ORIGINAL ARTICLE

AJO-DO

Skeletal and dental changes after maxillary expansion with a bone-borne appliance in young and late adolescent patients

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Introduction: Rapid palatal expansion is a common therapy during orthodontic treatment and could be a preliminary step for correcting different malocclusions; furthermore, this treatment could be necessary at any age. Different anchorage approaches have been proposed to obtain an effective skeletal result, although every device produces both dental and skeletal effects. This study aimed to compare the dentoskeletal effects of a bone-borne palatal expander considering 2 groups of patients of different ages. **Methods:** Twenty-four patients consecutively treated were included in the study; patients were divided into 2 groups according to their age: group 1 with age ≤16 years and group 2 patients >16 years. All patients had a preexpansion cone-beam computed tomography scan; a second scan was required at the end of activations. All patients received a bone-borne appliance anchored on 4 miniscrews. **Results:** Significant intragroup differences were found for maxillary width and dental diameters. No significant differences were found between groups with regard to longitudinal changes, except for the maxillary right plane. **Conclusions:** The use of bone-borne maxillary expansion was effective in generating palatal widening both in growing and young adult patients. No significant skeletal or dental differences were found between groups. (Am J Orthod Dentofacial Orthop 2021;■:e1-e13)

Maxillary transversal deficiency is a common problem affecting patients within various individual characteristics[1-4]; in fact, a maxillary expansion can be indicated for patients with skeletal Class I, Class II, and Class III malocclusion, and every time the palatal expansion becomes a therapeutic objective, it is well known that such an expansion affects both dental and skeletal components.[5-7] The standard approach to setting up an orthodontic treatment starts from diagnosis, and through a consistent analysis of treatment objectives, force, and anchorage evaluations lead to the appliance design to obtain these results.

Maxillary expansion with dental support in growing patients can achieve both skeletal and dental movement,[8-10] whereas the use of such an appliance in adult patients results in prevalent dental shifting. To avoid these undesired side effects, or alternatively, when a skeletal expansion is needed, maxillary expanders anchored on 2 or 4 miniscrews have been proposed.[11] Miniscrews in the palate are considered efficient and safe support in terms of anchorage and success rate.[12-14]

Miniscrew-supported expansion approaches can include a teeth-bone anchored device (hybrid),[15,16] or a completely skeletal anchorage without dental support (bone-borne).[17,18] Recently, different studies have been published on the potential of such an approach to obtain substantial skeletal effects in adult patients, but generally, these publications are limited to case reports or series.[19-22]

A palatine suture maturation criterion has been proposed as a staging method to avoid the side effects of

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rapid maxillary expansion failure or unnecessary surgically assisted rapid maxillary expansion,[23] and correspondence with cervical vertebral maturation (CVM) stages was investigated as well,[24] showing that earlier CVM stages (cervical stage [CS] 1, CS 2, and CS 3) can be used as reliable indicators for the midpalatal maturational stages A, B, and C, whereas for postpubertal patients (CS 4 and CS 5) an individual assessment of the midpalatal suture with cone-beam computed tomography (CBCT) should be undertaken because fusion of the midpalatal suture already could have occurred partially or totally (stages D and E in midpalatal suture maturation). In the same study, it was found that the CVM method and chronological age were almost equally effective in predicting the midpalatal sutural stages, with the CVM method performing slightly better than chronological age.

The prediction capability of the palatal suture classification for dental and skeletal changes has been recently questioned, and a reliability testing in disagreement with that of the original study was reported. Moreover, the suture evaluation methodology was described as nonintuitive and influenced by the degree of postacquisition image sharpness and clarity.[25]

There are different possible advantages to using a bone-borne device, such as the reduction of root resorption, bony dehiscence, and more physiological suture expansion, as Mosleh et al[16] recently stated.

The present study aimed to compare the dental and skeletal effects of a bone-borne expander applied in 2 groups of consecutively treated patients, divided by chronological age.

MATERIAL AND METHODS

This was a retrospective study of consecutively treated patients. The sample included a total of 24 patients, 12 males and 12 females. Patients were divided into 2 groups according to age: group 1 with age ≤16 years and group 2 with age >16 years. According to the age distribution, there were 11 patients in group 1 and 13 patients in group 2. The mean age was 13.9 (standard deviation [SD]) and 20.4 (SD) for groups 1 and 2, respectively.

Patients were treated from April 2018 to April 2020. Ethical committee approval was obtained by Genova University. The inclusion criteria were as follows: no systemic disease, no previous orthodontic treatment, no alteration of bone metabolism or use of drugs altering the bone metabolism, transverse maxillary deficiency with unilateral or bilateral posterior crossbite (10 unilateral crossbite, 6 bilateral crossbite, and 8 maxillary transversal deficiency without dental crossbite), permanent dentition including second molar eruption, no surgical or other treatment that might influence the rapid maxillary expansion outcome during the expansion period.

All patients underwent an orthodontic therapy in which the first step was a maxillary expansion, and a preinsertion CBCT scan was obtained. A second CBCT was required at the end of the activations.

To achieve the best miniscrew position in terms of bone quantity and considering the device design, digital insertion planning was performed. Intraoral scans were superimposed with the initial CBCT using a specific Dolphin software module (3-dimensional module; Dolphin Imaging & Management Solutions, Chatsworth, Calif), overlapping the model's details to the dental-skeletal profile of the CBCT itself. The device used for the expansion includes 4 miniscrews: 2 in the anterior area of the palate, at the third ruga level, and 2 other miniscrews inserted between the second premolar and the first molar area, where the root distance is more favorable, approximately at a distance of 6-8 mm from the alveolar crest (Fig 1).

If anatomic conditions prevented such an ideal position, an alternative extraradicular site was selected at the level of the second premolar between the nasal and sinus cortical.

