Age-related differences in dentoskeletal and soft tissue changes due to rapid maxillary expansion using a tooth-borne expander: A retrospective observational study

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Abstract

Objective: The purpose of this study was to compare the differences in dentoskeletal and soft tissue changes after conventional tooth-borne RME (rapid maxillary expansion) between adolescents and adults. Methods: Dentoskeletal and soft tissue variables of 17 adolescents and 17 adults were analyzed on posteroanterior and lateral cephalograms and frontal photographs at pretreatment (T1) and after conventional RME using tooth-borne expanders (T2). Changes in variables within each group between T1 and T2 were analyzed using the Wilcoxon signed-rank test. The Mann-Whitney U test was used to determine the difference in pretreatment age, expansion and post-expansion durations, and dentoskeletal and soft tissue changes after RME between the groups. The Spearman's correlation between pretreatment age and transverse dentoskeletal changes in the adolescent group was calculated. Results: Despite the similar amount of expansion at the crown level in both groups, the adult group underwent less skeletal expansion with less intermolar root expansion than the adolescent group after RME. The skeletal vertical dimension increased significantly in both groups, without intergroup differences. The anteroposterior position of the maxilla was maintained in both groups, while a greater backward displacement of the mandible was evident in the adult group than in the adolescent group after RME. The soft tissue alar width increased in both groups without a significant intergroup difference. In the adolescent group, pretreatment age was not significantly correlated with transverse dentoskeletal changes. Conclusions: This study suggests that conventional RME may induce similar soft tissue changes but different dentoskeletal changes between adolescents and adults.

Key words: Aging; PA cephalometrics; Rapid maxillary expansion; Tooth-borne expander

INTRODUCTION

Rapid maxillary expansion (RME) is a method for orthopedic expansion of the maxillary arch by opening the midpalatal suture in patients with transverse maxillary discrepancy.[1,2] Unlike the mandible, wherein skeletal expansion is practically impossible without accompanying surgical procedures,[3] skeletal expansion of the maxilla is successfully performed using a conventional non-surgical tooth-borne expander[1] such as the widely used hyrax-type expander.[4]

Since transverse growth of the maxillary complex is completed before anteroposterior and vertical growth,[5] transverse maxillary discrepancy should be corrected relatively early. It has been reported that the patients older than 15 years usually cannot undergo successful skeletal expansion using a conventional tooth-born expander because the closure of the midpalatal suture has begun and resistance to orthopedic expansion is considerably increased.[6,7] If orthopedic expansion with a conventional tooth-borne expander fails, heavy forces are transmitted to the anchor teeth and surrounding periodontium within a short period. Therefore, conventional RME using a tooth-borne expander in late adolescents and adults may lead to potential complications, including pain, gingival recession, bone loss, and root resorption, as well as questionable success of orthopedic expansion.[8]

In this regard, surgically assisted rapid maxillary expansion (SARME)[9] and bone-borne expanders using skeletal anchorage[10,11] were introduced to overcome the potential shortcomings of the conventional tooth-borne expanders. However, these procedures increase the costs and risks of infection because of the need for additional invasive surgical procedures.[12]

Many studies have reported the successful opening of the midpalatal suture using conventional RME in growing patients. Conventional RME induces a triangular expansion with the nasal bone as the hinge on the frontal plane,[2,6,13] an increase in the vertical dimension of the face, the backward rotation of the mandible,[1,14,15] and an increase in soft tissue alar width[16,17] in adolescents. Clinically successful correction of transverse maxillary deficiency using conventional RME in adults has been reported.[18,19] However, information on the dentoskeletal and soft tissue changes caused by conventional RME in adults is limited, because most studies have used plaster models for analyzing the expansion.[8,19] Considering the progressive ossification and interdigitation of the midpalatal suture with aging, conventional RME may induce different dentoskeletal and soft tissue changes with aging. Hence, the aim of this study was to evaluate the differences in dentoskeletal and soft tissue changes between adolescents and adults after conventional RME using tooth-borne expanders. The null hypothesis was that there would be no significant difference in dentoskeletal and soft tissue changes after RME using conventional tooth-borne expanders between the two groups.

MATERIALS AND MEDHODS

This retrospective two-group observational study was designed and performed according to the STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines.[20] Consecutive patients of pretreatment age younger than 15 years or older than 18 years who underwent RME using a hyrax-type expander at Department of Orthodontics, Seoul National Univerity Dental Hospital from 2009 to 2019 were included in this study. Patients who had a complete series of posteroanterior (PA) and lateral cephalograms and frontal photographs at pretreatment (T1) and after expansion (T2) were included. All patients were diagnosed with transverse maxillary discrepancy. The records at T1 were collected for routine pretreatment evaluation, and the records at T2 were collected before commencing the second phase of treatment (at least 2 months after cessation of expansion). Cephalograms and frontal photographs were obtained with the patient in the resting lip and natural head positions. All cephalograms were taken using an Asahi CX-90SP II (Asahi Roentgen, Kyoto, Japan) under the same conditions (76 kVp, 80 mA, 0.32 second of exposure, and magnification ratio of 110%). Patients with the following conditions were excluded: (1) craniofacial syndromes; (2) history of trauma; (3) temporomandibular disorders; (4) history of orthodontic treatment; and (5) gingival recession or possible bony dehiscence around the anchor teeth. The study design was approved by the Institutional Review Board of the University (S-D20190027).

