Original Article

Nonextraction Treatment with Rapid Maxillary Expansion and Mandibular Symphyseal Distraction Osteogenesis and Vertical Skeletal Dimensions

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ABSTRACT

Objective: To investigate the effects of rapid maxillary expansion (RME) and mandibular symphyseal distraction osteogenesis (MSDO) on vertical dimensions of the face.

Materials and Methods: Fourteen patients, nine girls and five boys, underwent RME and MSDO procedures. Distraction was carried out at a rate of 1 mm per 24 hours with a tooth-borne appliance. The amount of distraction was 7 mm for each patient. Standardized lateral cephalograms were taken at the following time periods: before treatment (T0), after RME (T1), at the completion of MSDO (T2), and at the end of fixed orthodontic treatment (T3). The data were evaluated by using a general linear model of repeated-measures analysis of variance and paired *t*-tests at the 95% confidence level.

Results: RME significantly increased the vertical dimensions of the face and decreased the overbite ($P < .001$). Although the vertical parameters of the face on the lateral cephalogram decreased after MSDO, these decreasing effects were statistically insignificant just for the distances measured from the horizontal reference line to the chin points. In other words, MSDO decreased the vertical skeletal dimensions that were increased by RME, but this neutralizing effect of MSDO was not as much as the increase caused by RME.

Conclusion: Treatment modalities (RME, MSDO, and fixed orthodontic treatment) described in this study, in total, had little effect on the vertical skeletal measurements of the face.

KEY WORDS: Mandibular symphyseal distraction osteogenesis; Rapid maxillary expansion; Nonextraction treatment; Vertical dimension

INTRODUCTION

Transverse skeletal deficiencies are clinical problems associated generally with narrow basal and dentoalveolar bones. Rapid maxillary expansion (RME) is a common treatment modality for patients who require correction of maxillary transverse discrepancy. This treatment has been associated with downward movement of the maxillary posterior teeth as well as the maxilla.[1–7] In comparison with maxillary deficiencies,[8–10] the diagnosis and treatment of mandibular transverse discrepancies has received little attention. The traditional approaches for correcting mandibular discrepancy are arch expansion and extraction of teeth.

Transverse mandibular deficiencies are commonly corrected with orthodontic expansion, lip bumpers,[11,12] Schwarz devices,[13] or functional appliances in growing patients.[14,15] However, mandibular dental expansion does not offer a definitive solution because mandibular intercanine width increases are considered unstable and have a strong tendency to return to the pretreatment dimension.[16–18] Permanent retention is the only way to ensure long-term posttreatment stability when the intercanine dimension is expanded.[19–22]

In the mandible, extractions are usually unavoidable in patients with severe dental crowding. Excessive overjet, an unattractively convex profile, a deep curve

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of Spee, or a combination of these also contribute to the extraction decision. However, extraction treatment may also present some complications, including undesired changes in the facial profile, lack of improvement of dark buccal corridors, tendency for extraction spaces to reopen, and, sometimes, objections to extractions by patients, parents, and referring dentists.[23]

During the past 15 years, distraction osteogenesis has been gaining popularity as a treatment modality to correct many skeletal problems.[24–26] It was introduced in the beginning of the 20th century and popularized by Ilizarov in the 1960s.[27,28] Guerrero[29] pioneered the use of mandibular midsymphyseal distraction osteogenesis, calling it "surgical rapid mandibular expansion."

Mandibular symphyseal distraction osteogenesis (MSDO) is an alternative approach for correcting mandibular transverse deficiencies and dental crowding. When this technique is used to correct the mandibular transverse problem, a midsymphyseal osteotomy is performed followed by a gradual stretching of the callus.[29] Patients with mandibular transverse deficiencies, such as the narrow and tapered forms seen in hemifacial microsomia, craniosynostosis, and hypoglossia-hypodactyly syndrome, or those with tooth-arch length discrepancies and/or lingually tipped teeth, would benefit from widening of the mandible by symphyseal distraction.[30] In 1997, Guerrero et al[31] reported successfully widening the mandible by distraction osteogenesis in 10 patients.

The correction of upper and lower jaw transverse deficiencies has not been discussed in depth in the literature. The literature does not report any cephalometric investigation of the vertical changes produced by MSDO. More significantly, no scientific contribution is available regarding the effects of a combined expansion protocol that includes RME and MSDO.