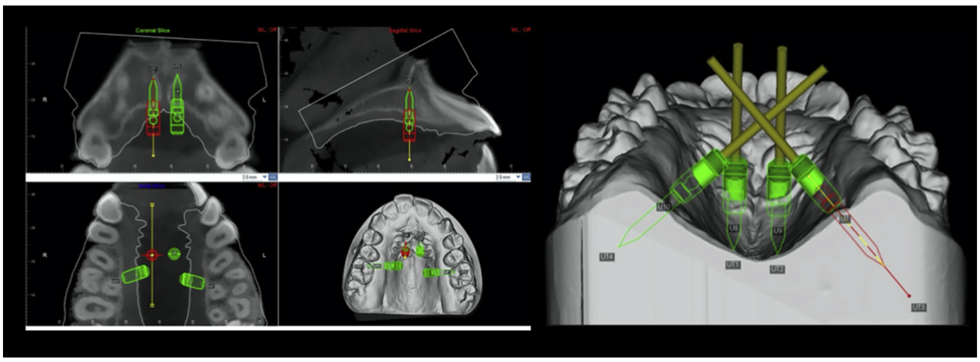

Fig 1. Digital insertion planning.

All virtual insertion planning had the objective of obtaining a bicorticalism, exploiting the greatest bone availability, thus choosing the corresponding correct miniscrew length. Miniscrews used in the present study varied between 9 mm and 15 mm in length, while the diameter was 2 mm for all patients (Spider Screw; HDC, Thiene, Italy).

For each patient, 2 insertion guides were designed and 3-dimensionally printed (Form 2; Formlabs, Somerville, Mass), including 2 sleeves each in a cross position, each guide allowing the insertion of 2 miniscrews (Fig 2).

After a chlorhexidine gluconate oral rinse, a preliminary guide fitting check was performed, and thereafter, local anesthesia was applied in correspondence with the palatal insertion sites.

To improve procedure precision and surgery ergonomics, guides were fixed to the teeth using a fluid resin (trial gel; Dentsply GAC International, Islandia, NY); all the miniscrew insertions were preceded by pilot drill use for a cortical perforation. A dedicated pickup instrument was used to attain the correct depth stop indication planned with the digital insertion procedure. All screws were inserted with an insertion torque that was comprised between 15 and 30 Ncm using a low-speed handpiece. After the guide removal, the palatal surface was cleaned with a physiological solution, and the bone-borne expander was inserted. The insertion of a 4 miniscrew expander device can be difficult because of the different screw axis insertions (3 different axes) and because of the undercut generated by the posterior screws; the bone-borne expander was set with 0.8 mm expansion already inserted. The device was then completely closed, fit to the anterior screws, and reactivated until a complete passiveness of the structure was attained on all the screws. Thereafter, the fixation screws were screwed to the skeletal anchorage devices.

The activation protocol was 2 turns per day until reaching the desired expansion. The device remained for another 12 months after the end of the expansion for all patients (Fig 3).

Data were analyzed by ITK-SNAP. To set an identical reference plane in the T1 and T2 stages, the CBCT images were oriented along the palatal suture (x-plane), parallel to the palatal plane (y-plane), and tangent to the nasal floor (z-plane).

The size of the CBCT (the number of *cuts* on the x-, y-, z-axes) and the volume of the voxels were changed to obtain isotropic voxels in all the examined CBCTs. The SlicerCMF4-1 program was used, and data were loaded in the *Guys Imaging Processing Laboratory* format. Using the downsize image–spacing function, voxels were set to the same size in the x-, y-, and z-axes.

All measurements were performed on the maxillary first premolar and molar area. Data acquisition and analysis were blinded with respect to the groups' age.

Maxillary width was evaluated with linear measurements at different levels: nasal floor and hard palate (Fig 4, *A*).

Nasal floor (NF) indicates the maxillary width tangent to the nasal floor at its most inferior level.

Hard palate (HP) indicates the maxillary width tangent to the hard palate at the most inferior level.

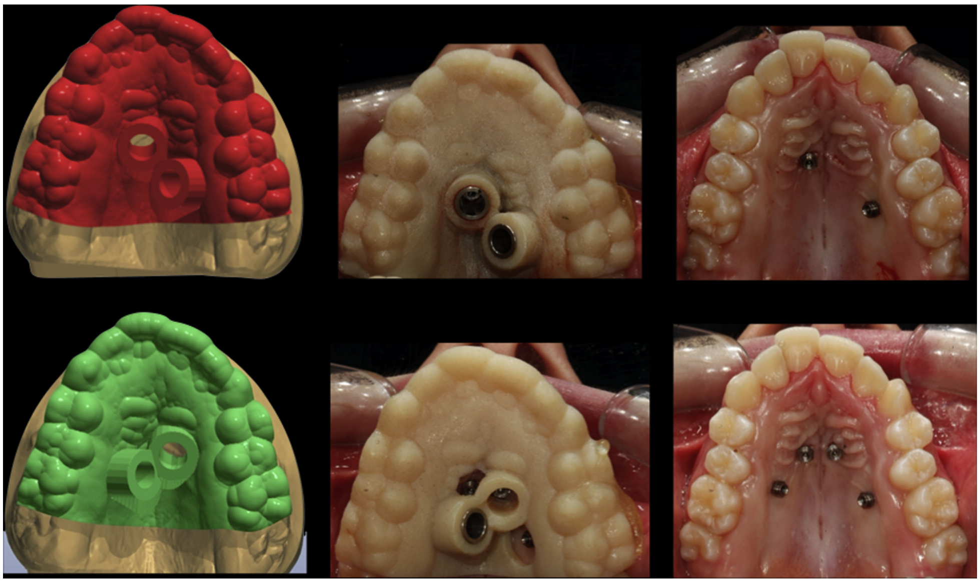

Fig 2. 3-dimensional digital planned guide used for miniscrews insertion.

Fig 3. A clinical patient before and after expansion.