Based on the inclusion and exclusion criteria, 34 patients were included in this study. Of these, 17 patients younger than 15 (11.2–14.6) years were categorized in the adolescent group and the remaining patients who were older than 18 (18.2–26.7) years were included in the adult group. The age criterion was selected because somatic growth in Koreans is completed after the age of 17 years.[21] When cervical vertebral maturation was used to assess the skeletal maturation,[22] all subjects in the adolescent group had CVM stage 4 (circumpubertal) or less and those in the adult group had CVM stage 5 or more (completion of active growth). Power analysis was performed using G*Power 3.1 (Heinrich-Heine, Düsseldorf, Germany).[23] Based on a previous study,[8] at least 12 patients per group were required to determine the difference between groups with an alpha error of 0.05 and a power of 0.8. Therefore, 17 patients were included in each group.

After fitting bands on the maxillary first premolars and molars of patients, an expander with a jackscrew (Dentaurum GmbH & Co. KG, Ispringen, Germany) was fabricated in a conventional way. Adolescents were instructed to activate the expander by two-quarter turns per day (0.50-mm widening per day), while adults were instructed to activate by two-quarter turns per day and reduce it to one-quarter turn per day (0.25-mm widening per day) after suture opening. Successful opening of the midpalatal suture was presumed by the appearance of midline diastema[6] and PA cephalogram at T2. The transverse maxillary deficiency was overcorrected until the palatal cusp tip of the maxillary molar contacted the buccal cusp tip of the mandibular molar just before coming in a scissor-bite relationship. During the expansion period, patients were recalled at one-week intervals to assess the progress. After the completion of expansion, the expander's jackscrew was fixed, and the expander was retained for more than two months.

An investigator blinded to patient information performed the measurements of dentoskeletal and soft tissue variables on cephalograms and frontal photographs. Dentoskeletal variables were assessed using the V-Ceph 8.0 software (Osstem Implant, Seoul, Korea) on PA and lateral cephalograms. Previously described soft tissue variables[16] were analyzed on frontal photographs using PACS viewer (Infinitt Healthcare, Seoul, Korea). All soft tissue variables were presented as a percentage of the interpupillary distance to nullify the effect of size difference in photographs. The landmarks, reference planes, measured variables, and abbreviations used in this study are presented in Figures 1-4. The dentoskeletal and soft tissue changes caused by RME within a group were analyzed. Additionally, the differences in dentoskeletal and soft tissue changes between the groups were compared after the amount of change was calculated by subtracting the values at T1 from those at T2.

To evaluate intra-examiner reliability, four patients were randomly selected from each group at fourweek intervals. When the same investigator repeated all the measurements, the intraclass correlation coefficients of all measurements exceeded 0.898. When the Dahlberg's formula was used, the error of the linear measurement was in the range of 0.32-0.47 mm and the angular measurement was 2.40°, respectively.

The chi-square test was performed to analyze the differences in sex distribution between the two groups. Because most variables did not satisfy normality of sample distribution as a result of the Shapiro-Wilk test, non-parametric analyses were used. The changes in the dentoskeletal and soft tissue variables within a group between T1 and T2 were analyzed using the Wilcoxon signed-rank test. The Mann-Whitney U test was used to analyze the differences in pretreatment age, expansion duration, post-expansion duration, and dentoskeletal and soft tissue changes between the two groups. To evaluate the relationship between transverse dentoskeletal changes and pretreatment age in the adolescent group, Spearman's correlation was calculated. All analyses were performed using IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). The significance level was set at an alpha value of 0.05.

RESULTS

Table 1 shows that there were no significant differences in sex distribution, expansion duration, and post-expansion duration between the two groups; but the pretreatment age differed significantly between the two groups. In addition, there was no significant difference between the two groups in pretreatment transverse dentoskeletal variables including nasal width, maxillary width, intermolar root and crown width, and intermolar angle; therefore both groups had similar transverse maxillary deficiency at T1 (data not shown).

Changes in transverse dentoskeletal variables are presented in Table 2. After maxillary expansion, the width of the maxillary arch at the crown of the maxillary first molar significantly increased in both groups (intermolar crown width), but the amount of expansion did not differ significantly between the two groups. The width of the maxillary arch at the root of the maxillary first molar also significantly increased in both groups (intermolar root width), but the increase in intermolar root width was significantly greater in the adolescent group than in the adult group. The intermolar angle was significantly increased after RME compared to pretreatment in the adult group only. Both groups exhibited a significant increase in maxillary width and nasal width, but the amount of expansion was greater in the adolescent group than in the adult group (Table 2).

Table 3 shows the changes in sagittal skeletal variables by RME. Both groups showed a significant increase in vertical dimension after RME (Frankfort-mandibular plane angle [FMA], sella-nasion to mandibular plane angle [SN-MP], and lower anterior facial height [LAFH]) without significant intergroup differences. The anteroposterior maxillary position did not change significantly (sella-nasion-A point [SNA], and A point to nasion perpendicular [A to N perp]) in either group; however, the mandible shifted posteriorly after treatment in the adult group only (sella-nasion-B point [SNB], A point-nasion-B point [ANB], and pogonion to nasion perpendicular [Pog to N perp]), leading to significant differences in mandibular position between the two groups (SNB, ANB, and Pog to N perp) (Table 3).