Therefore, the aim of this prospective clinical study was to investigate the effects of orthodontic treatment combined with RME and MSDO on vertical skeletal dimensions. The specific goals were (1) to evaluate the effects of RME, (2) to assess the effects of MSDO using a custom made tooth-borne expansion device, and (3) to evaluate effects of this mode of orthodontic treatment in total.

MATERIALS AND METHODS

This study was performed on a total of 14 patients (nine girls and five boys; mean age 14 years 7 months; range 13 years 8 months to 17 years 4 months) with a skeletal Class I pattern and at least 7 mm of discrepancy in the lower anterior region, and unsuitable for tooth extraction. After we received ethics committee approval from the human investigation committee at our institution, treatment procedures were fully explained and parental informed written consent forms for the study were gained.

All patients were evaluated preoperatively with the aid of a standardized presurgical screening questionnaire, a history and physical examination, study casts, and standardized cephalometric and dental radiographs. Additionally, the subjects were evaluated for subjective and objective evidence of temporomandibular joint pathology and the presence of dental or periodontal abnormalities.

The treatment plans for all patients, namely application of MSDO following RME, were decided according to the clinical judgment of two orthodontists and one oral and maxillofacial surgeon, based primarily on mandibular and maxillary dental crowding. After the completion of these procedures, all patients received nonextraction fixed orthodontic treatment.

Treatment Protocol

The RME appliance used in this study consisted of an all-wire framework with an expansion screw soldered to bands on the maxillary permanent first molars and first premolars. The expansion screw and frame were placed as close to the roof of the palate as possible without impinging on the maxillary soft tissue. The expansion regimen for the group was two turns per day (0.5 mm) until the required expansion to solve the upper-arch crowding was achieved. The mean maxillary expansion was 6.8 mm (range 5.0 to 7.5 mm).

MSDO was accomplished with a tooth-borne distraction appliance, which consisted of a hyrax-type expansion screw placed between the right and left first mandibular premolar and molar teeth at the lingual side of the lower jaw (Figure 1). Several days before the planned surgery, the distraction appliance was bonded into place. A preoperative tutorial was given to the patients and their caregivers on the operation of their devices and the critical nature of the timing and frequency of their activation.

The surgery consisted of an intraoral symphyseal osteotomy, as described by Guerrero et al.[31] A horizontal incision was made 5–7 mm labial to the depth of the vestibular sulcus, and the muscle was reflected. The inferior portion of the mental symphysis was sectioned vertically with a reciprocating saw, and a small interdental osteotome was used with light tapping pressure to complete the interdental osteotomy. After the osteotomy, the bonded distractor was tested for expansion. All distractions were carried out at a rate of 1 mm per day after the latency period of 7 days. The amount of distraction was 7 mm for each patient (Figure 2). Although in five of the patients more space