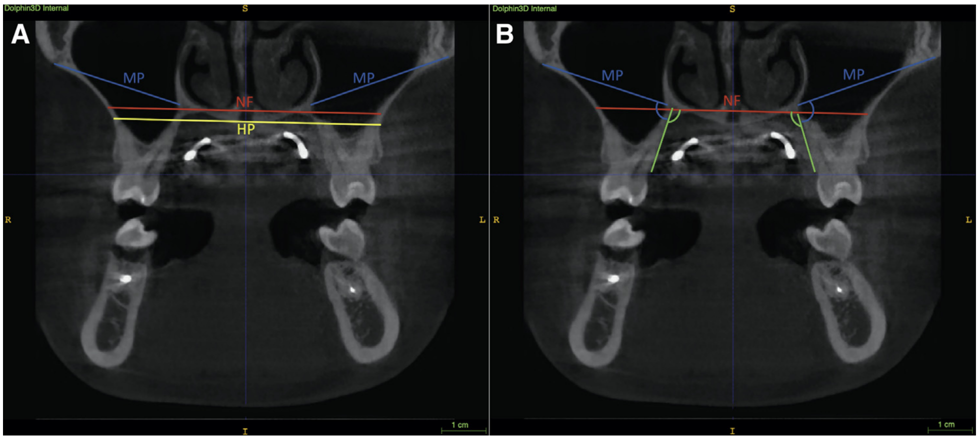

Fig 4. **A,** Maxillary width measurements. NF indicates the maxillary width tangent to the nasal floor at its most inferior level. Hard palate (HP) indicates the maxillary width tangent to the hard palate at the most inferior level. MP indicates a segment connecting the most lateral point of the maxillary bone and the point where the cortex of the bone that forms the floor of the nasal cavities meets the maxillary sinus. **B,** Alveolar inclination. The inclination of the alveolar process was evaluated by observing the angle between the tangent to the palatal side of alveolar bone and NF plane (medial angle), MP plane (lateral angle).

Maxillary plane (MP) indicates a segment connecting the most lateral point of the maxillary bone and the point where the cortex of the bone that forms the floor of the nasal cavities meets the maxillary sinus.

All evaluations were carried out at the height of the furcation of the first molar in the coronal slice.

The inclination of the alveolar process was evaluated observing the angle between the tangent to the palatal side of alveolar bone, NF plane (medial angle), and MP plane (lateral angle; Fig 4, *B*).

The tooth inclination (Fig 5, *A*) was evaluated by analyzing the angle formed by the dental axis (line passing through the palatal mesial cusp and palatal root apex), NF plane (medial angle), and MP plane (lateral angle).

The vertical dental height was evaluated by measuring the distance between the MP and MV cusps and the NF plane (Fig 5, *B*).

Periodontal evaluations and buccal bone width on both sides were evaluated on the coronal slices at the height of the MV root of the first molar (Fig 6, *A*):

Taking a 0.3 mm apical from the cementoenamel junction (CEJ) on MV root and calculating the distance from the vestibular alveolar bone at this level.

Taking a 0.6 mm apical from the CEJ on MV root and calculating the distance from the vestibular alveolar bone at this level.

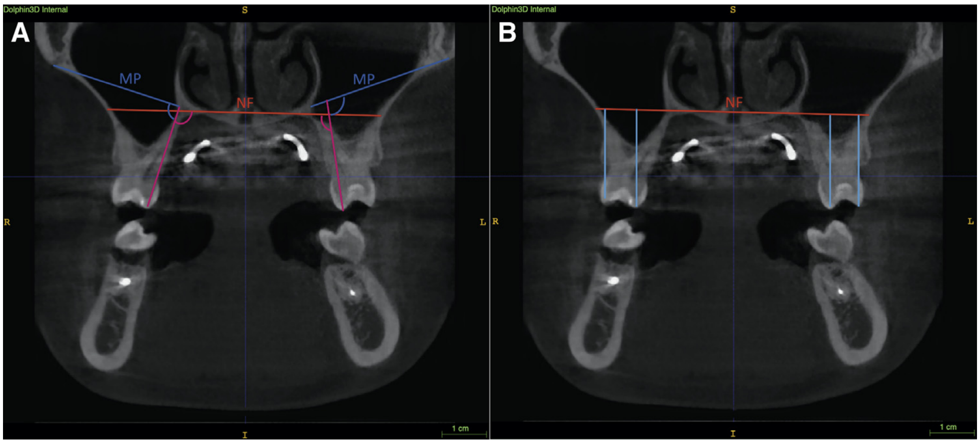

Fig 5. A, Tooth inclination. The measurement was performed by observing the angle formed by the dental axis (line passing through the palatal mesial cusp and palatal root apex) and NF plan (medial angle) or MP plan (lateral angle). **B,** Vertical dental height. The vertical dental height was evaluated by measuring the distance between the MP and mesio-vestibular (MV) cusps and the NF plane.

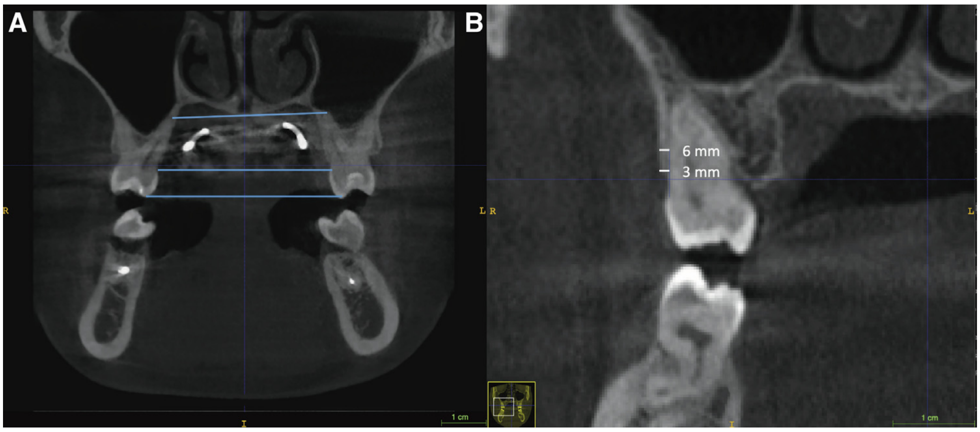

Fig 6. A, Buccal bone width was measured by taking a 0.3 mm apical from the CEJ on MV root and calculating the distance from the vestibular alveolar bone at this level. Then taking a 0.6 mm apical from the CEJ on MV root and calculating the distance from the vestibular alveolar bone at this level. **B,** Transverse distance. It was evaluated by measuring the distance between palatal root apices, palatal root CEJ, and palatal cusps.