The changes in soft tissue variables following RME are presented in Table 4. Both groups showed a significant increase in alar width after RME; however, there was no significant difference in alar width change between the two groups. The vertical soft tissue variables including nose length, upper lip length, and lip chin length did not change significantly in either group after RME, and these changes were not significantly different between the groups (Table 4).

The analysis of the relationship between transverse dentoskeletal changes and pretreatment age in the adolescent group showed no statistically significant variables (Table 5).

DISCUSSION

Several studies have reported successful expansion of the maxilla in adults; however, dentoskeletal changes after RME are not fully understood because the expansion was measured on plaster models.[8,19] In addition, few studies have investigated soft tissue changes after conventional RME in adults. Considering that the maturation of the midpalatal sutures is significantly influenced by aging, the dentoskeletal and soft tissue changes may be significantly different between growing and non-growing patients. In this study, age-related differences in dentoskeletal and soft tissue changes after conventional

RME using a tooth-borne expander were analyzed on PA and lateral cephalograms and frontal photographs.

In this study, there were no significant differences in the durations of expansion and post-expansion between the two groups (Table 1). In addition, conventional RME increased the width of the maxilla in the region of the maxillary first molar crown significantly by approximately 6 mm in both groups, and the amount of intermolar expansion was not significantly different between the two groups (intermolar crown width, Table 2). Considering a similar sex distribution, these results indicate that both groups had similar clinical conditions except for the pretreatment age (Table 1).

The effects of conventional RME on skeletal expansion in adults remain controversial. A previous study that analyzed plaster models[8] presumed that the expansion of the adult maxillary arch was caused by displacement of the alveolar process, and palatal splits rarely occur,[8] while another study that included the results of bone scintigraphy[24] reported that the midpalatal suture was opened after RME. In this study, significant increases in maxillary, nasal, and intermolar root widths were observed after conventional RME in the adult group (Table 2). This suggests that conventional RME may expand not only the alveolar process but also the maxillary basal bone in adults.

In both groups, the amount of expansion decreased from the maxillary first molar crown region to the nasal cavity (Table 2), leading to a triangular expansion in the frontal plane (Figure 5). However, there were significant differences in the expansion pattern superior the crown level between the two groups. Intermolar root width, maxillary width, and nasal width were increased to a lesser extent in the adult group than in the adolescent group (Table 2 and Figure 5). In addition, there was a significant difference in intermolar angle changes between the two groups. The amount of buccal tipping of the molar was significantly increased only in the adult group following conventional RME (intermolar angle, Table 2). These results indicate that skeletal expansion was greater in the adolescent group than in the adult group, despite a similar amount of expansion at the crown level. The smaller amount of skeletal expansion in the adult group compared to the adolescent group may be due to the increased resistance to expansion as ossification of the midpalatal and circummaxillary sutures progresses with aging.[6,7]

In this study, expansion schedule was different after suture opening. Before suture opening, adolescent and adult patients were instructed to activate the expander by two-quarter turns per day (0.50-mm widening per day). After suture opening, adolescents were still instructed to activate the expander by two-quarter turns per day, while adults were instructed to activate one-quarter turn per day (0.25-mm widening per day). As the expansion duration between the two groups was not significantly different (Table 1), it might be thought that more expansion was expected in the adolescent group than the adult group. However, there was no significant difference in the intermolar crown width increase between the two groups (Table 2). This is because there may be no significant difference in the amount of expansion after suture opening between two groups. The expander was used as a retainer prior to commencing the second phase treatment and there was no significant difference in the post-expansion duration between the two groups; therefore, there may be no significant difference in the magnitude of relapse between the two groups.

After RME, the vertical dimension was increased significantly (FMA, SN-MP, and LAFH) in both groups, without a significant intergroup difference (Table 3). In adolescent patients, a significant increase in vertical dimension after maxillary expansion has been reported to be associated with premature occlusal contacts.[1,15] As the maxillary buccal segments expand after RME, premature contacts may occur between the maxillary and mandibular posterior teeth, leading to an increase in LAFH and vertical dimension in both adolescent and adult groups. However, another study comparing the effects of conventional RME between adolescents and adults[8] reported that there was no change in the mandibular plane angle in both groups after maxillary expansion, but LAFH increased only in adolescents. The previous study[8] differs from our study in the design of the expander and the expansion protocol. In addition, since the records after the completion of fixed orthodontic treatment following maxillary expansion were evaluated in a previous study,[8] the effects of fixed orthodontic treatment may have been combined.

The anteroposterior changes in the mandibular position after RME differed significantly between the two groups. The anteroposterior position of the mandible was not significantly changed in the adolescent group, whereas in the adult group, significant backward displacement was evident (SNB, Pog to N perp, and ANB, Table 3). Although there was no significant difference between the two groups, the values of all vertical skeletal variables (FMA, SN-MP, and LAFH) were slightly higher in the adult group than in the adolescent group (Table 3). The significantly greater increase in the intermolar angle in the adult group (Table 2) may induce more severe premature contacts between the maxillary and mandibular molars, greater increase in the mandibular plane angle, and more backward displacement of the mandible in the adult group. On the contrary, more parallel dental expansion observed in the adolescent group than in the adult group (intermolar angle, Table 2) may have less influence on the anteroposterior position of the mandible.