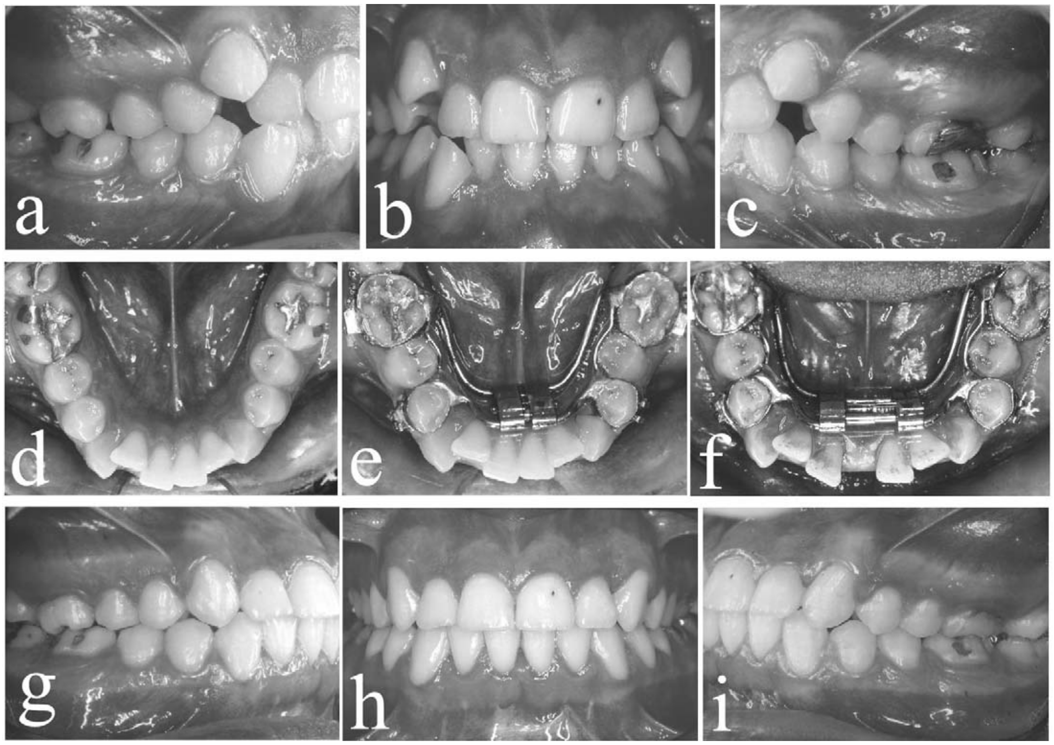

Figure 1. Different treatment stages of a patient. (a–d) Intraoral views before treatment; (e) distractor adapted to the mandible before surgery; (f) after MSDO; (g–i) end of the treatment.

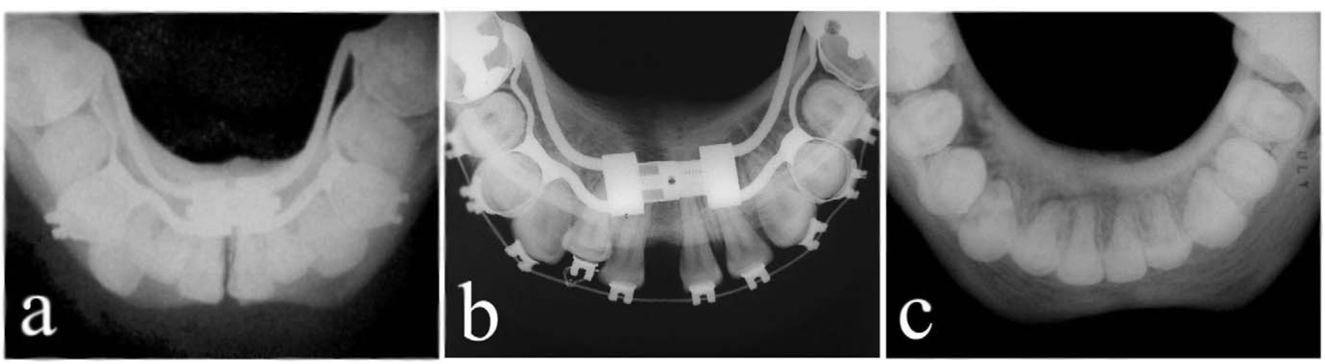

Figure 2. Occlusal radiographs of mandibular anterior region: (a) after surgery; (b) after consolidation period; (c) end of treatment.

(8–9 mm) was required to solve the mandibular dental crowding, the amount of MSDO was kept at 7 mm for all patients in order to standardize the procedure. For the patients who required extra space, either stripping procedures were applied or a slight protrusive position of the lower incisors was accepted at the end of the treatment.

After a consolidation period of about 3 months, all patients received fixed orthodontic treatment. Orthodontic tooth movement was started after radiographic evidence of bone healing. An acrylic pontic was placed in the area of the surgical cut for esthetics and to prevent tipping of the teeth into the osteotomy site. The pontic was regularly reduced in size mesiodistally during orthodontic leveling and alignment until the space was closed. The mean total orthodontic treatment time was 16 months (range 10 to 24 months, including the RME and MSDO procedures).

Cephalometric Analysis

Standardized lateral cephalograms of each patient were taken before treatment (T_0), after rapid maxillary expansion (T_1), at the completion of symphyseal distraction (T_2), and at the end of fixed orthodontic treatment (T_3). Anatomical landmarks were traced on these radiographs and the selected parameters were measured (Figure 3).