The transverse dental distance was measured at the tooth apex, CEJ, and crown level (Fig 6, *B*). The transverse distance was evaluated, measuring the distance (1) between palatal root apices, (2) between palatal root CEJ, and (3) between palatal cusps.

These measures were also checked in the axial slices. All evaluations were carried out at the height of the furcation of the first molar in the coronal slice. The bispinal distances were measured in axial view, only at T1 (Fig 7).

Anterior: at the most anterior point where the cortices are visible; half: between 5′ and 6′; posterior: in the most posterior point where the cortices are visible.

Statistical analysis

Continuous variables are presented as means ± SD and medians with interquartile range, whereas categorical variables are given as a number and/or percentage of subjects. All the baseline differences between groups were tested by the Student *t* test or Mann-Whitney U test. Intragroup differences over time were tested by the paired *t* test or Wilcoxon signed rank test. To investigate the association of differences over time with groups, the Student *t* test and Mann-Whitney U test were performed again. Differences with a $P < 0.05$ were selected as significant.

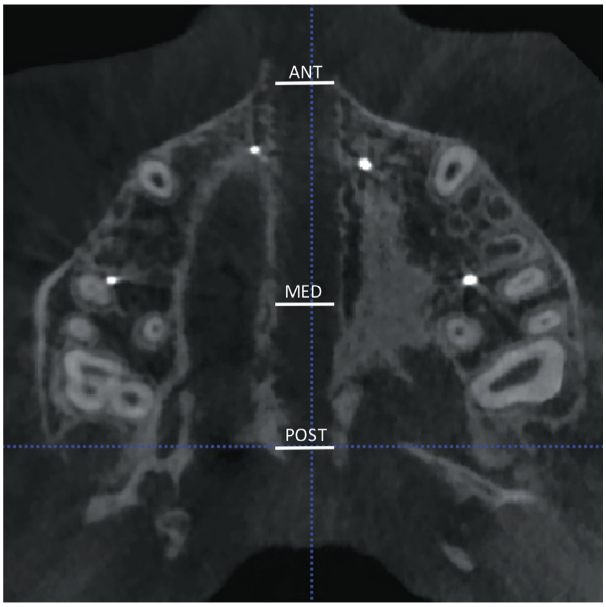

Fig 7. Bispinal distance. It was measured only at T1. *ANT*, the most anterior point where the cortices are visible; *MED*, the median is between 5' and 6'; *POST,* the most posterior point where the cortices are visible.

Table I. Demographic and clinical characteristics of groups

XXX	*Group 1 (≤16 y)*	*Group 2 (>16 y)*	*Row total*
No. of patients	11	13	24
Sex			
Female	7	5	12
Male	4	8	12
Age (y)	13.96 ± 1.82	20.43 ± 3.81	17.47 ± 4.55
CVM stage			
CS 2	2	0	2
CS 3	1	0	1
CS 4	7	1	8
CS 5	1	11	12
CS 6	0	1	1
Palatine suture maturation			
Stage B	1	0	1
Stage C	10	5	15
Stage D	0	8	8
Mean screw nominal expansion (mm)	8.56 ± 1.67	7.78 ± 3.73	8.12 ± 2.98
Activation days	20.40 ± 3.63	19.73 ± 3.41	20.05 ± 3.44

Data were acquired and analyzed in the R (version 3.4.4; The R foundation, The R project for statistical computing. http://www-R-project.org) software environment.[23,26]

RESULTS

The sample included in the final analysis comprised 22 patients. The mean age was 17.50 years. The minimum age was 11 years, and the maximum age was 29 years. The demographic and clinical characteristics of groups are shown in Table I.

The mean amount of activation of the expansion screw was 8.12 ± 2.98 mm (range, 0-10.30 mm). And the duration of the expansion ranged from 12 to 24 days.

Two patients (17 and 18 years old) out of 24 did not show any suture expansion, indicating a success rate of 91.7%. After a week of activations, miniscrews and expansions screws showed a migration into palatal mucosa generating decubitus, and the removal of the appliance was consequently necessary.

Differences analysis at baseline between groups are shown in Table II; no significant differences were found except for the transverse distance of the first molar at the apex level (P = 0.007). Significant intragroup differences over time were found for the tooth axis to NF and the vertical dental height at the vestibular cusp of the right first molar in group B (P = 0.028 and P = 0.029, respectively) and for buccal bone width at 6 mm of the left first molar in group B (P = 0.032). Significant differences over time were found in each group for maxillary width and dental diameters ($P < 0.01$ in all patients for both groups; Table III).

No significant differences were found between groups with regard to longitudinal changes, except for the maxillary right plane (P = 0.035; Table III; Figs 8-10).

Intraclass correlation coefficient values were evaluated for all the measurements, and the values ranged between 0.962 and 0.998; the CVM stage and palatine suture maturation as well were tested with Kappa with results of 0.68 and 0.45 (a substantial and moderate agreement, respectively).