The results of the present study showed that the anteroposterior position of the maxilla (SNA and A to N perp) was not significantly influenced by conventional RME in both the adolescent and adult groups (Table 3). This is consistent with the results of a previous study that showed the absence of any effect of maxillary expansion on the anteroposterior position of the maxilla.[25] However, it was suggested that in growing patients, RME may lead to forward displacement of the maxilla by affecting the circummaxillary suture.[26] Although some studies[1,27] have presented significant anterior movement of the maxilla after RME, the change was too small (less than 1 mm) to be clinically significant. Therefore, conventional RME may have a greater impact on the anteroposterior position of the mandible than on the maxilla.

Unlike the dentoskeletal changes, there were no significant differences in soft tissue changes between the two groups (Table 4). The alar width significantly increased following RME in both groups, but there was no significant difference between them (Table 4). Because the normal interpupillary distance is approximately 60 mm,[28] the increase in alar width by approximately 1–1.5% (Table 4) is less than 1 mm of actual increase, which may not be clinically relevant.

Soft tissue nose length and other vertical soft tissue variables (upper lip length and lip chin length) did not show statistically significant changes after RME in either group despite the increase in the skeletal vertical dimension (Table 4). The skeletal vertical changes after RME may be too small to induce soft tissue changes.

The pretreatment age of adolescent patients included in this study ranged from 11.2 years to 14.6 years. Considering that the ossification of the midpalatal suture occurs even in adolescents aged 11 years,[29] a significant difference in the amounts of skeletal expansion was expected within the adolescent group. However, there was no statistically significant correlation between any transverse dentoskeletal changes and pretreatment age (Table 5), indicating that age < 15 years did not affect transverse dentoskeletal changes caused by RME in the adolescent group. This may justify our categorization of patients aged 11–14 years into one group.

Although there are concerns about the periodontal side effects such as gingival recession or bony dehiscence of conventional RME in adults,[8] no periodontal side effects were identified in the patients included in this study. This is probably because periodontally compromised patients were not included in either group.

Our study showed that the amount of skeletal expansion was greater in the adolescent group than the adult group. Skeletal expansion of about 2.7 mm and 1.3 mm were observed in the adolescent and adult groups, respectively, after dental expansion of about 6.0 mm. For a definite skeletal expansion in adults, procedures such as SARME[9] or expansion using skeletal anchorage,[10,11] have been introduced. In particular, a recent meta-analysis demonstrated that mini-implant assisted RME can induce skeletal expansion of average 2.3 mm with dental expansion of about 6.6 mm in the adults.[30] This indicates that similar amount of skeletal expansion can be expected in the adult group as much as the adolescent group when using skeletal anchorage. However, expansion using skeletal anchorage or SARME may be difficult to be performed in patients who do not want surgery or are concerned about additional costs. The results of our study suggest that conventional RME may be a viable suboptimal option for adult patients who cannot undergo invasive expansion procedures. Instead, it is necessary to consider overexpansion or compensation by adjusting the inclination of the posterior teeth because conventional RME in adults leads to more dental effects than in adolescents.

In this study, patients were only observed for a short period (average post-expansion period of 3 months). Additional dentoskeletal and soft tissue changes may occur during a retention period of more than one year. In addition, only two-dimensional images such as cephalograms and frontal photographs were used in this study; therefore, three-dimensional volume changes could not be measured. Since a cephalogram projects a three-dimensional structure onto a two-dimensional plane, the image may become unclear due to the overlap of structures and distortion. The frontal photograph can also cause unwanted distortion depending on the shooting conditions. Therefore, a long-term study utilizing three-dimensional modalities such as computed tomography and stereophotogrammetry is needed to clarify the differences in dentoskeletal and soft tissue changes following conventional RME according to age.