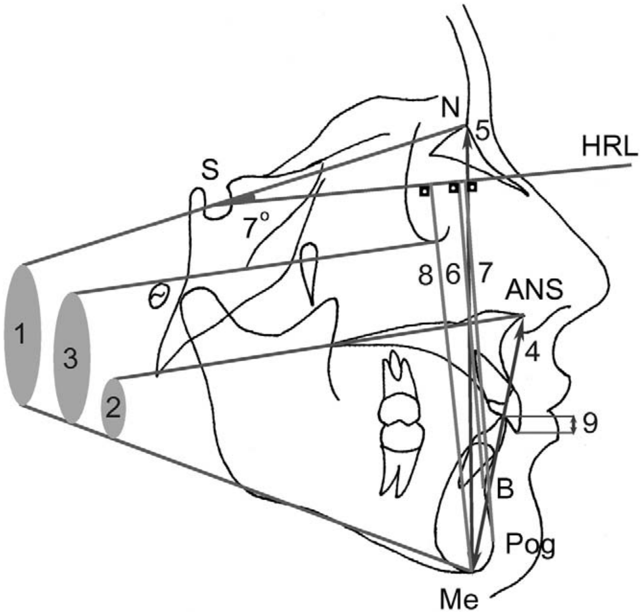

Figure 3. Linear and angular measurements used in this study. (1) Sella-nasion/mandibular plane (°); (2) mandibular plane/maxillary plane (°); (3) FMA (°); (4) anterior nasal spine/menton (mm); (5) nasion/menton (mm); (6) horizontal reference line/B point (mm); (7) horizontal reference line/pogonion (mm), (8) horizontal reference line/menton (mm); (9) overbite (mm).

Statistical Analysis

All the data were transferred to (release 12.0, SPSS Inc, Chicago, IL) software for statistical analysis. Descriptive statistics, including means and standard deviations, were calculated for each of the cephalometric measurements at each stage. The data were evaluated using a general linear model of repeated measures analysis of variance and paired *t*-tests at the 95% confidence level. The statistical comparisons were performed following RME, MSDO, and fixed orthodontic treatment.

RESULTS

Means and standard deviations of the measured vertical cephalometric values at the beginning of the treatment (T_0), after RME (T_1) and MSDO (T_2), and at the end of fixed orthodontic treatment (T_3) are summarized in Table 1. The results revealed that all the mean cephalometric values, apart from the overbite, increased after RME. However, the mean values of these cephalometric measurements decreased and overbite increased after MSDO.

The comparison of the effects of RME (T_0 vs T_1), MSDO (T_1 vs T_2), fixed orthodontic treatment (T_2 vs T_3) and treatment in total (T_0 vs T_3) on the vertical cephalometric measurements is summarized in Table 2. The mean SN/MP, ANS/Me, and overbite values at the four stages of treatment are also diagrammatically shown in Figure 4.

RME Effects (T_0 vs T_1)

RME significantly increased the vertical dimensions of the face (SN/MP, MP/PP, ANS/Me, N/Me, HRL/B, HRL/Pog, and HRL/Me; $P < .001$, and FMA, $P < .01$), and decreased the overbite (Table 2). In other words, the difference between T_0 and T_1 was statistically significant for all measured parameters.

MSDO Effects (T_1 vs T_2)

The vertical dimensions of the face decreased after MSDO (T_2 vs T_1). These decreasing effects were statistically significant for anterior face height (N/Me; $P < .05$), lower anterior face height (ANS/Me; $P < .05$) and vertical angular parameters (SN/MP, MP/PP, and FMA) (Table 2). An increase in the mean overbite value was observed after MSDO, but this increase (1.79 mm) was not statistically significant ($P = .051$).

Table 1. Means and Standart Deviations of the Cephalometric Measurements[a]

Cephalometric Measures	Before Treatment (T_0)		After RME (T_1)		After MSDO (T_2)		End of Treatment (T_3)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SN/MP (°)	36.07	4.79	37.36	4.83	36.36	4.77	35.96	4.75
MP/PP (°)	26.25	4.13	27.11	4.45	26.04	4.4	25.96	4.37
FMA (°)	25.61	5.01	26.86	5.11	26.04	4.76	25.89	5.06
ANS/Me (mm)	68.25	4.95	69.96	4.97	69.14	4.75	68.93	4.86
N/Me (mm)	120.36	5.78	122.14	5.93	121.54	5.91	121.79	6.03
HRL/B (mm)	89.28	4.75	90.57	5.07	90.29	4.78	90.18	4.72
HRL/Pog (mm)	105.71	5.5	107.18	5.67	106.43	5.69	107	5.11
HRL/Me (mm)	110.43	5.32	111.86	5.49	111.64	5.38	111.68	5.37
Overbite (mm)	4.43	1.89	2.64	2.17	3.25	1.51	2.54	0.46

[a] RME indicates rapid maxillary expansion; MSDO, mandibular symphyseal distraction osteogenesis.