DISCUSSION

This study compared the effects of the same bone-borne approach in 2 different patient groups divided by chronological age. Patients with CVM stages from CS 2 to CS 5 were labeled as suture maturation stage C in the early group, whereas 5 out of 12 (41.7%) patients with CVM stages CS 5-CS 6 in the late group revealed a lower suture maturation stage (stage C) than the one predicted by the criterion of skeletal maturity for the assessment of midpalatal suture maturation.[24] This

Table II. Baseline characteristics of the whole population (N = 22)

XXX	*Total*	*Group 1 (≤16 y)*	*Group 2 (>16 y)*	P *value*
N	22	11	11	
Maxillary width, mm				
NF	64.15 ± 6.41	64.93 ± 7.74	63.37 ± 5.00	0.581
HP	60.99 ± 5.52	61.83 ± 6.84	60.15 ± 3.95	0.490
MP				
Right	26.60 ± 2.76	27.27 ± 3.02	25.87 ± 2.38	0.257
Left	26.56 ± 3.35	26.95 ± 3.97	26.12 ± 2.67	0.582
Alveolar inclination, °				
to NF, right	103.26 ± 4.86	104.25 ± 4.58	102.27 ± 5.15	0.354
to NF, left	104.88 ± 5.87	106.95 ± 6.12	102.80 ± 5.04	0.098
to MP, right	82.19 ± 6.74	82.02 ± 6.02	82.38 ± 7.78	0.906
to MP, left	79.00 ± 5.96	77.80 ± 6.04	80.31 ± 5.90	0.348
Tooth axis, °				
to NF, right	97.60 (95.90-102.50)	100.85 (95.20-109.40)	96.10 (75.10-106.20)	0.078
to NF, left	99.25 ± 6.80	101.44 ± 7.78	97.26 ± 5.38	0.166
to MP, right	85.85 ± 5.63	83.84 ± 6.50	88.07 ± 3.61	0.085
to MP, left	85.29 ± 8.49	82.25 ± 6.78	88.64 ± 9.24	0.085
Vertical dental height, mm				
Vestibular cusp, right	22.50 ± 2.12	22.24 ± 2.49	22.76 ± 1.76	0.575
Vestibular cusp, left	21.93 ± 2.44	21.14 ± 2.80	22.72 ± 1.82	0.133
Palatal cusp, right	23.51 ± 2.17	23.41 ± 2.28	23.62 ± 2.16	0.825
Palatal cusp, left	22.76 ± 2.26	22.33 ± 2.52	23.19 ± 2.00	0.385
Buccal bone width (mm)				
3 mm apical, Right	1.21 ± 0.76	1.30 ± 0.79	1.13 ± 0.76	0.624
3 mm apical, Left	1.13 ± 0.77	1.44 ± 0.80	0.82 ± 0.62	0.054
6 mm apical, Right	1.64 ± 0.71	1.79 ± 0.85	1.49 ± 0.53	0.342
6 mm apical, Left	1.63 ± 0.68	1.88 ± 0.81	1.38 ± 0.41	0.087
Transverse distances of teeth (mm)				
First molar				
Apex	31.92 ± 2.56	30.53 ± 2.54	33.32 ± 1.74	0.007
CEJ	32.08 ± 2.92	31.73 ± 3.34	32.43 ± 2.55	0.588
Cusp	37.57 ± 3.54	37.49 ± 4.11	37.66 ± 3.07	0.916
First premolar				
Apex	30.29 ± 2.83	30.07 ± 3.54	30.49 ± 2.16	0.740
CEJ	25.85 ± 2.59	26.29 ± 2.42	25.45 ± 2.79	0.475
Cusp	28.45 ± 3.13	28.91 ± 2.94	28.03 ± 3.39	0.533

Note. Results are expressed as mean ± SD or median (interquartile range); *P* = Student *t* test *P* adjusted using Bonferroni method or Mann-Whitney U test *P* adjusted by using Bonferroni method.

Table III. Differences over time in the whole population (N = 22)

XXX	*Group 1 (≤16 y)* *T1 − T0*	*Group 2 (>16 y)* *T1 − T0*	*Intergroup* P *value*
N	11	11	
Bispinal distance, mm			
Anterior	5.00 ± 1.84	4.40 ± 1.51	0.422
Median	4.86 ± 1.85	4.19 ± 1.44	0.361
Posterior	3.54 ± 1.65	2.84 ± 1.80	0.366
Maxillary width, mm			
NF	2.82 ± 2.84	2.14 ± 2.11	0.533
P value	0.008	0.007	
HP	2.80 ± 2.39	2.33 ± 1.62	0.595
P value	0.003	<0.001	
MP			
Right	−0.84 (−2.14, −0.20)	−0.11 (−0.35, 0.29)	0.035
P value	0.053	0.838	