CONCLUSION

This study indicates that conventional RME may induce greater skeletal expansion in growing patients than non-growing patients without significant difference in soft tissue changes between the patients.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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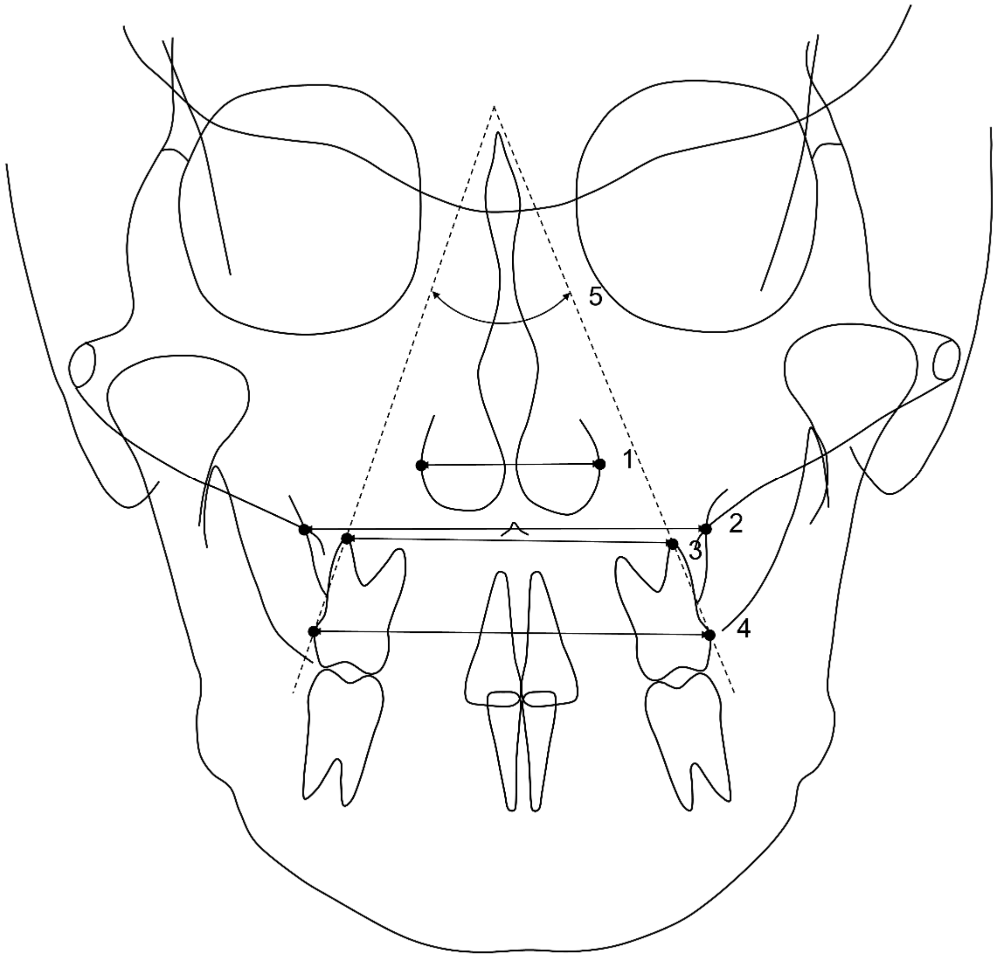

Figure 1. Transverse dentoskeletal variables assessed in the posteroanterior cephalogram. 1, nasal width: the longest distance between left and right lateral bony walls of the nasal cavity; 2, maxillary width: the distance between left and right jugal points (intersection of the maxillary tuberosity and outline of the zygomatic buttress); 3, intermolar root width: the distance between left and right buccal root tips of the maxillary first molars; 4, intermolar crown width: the distance between the most lateral points on the buccal surfaces of the maxillary first molar crowns. 5, intermolar angle: the angle between the lines connecting the most lateral point of the crown to the buccal root tip of both maxillary first molars.

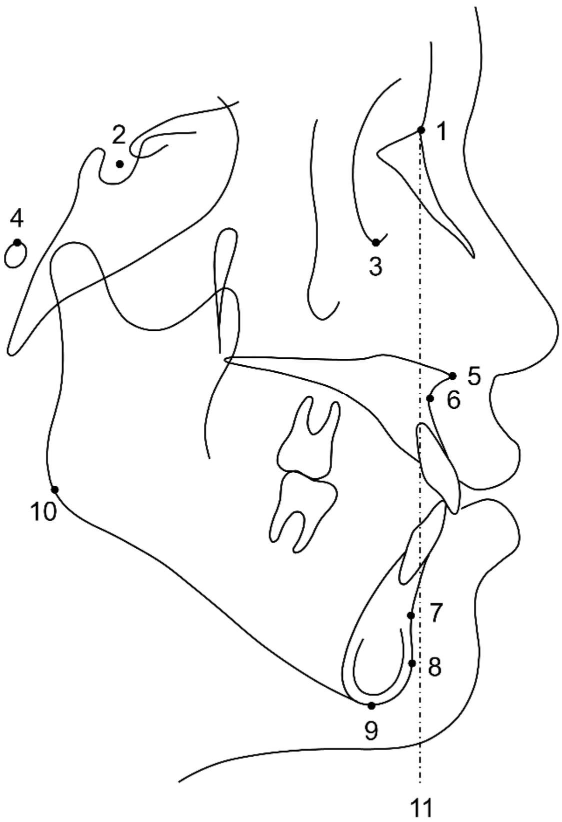

Figure 2. Sagittal landmarks and the vertical reference plane assessed in the lateral cephalogram. 1, nasion; 2, sella; 3, orbitale; 4, porion; 5, anterior nasal spine; 6, A point; 7, B point; 8, pogonion; 9, menton; 10, gonion; 11, nasion perpendicular plane: a line perpendicular to the Frankfort horizontal plane and passing through the nasion.