Table 2. Comparison of the Cephalometric Measurements at the Stages of Treatment[a]

Cephalometric Measures	RME Effect (T_0 vs. T_1)		MSDO Effect (T_1 vs. T_2)		Fixed Orthodontic Treatment Effect (T_2 vs. T_3)		Total Treatment Effect (T_0 vs. T_3)	
	P		*P*		*P*		*P*	
SN/MP (°)	.000	***	.001	***	.077	NS	.657	NS
MP/PP (°)	.001	***	.002	**	.821	NS	.241	NS
FMA (°)	.003	**	.017	*	.731	NS	.519	NS
ANS/Me (mm)	.000	***	.015	*	.542	NS	.022	*
N/Me (mm)	.000	***	.013	*	.451	NS	.001	***
HRL/B (mm)	.000	***	.328	NS	.706	NS	.011	*
HRL/Pog (mm)	.000	***	.059	NS	.260	NS	.001	***
HRL/Me (mm)	.000	***	.374	NS	.897	NS	.000	***
Overbite (mm)	.000	***	.051	NS	.112	NS	.003	**

[a] RME indicates rapid maxillary expansion; MSDO, mandibular symphyseal distraction osteogenesis; and NS, not significant.
* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

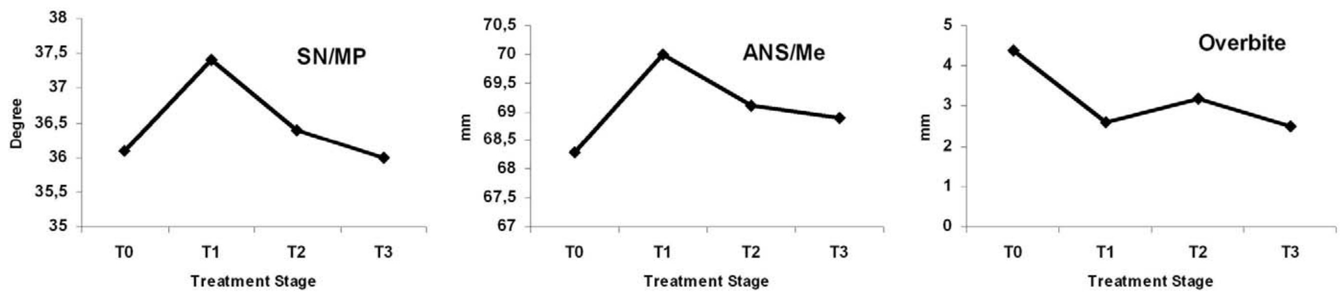

Figure 4. Changes in SN/MP, ANS/Me, and overbite parameters during treatment stages. T_0 indicates before treatment; T_1, after RME; T_2, after MSDO; and T_3, after treatment.

Fixed Orthodontic Treatment Effects (T_2 vs T_3)

Although all measured vertical angular parameters (SN/MP, MP/PP, and FMA), lower anterior face height (ANS/Me), and overbite decreased at the end of fixed orthodontic treatment (T_3), anterior face height (N/Me) and the distances measured from the horizontal reference line to the chin points (HRL/B, HRL/Pog, and HRL/Me) increased slightly (Table 1). However, at the end of the fixed orthodontic treatment applied after MSDO, no statistically significant changes were found in any parameters when compared with those of after MSDO (T_2 vs T_3) (Table 2).