Table III. Continued

XXX	*Group 1 (≤16 y) T1 − T0*	*Group 2 (>16 y) T1 − T0*	*Intergroup* P *value*
Left	−0.81 (−1.78, 0.66)	0.42 (−0.97, 1.45)	0.159
P value	0.266	0.432	
Alveolar inclination, °			
to NF, right	1.83 ± 4.39	2.00 ± 3.99	0.924
P value	0.198	0.127	
to NF, left	−0.35 ± 3.74	2.33 ± 3.73	0.109
P value	0.765	0.065	
to MP, right	−0.45 ± 3.42	0.93 ± 2.41	0.305
P value	0.675	0.254	
To MP, left	1.74 ± 3.19	−0.44 ± 3.82	0.172
P value	0.102	0.724	
Tooth axis, °			
to NF, right	2.00 ± 3.14	3.61 ± 4.66	0.371
P value	0.075	0.028	
to NF, left	−0.45 (−1.88, 4.10)	1.80 (−0.15, 3.00)	0.109
P value	0.76	0.175	
to MP, right	−0.91 ± 3.98	0.65 ± 5.77	0.476
P value	0.466	0.73	
to MP, left	0.89 ± 4.56	−2.79 ± 4.34	0.172
P value	0.532	0.073	
Vertical dental height, mm			
Vestibular Cusp, right	−1.08 ± 1.98	−0.50 ± 1.05	0.402
P value	0.101	0.148	
Vestibular cusp, left	−0.14 ± 0.63	−0.36 ± 1.14	0.577
P value	0.485	0.319	
Palatal cusp, right	−1.01 ± 1.54	−0.76 ± 0.99	0.661
P value	0.056	0.029	
Palatal cusp, left	−0.23 ± 0.71	−0.19 ± 0.97	0.905
P value	0.299	0.534	
Buccal bone width, mm			
3 mm apical, right	−0.34 ± 0.73	−0.31 ± 0.53	0.920
P value	0.158	0.080	
3 mm apical, left	−0.28 (−0.68, −0.07)	−0.14 (−0.46, 0.01)	0.224
P value	0.083	0.407	
6 mm apical, right	0.03 ± 0.73	−0.15 ± 0.70	0.563
P value	0.893	0.498	
6 mm apical, left	−0.40 (−0.68, 0.02)	−0.35 (−0.70, −0.02)	0.922
P value	0.24	0.032	
Transverse distance of tooth, mm			
First molar			
Apex	5.76 ± 2.09	4.12 ± 2.14	0.084
P value	<0.001	<0.001	
CEJ	5.73 ± 2.64	5.02 ± 2.34	0.515
P value	<0.001	<0.001	
Cusp	6.02 ± 3.15	4.92 ± 2.62	0.381
P value	<0.001	<0.001	
First premolar			
Apex	6.21 ± 2.75	4.42 ± 2.26	0.118
P value	<0.001	<0.001	
CEJ	6.55 ± 2.83	5.62 ± 2.99	0.476
P value	<0.001	<0.001	
Cusp	6.57 ± 2.70	5.38 ± 2.75	0.332
P value	<0.001	<0.001	

Note. Values are expressed as mean ± SD or median (interquartile range); Intergroup P = Student t test P adjusted by using Bonferroni method or Mann-Whitney U test P adjusted by using Bonferroni method. Intragroup T1 − T0 P = paired t test P, or Wilcoxon signed rank test P.

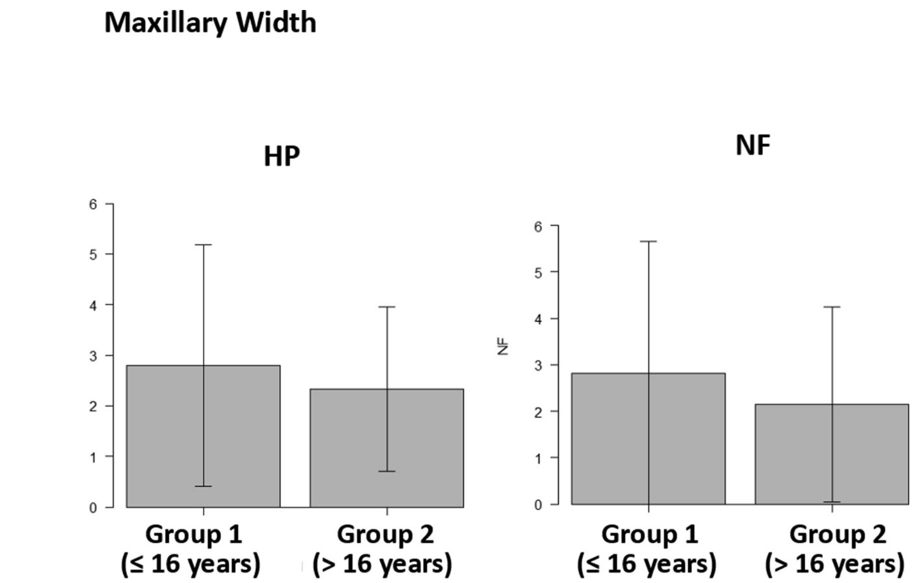

Fig 8. Maxillary width differences over time for each group.