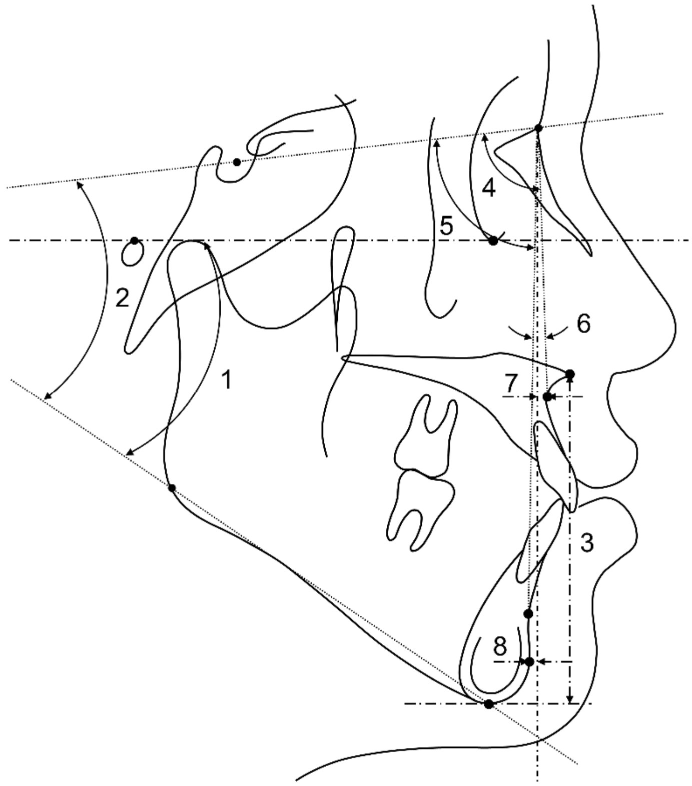

Figure 3. Sagittal skeletal variables assessed in the lateral cephalogram. 1, Frankfort-mandibular plane angle (FMA); 2, sella-nasion to mandibular plane angle (SN-MP); 3, lower anterior facial height (LAFH, distance between the anterior nasal spine and menton parallel to the nasion perpendicular); 4. sella-nasion-A point (SNA); 5, sella-nasion-B point (SNB); 6, A point-nasion-B point (ANB); 7, A point to nasion perpendicular (A to N perp); 8, pogonion to nasion perpendicular (Pog to N perp); A to N perp, Pog to N perp, and LAFH are linear measurements, and the remaining variables are angular measurements.

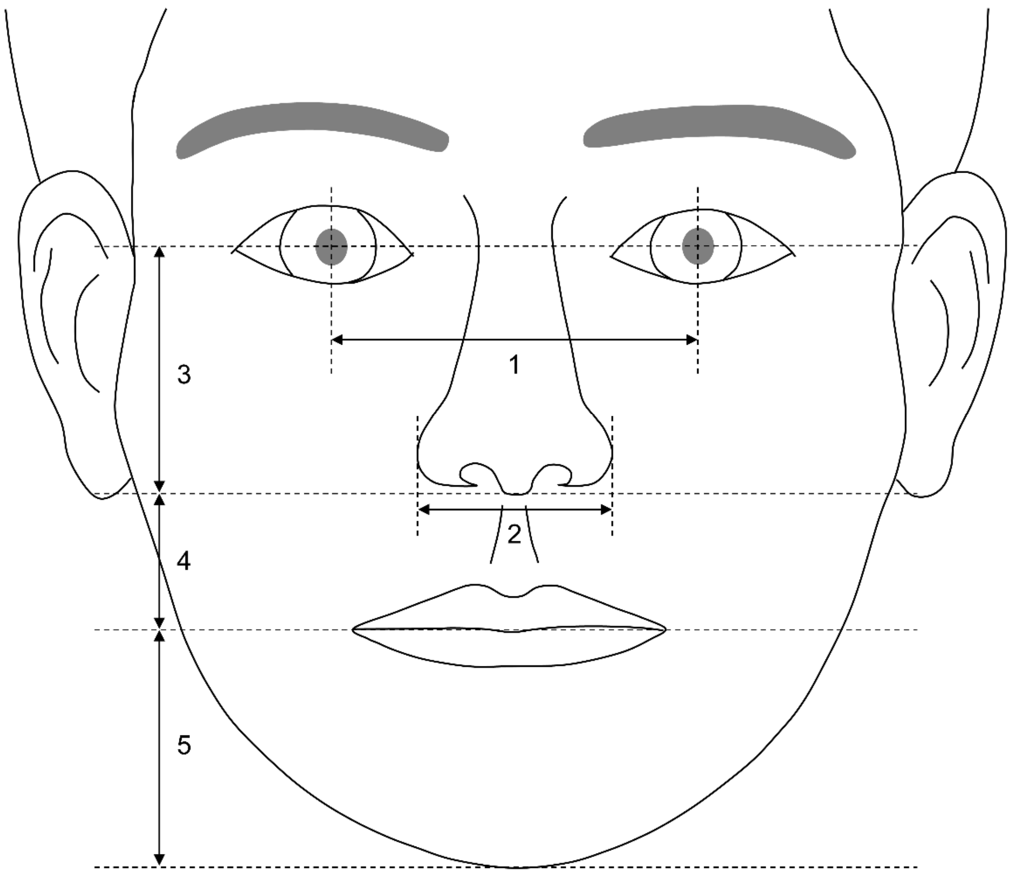

Figure 4. Soft tissue variables assessed in the frontal photograph[16]. 1, interpupillary distance: the distance between left and right pupils; 2, alar width: distance between left and right alars. 3, nose length: distance between the midpoint of the pupils and subnasale; 4, upper lip length: distance between subnasale and stomion; 5, lip chin length: distance between stomion and menton. Vertical measurements including nose length, upper lip length, and lip chin length were measured as a distance parallel to the vertical bisector of the pupils.