Total Treatment Effects (T_0 vs T_3)

After all treatment stages, including RME, MSDO, and fixed orthodontic treatment, the vertical dimensions of the face were increased. However, there were statistically significant differences only in the mean values of anterior face height (N/Me; $P < .001$), lower anterior face height (ANS/Me; $P < .05$), and the distances between the horizontal reference line and the chin points (HRL/B, HRL/Pog, and HRL/ Me) (Table 2). In other words, statistically significant differences were found between the T_0 and T_3 stages of the treatment for the vertical linear measurements. A statistically significant decrease was also found in the mean overbite value at the end of the treatment ($P < .01$).

DISCUSSION

MSDO has become a popular technique to treat mandibular skeletal deficiency in the transverse dimensions. Although a number of case reports and clinical studies have been published describing the use and effects of MSDO, there is still a lack of knowledge regarding the effects of MSDO on vertical skeletal structures.[32–38] This prospective clinical investigation of consecutively treated patients was aimed at describing the effects of MSDO in conjunction with RME on vertical skeletal structures. This study provides new information on a treatment protocol for arch expansion, RME and MSDO, the treatment effects of which have not previously been analyzed cephalometrically.

The control of vertical facial dimension is essential in patients who need correction of transverse skeletal discrepancy. Many investigators have reported that the maxilla moves forward and downward with the use of different RME appliances. They have reported that RME results in a downward movement of the maxilla, which creates an increase in the maxillary plane angle and upper face dimensions.[1–3,5–9] It has also been demonstrated that RME causes variable amounts of dental tipping and inferior movement of the maxillary plane, which are undesirable side effects, particularly in patients with open-bite tendency.[2–5] The bite-opening side effects seen with RME may settle during fixed orthodontic treatment once occlusal interferences are eliminated.[7]

In our study, we also noted that the total anterior face height (N/Me) and lower anterior face height (ANS/Me) were increased after RME (Table 1). The decrease in overbite and the increases in mandibular plane angle (SN/MP), FMA, and MP/PP parameters were statistically significant, reflecting the downward rotation of the mandible, which could be the result of the downward movement of the maxilla. Extrusion of the maxillary posterior teeth, or a downward displacement of the maxilla, has been suggested as a possible mechanism that leads to clockwise mandibular rotation.[6]

Although traditional approaches such as extractions, stripping, dental tipping, or mandibular arch expansion can resolve the crowding problems, treatment of transverse discrepancies with mandibular expansion or incisor protrusion has been shown to be unpredictable and could result in relapse and undesirable side effects in the long term.[39–43] On the other hand, expansion of the mandible by the principles of distraction osteogenesis generates new bone formation in the basal mandibular bone and holds greater potential compared with previous expansion methods. Therefore, mandibular widening with distraction osteogenesis would be an alternative treatment modality in subjects with transversal mandibular deficiency or crowding.

There are no data about the effect of MSDO on vertical skeletal dimension in the literature. In this study, MSDO decreased the vertical skeletal dimensions that were increased by RME. This neutralizing effect of MSDO was not the same amount as the increase caused by RME. Clockwise rotation of the mandible, because of extrusion and dental tipping of maxillary posterior teeth after RME, has a tendency to return the mandible to its original position by reestablishment of posterior interdigitation following MSDO. Therefore, increased SN/MP, MP/PP, FMA, ANS/Me, and N/Me parameters because of RME showed a statistically significant decrease after MSDO. It may tentatively be suggested that this decrease in vertical dimensions experienced during MSDO is likely because of a return to a cusp-fossa and cusp-embrasure occlusion rather than a true intrusion or a skeletal effect.

In our study, when vertical linear measurements were compared, statistically significant differences were found between the values recorded at the beginning and the end of the study (T_0 vs T_3). However, it should be kept in mind that there was a long time interval (16 months) between the two measurements (T_0 and T_3) and vertical growth continued during this time interval in all subjects.

Wendling et al[44] reported that bonded acrylic splint RME in conjunction with a lower Schwarz appliance increased the lower anterior facial height. In this study, the increase in vertical dimension because of the RME may have been counterbalanced by lower arch decompensation (uprighting of the lower posterior teeth) and reestablishment of posterior interdigitation after MSDO.

CONCLUSIONS

Although MSDO decreased the vertical skeletal dimensions that were increased after RME, this neutralizing effect of MSDO was not as much as the increase caused by the RME. The treatment modality (RME, MSDO, and fixed orthodontic treatment) described in this study, in total, had little effect on the vertical skeletal measurements of the face.

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