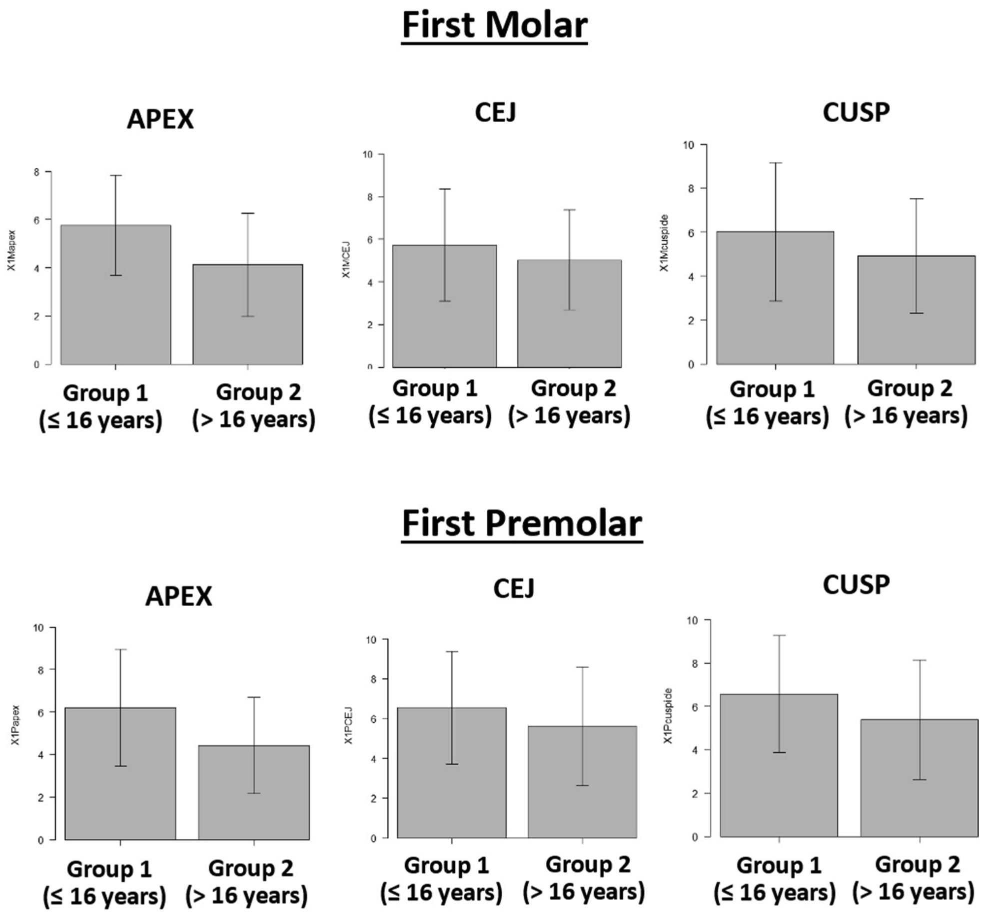

Fig 9. Transverse distance differences over time for each group.

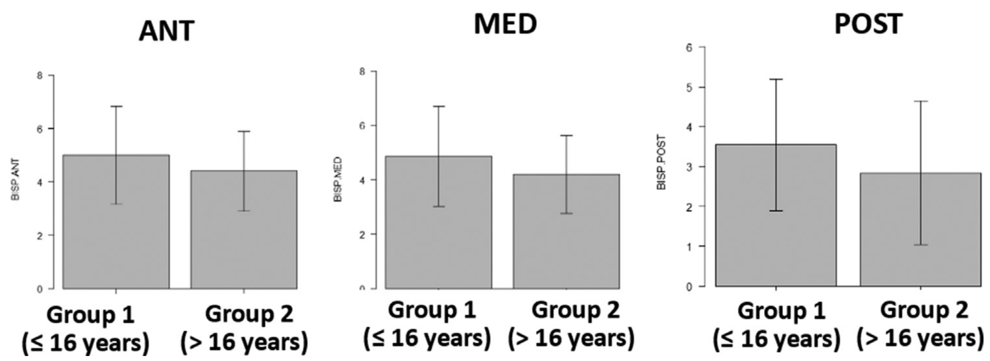

Fig 10. Bispinal distance at T1 for each group. *ANT*, anterior; *MED*, median; *POST*, posterior.

percentage is higher than the one of patients at CS 5 that presumably had not yet undergone partial or total fusion of the midpalatal suture found by Angelieri et al (13.5%),[24] suggesting that more postpubertal patients than those indicated by the CVM assessment method would actually exhibit a better response.

There were no noticeable differences at baseline; thus, the 2 groups showed similar maxillary and dental conditions before treatment.

In Figures 11 and 12, comparisons of the effect of different expansion devices are reported for patients under 16 years and older than 16 years. Data were extracted from the present study and other CBCT expansion researches.

Considering the bispinal distance (occlusal view) between groups, no significant or clinical differences were noticed. Considering the bispinal distance, both groups showed a greater expansion in the anterior area and mandibular expansion in the posterior area. Even though no significant differences were found, the posterior expansion was greater in the younger group (3.54 mm) when compared with the >16 years group (2.84 mm); this different result in the posterior area between 2 groups indicate a more parallel suture opening in the youngest patients. The different bone quality between 2 patient groups can be considered one of the key factors that play a role in reply to the expansion force as recently reported.[27]

The maxillary skeletal expansion was similar between groups: 2.82 mm and 2.14 mm for group 1 and group 2, respectively.

Other studies found similar results even though the different designs of the appliance were used,[11] while considering tooth-borne or 2 miniscrews devices different amount of skeletal expansion were reported.[28-30]

Similar amounts of transversal expansion at bispinal distance were found in 15 adult patients with a mean age of 17 years with little dental movement.[18]

Considering dental effects using the 4 screws anchored expander, the movements observed at the left and right of the first molar, no statistically significant differences were noticed after expansion between groups, nor between before/after analysis except for the inclination of the right molar on the NF (3.61°; SD, 4.66). The first molar axis tipping was between −0.45° and 3.61° with respect to the NF, while the values were included between −2.79° and 0.89° with respect to the MP. These values indicate minimal dental inclination. Haas-type and hyrax-type expanders in growing patients (10.7 years; range, 7.2 to 14.5 years) produce first molar buccal tipping between 6.80° and 6.19°, as Weissheimer et al[30] have reported.

Interestingly, the number of expansions observed at the molar level (cusp, apex, and CEJ) was approximately 1 mm higher than those observed at the bispinal level (medium level), corroborating the small dental compensation of the expansion.

Dental diameter varied with larger values in the premolar area with respect to the molar area, consistently with the expansion observed at the bispinal level, in which the anterior values were higher than the medium and posterior. These values agreed with previous studies, in which the expansion pattern was triangular with a wider base at the anterior portion of the maxilla.[28,31]

The values of dental expansion were lower for group 2 than group 1, although no statistical differences were found; generally, 1 mm less expansion was detected at the molar and premolar level, and the apex had the lowest values compared with the cusp and CEJ measurements.

Furthermore, slight signs of buccal bone resorptions were observed. In particular, evidence of bone loss reached values between 0.14 mm (3 mm level to CEJ) to 0.40 mm (6 mm level from the CEJ). No intragroup intergroup differences were observed. Moon et al[11] reported decreases in buccal alveolar bone height and thickness in patients treated with maxillary skeletal expander