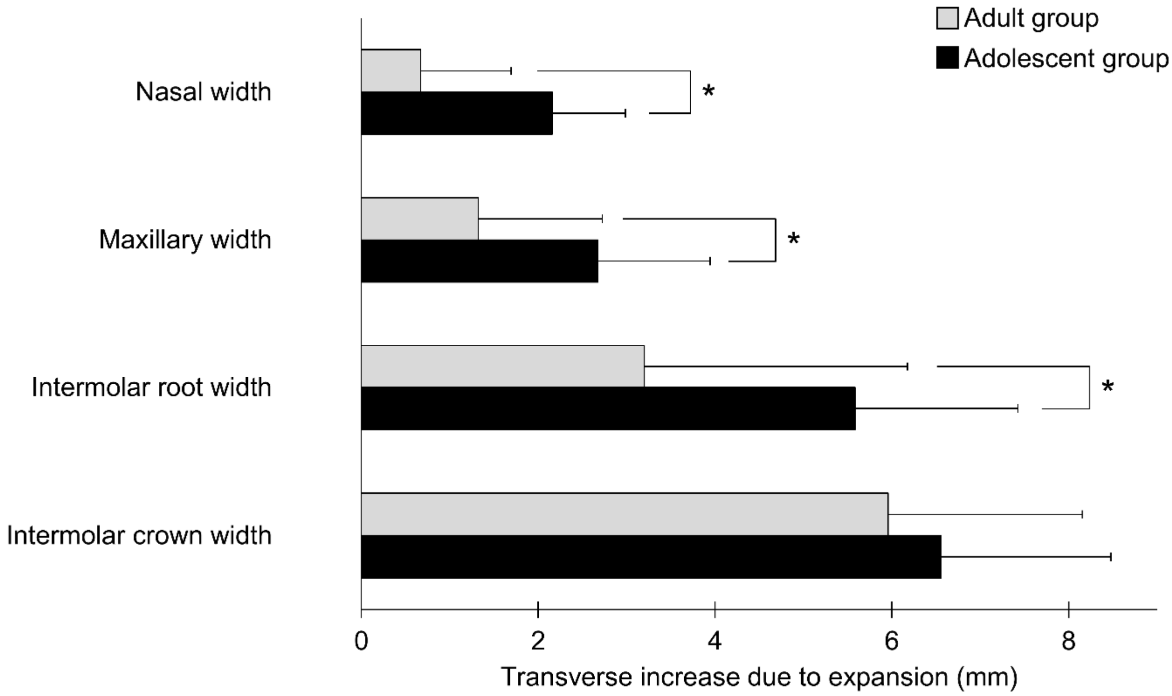

Figure 5. Differences in transverse dentoskeletal variable changes following rapid maxillary expansion between the groups; *, statistically significant difference ($p < 0.05$)

Tables

Table 1. Demographic data of patients

Demographics	Adolescent group	Adult group	Significance
Subjects (% of total)	17 (50.0)	17 (50.0)	
Sex (% of group)			
Male	6 (35.3)	7 (41.2)	0.724†
Female	11 (64.7)	10 (58.8)	
Pretreatment age (years)	12.48 ± 1.18	20.99 ± 2.49	< 0.001‡
Expansion duration (days)	23.24 ± 9.10	24.12 ± 8.02	0.586‡
Post-expansion duration (months)	3.31 ± 0.62	2.97 ± 0.55	0.182‡

†The chi-square test was used to analyze the significance of difference between the groups.

‡The Mann-Whitney U test was used to analyze the significance of differences between the groups.

Data are either presented as n (%) or mean ± standard deviation.

Table 2. Changes in the transverse dentoskeletal variables after rapid maxillary expansion (RME) and differences in the changes between the groups

Transverse dentoskeletal variables	Adolescent group				Adult group				Intergroup ***p*-value**‡
	T1	T2	Change	Intragroup *p*-value†	T1	T2	Change	Intragroup *p*-value†	
Nasal width (mm)	32.74 ± 3.45	34.90 ± 3.89	2.15 ± 0.83	< 0.001	33.88 ± 3.20	34.55 ± 3.00	0.67 ± 1.02	0.028	< 0.001
Maxillary width (mm)	68.47 ± 3.82	71.14 ± 4.17	2.67 ± 1.27	< 0.001	65.82 ± 3.59	67.14 ± 3.83	1.32 ± 1.41	0.001	0.002
Intermolar root width (mm)	51.27 ± 3.48	56.86 ± 4.04	5.58 ± 1.84	< 0.001	49.79 ± 2.83	52.99 ± 3.01	3.20 ± 2.98	0.001	0.006
Intermolar crown width (mm)	59.18 ± 3.61	65.73 ± 4.43	6.55 ± 1.92	0.002	58.83 ± 3.03	64.79 ± 3.22	5.96 ± 2.20	< 0.001	0.318
Intermolar angle (°)	35.61 ± 7.70	38.86 ± 8.00	3.25 ± 7.41	0.102	37.18 ± 8.88	47.49 ± 10.18	10.31 ± 12.06	0.006	0.040

T1, pretreatment; T2, after expansion (at least 2 months after cessation of expansion); Change, change in each variable after RME.

