tooth-borne distractor offers a more effective and comfortable treatment modality for patients.[24]

In the present study, the linear and angular measurements were evaluated with 3D images obtained by the stereophotogrammetry technique (3dMD Face) to compare the changes among pretreatment, postdistraction, and postconsolidation. It should be noted that 3D imaging has become more common for measuring the size, weight, and proportions of an examined area of the human body, especially in the anthropometry field.[25] Stereophotogrammetry is a noninvasive, rapid, and radiation-free system with reproducibility, high-quality resolution, and easy storage.[25,26] However, this technical equipment is costly, and the system is available only in certain research centers.[26] Therefore, it is recommended that stereophotogrammetry be used in the evaluation of soft tissue facial changes.

The present study evaluated only tooth-borne distractors to determine facial soft tissue changes after maxillomandibular expansion in the short term. Additional studies are needed to evaluate other distractors with long-term follow-up for further comparisons.

CONCLUSIONS

- MMDO and RME procedures provide an efficient nonextraction treatment alternative for transverse maxillomandibular deficiency.
- MMDO may improve the facial soft tissue profile in the transverse and vertical dimensions of the mandibular region.

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