†The Wilcoxon signed-rank test was used to analyze the significance of changes in the variables within a group.

‡The Mann-Whitney U test was used to analyze the significance of differences in changes between the groups.

Data are presented as mean ± standard deviation.

Table 3. Changes in sagittal skeletal variables following rapid maxillary expansion (RME) and differences in the changes between the groups

Sagittal skeletal variables	Adolescent group				Adult group				Intergroup ***p*-value**‡
	T1	T2	Change	Intragroup *p*-value†	T1	T2	Change	Intragroup *p*-value†	
Vertical skeletal variables									
FMA (°)	28.37 ± 4.31	29.16 ± 4.10	0.79 ± 0.69	0.001	29.96 ± 4.39	31.33 ± 4.66	1.36 ± 0.96	0.001	0.076
SN-MP (°)	38.24 ± 4.39	38.97 ± 4.33	0.73 ± 0.79	0.004	40.18 ± 5.52	41.33 ± 5.68	1.15 ± 0.97	0.001	0.228
LAFH (mm)	71.88 ± 5.63	72.90 ± 5.79	1.03 ± 1.32	0.002	77.37 ± 7.77	79.01 ± 7.50	1.64 ± 1.26	0.001	0.102
Anteroposterior skeletal variables									
SNA (°)	80.59 ± 3.20	80.82 ± 3.50	0.23 ± 0.86	0.368	78.01 ± 3.38	78.76 ± 2.98	0.75 ± 1.50	0.084	0.209
SNB (°)	76.77 ± 3.91	76.82 ± 3.93	0.06 ± 0.75	0.356	77.25 ± 3.64	76.51 ± 3.84	-0.75 ± 1.01	0.016	0.024
ANB (°)	3.82 ± 2.63	4.00 ± 2.47	0.17 ± 0.88	0.523	0.76 ± 1.97	2.26 ± 2.34	1.50 ± 1.50	0.001	0.004
A to N perp (mm)	0.50 ± 3.60	0.71 ± 3.87	0.20 ± 1.17	0.356	-2.11 ± 3.18	-1.51 ± 2.82	0.60 ± 1.51	0.098	0.783
Pog to N perp (mm)	-6.64 ± 7.68	-6.70 ± 8.05	-0.06 ± 1.27	0.925	-5.56 ± 7.07	-8.05 ± 7.79	-2.48 ± 1.69	0.001	< 0.001

T1, pretreatment; T2, after expansion (at least 2 months after cessation of expansion); Change, change in each variable following RME; FMA, Frankfort-mandibular plane angle; SN-MP, sella-nasion to mandibular plane angle; LAFH, lower anterior facial height; SNA, sella-nasion-A point; SNB, sella-nasion-B point; ANB, A point-nasion-B point; A to N perp, A point to nasion perpendicular; Pog to N perp, pogonion to nasion perpendicular.

†The Wilcoxon signed rank test was used to analyze the significance of changes in the variables within a group.

‡The Mann-Whitney U test was used to analyze the significance of differences in changes between the groups.

Data are presented as mean ± standard deviation.

Table 4. Changes in the soft tissue variables following rapid maxillary expansion (RME) and differences in the changes between the groups

Soft tissue variables	**Adolescent group**				**Adult group**				**Intergroup**
	T1	T2	Change	Intragroup *p*-value†	T1	T2	Change	Intragroup *p*-value†	***p*-value‡**
Alar width (%)	60.07 ± 3.91	61.71 ± 4.29	1.64 ± 1.45	0.001	58.84 ± 4.22	59.82 ± 4.00	0.98 ± 1.78	0.022	0.344
Nose length (%)	78.16 ± 4.37	78.32 ± 4.26	0.16 ± 2.95	0.981	79.87 ± 5.30	79.68 ± 5.87	-0.19 ± 2.25	0.831	0.986
Upper lip length (%)	38.07 ± 4.54	37.89 ± 4.64	-0.18 ± 1.79	0.868	36.47 ± 3.42	37.41 ± 3.19	0.94 ± 1.96	0.055	0.153
Lip chin length (%)	73.61 ± 8.12	73.79 ± 5.76	0.18 ± 4.63	0.435	74.70 ± 4.97	75.82 ± 5.23	1.12 ± 3.18	0.163	0.221

T1, pretreatment; T2, after expansion (at least 2 months after cessation of expansion); Change, change in each variable following RME.

†The Wilcoxon signed rank test was used to analyze the significance of changes in the variables within a group.

‡The Mann-Whitney U test was used to analyze the significance of differences in changes between the groups.

Data are presented as mean ± standard deviation.

Table 5. Relationship between changes in transverse dentoskeletal variables and pretreatment age in the adolescent group

Transverse dentoskeletal changes	**Pretreatment age**	
	Correlation	Significance
Nasal width	-0.189	0.468
Maxillary width	-0.082	0.754
Intermolar root width	0.031	0.907
Intermolar crown width	-0.103	0.694
Intermolar angle	-0.078	0.765

Spearman correlation was calculated.