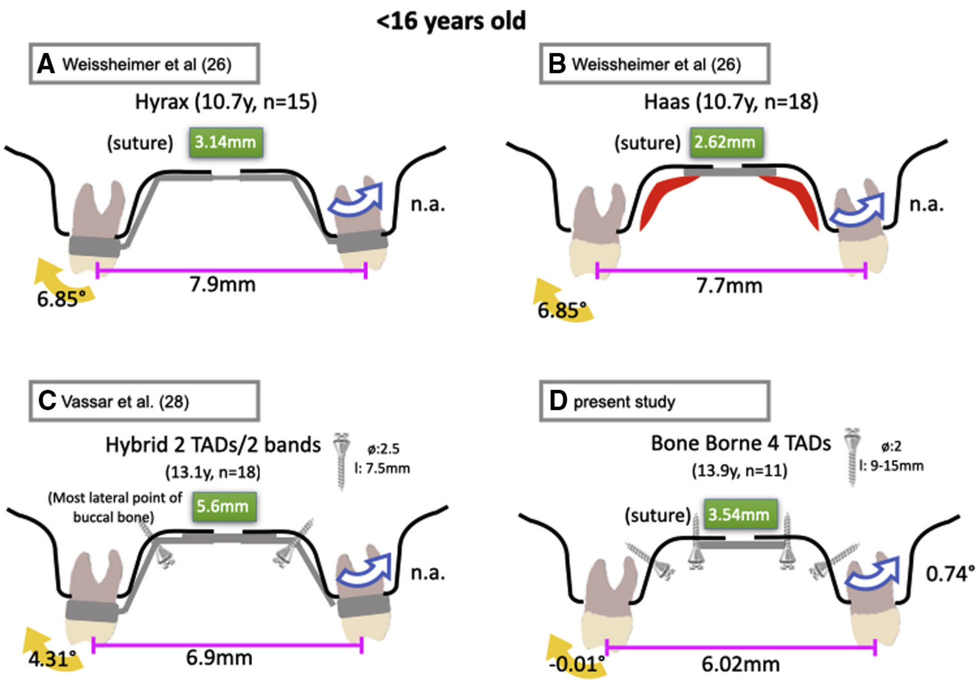

Fig 11. A comparison of different expansion device effects for patients aged ≤16 years: **A,** Hyrax; **B,** Haas; **C,** Hybrid; and **D,** Bone-Borne. Data were extracted from Weissheimer et al[30] (**A** and **B**), Vassar et al[32] (**C**), and the present study (**D**). *Green* is the amount of skeletal expansion. *Yellow arrow* is the dental tipping. *Blue arrow* is alveolar bending referred to as the nasal floor (NF). The *pink line* is the dental diameter expansion. All measurements are referred at the first molar level. *NA*, not available.

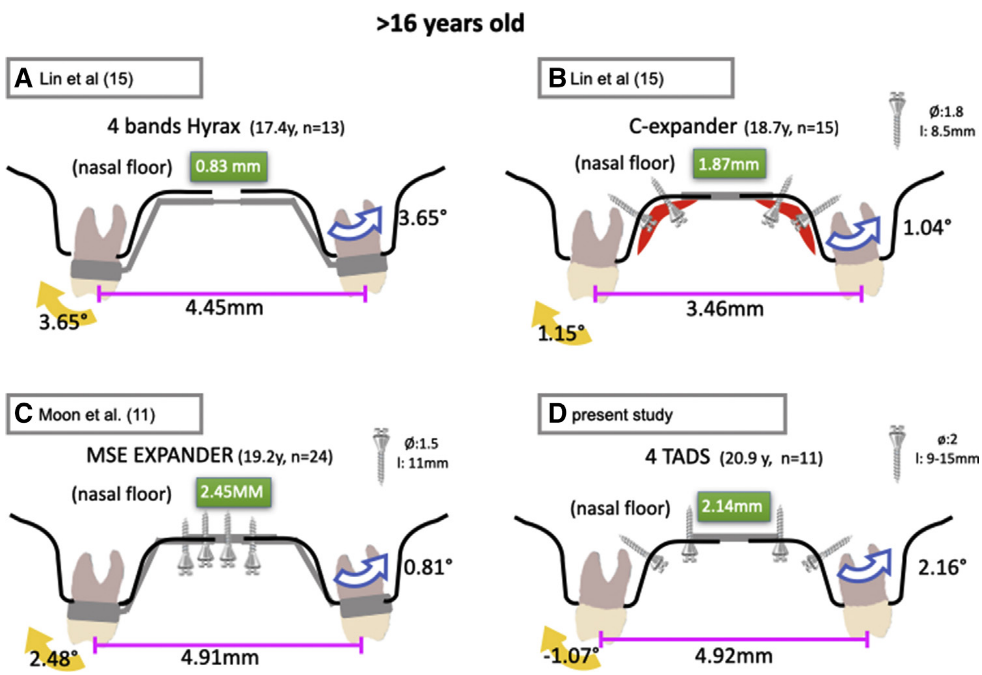

Fig 12. A comparison of different expansion device effects for patients aged >16 years: **A,** Hyrax; **B,** C-expander; **C,** MSE expander; **D,** Bone-Borne. Data were extracted from Lin et al[15] (**A** and **B**), Moon et al[11] (**C**), and the present study (**D**). *Green* is the amount of skeletal expansion. *Yellow arrow* is the dental tipping. *Blue arrow* is alveolar bending referred to as the nasal floor (NF). The *pink line* is the dental diameter expansion. All the measurements are referred at the first molar level. *NA*, not available.

(MSE-tooth-bone-borne appliance). Therefore, the tissue-bone-borne appliance was suggested for older patients.

In this perspective, the amount of buccal bone thickness loss found in the present study was slightly lower than that reported by Moon et al[11] using the MSE, and the C-expander remains the device with the lowest effect on buccal bone thickness at the level of the first molars.

All dental vertical measurements showed a negative value, both for group 1 and 2, thus indicating a slight relative intrusion of the first molars at the end of an expansion; these values agreed with those published by Lin et al,[15] where the effect of tooth-borne and bone-borne appliances in late adolescent patients (17.4 and 18.1 years old, respectively) on the first molar had a similar intrusion movement. Considering the alveolar bending after expansion, no differences between groups were observed. The movement observed with respect to the NF described an alveolar buccal tipping, except for the first left molar in the youngest patient group. Other authors have described similar movements at the premolar and molar level.[15] The same angulation variation has been observed, even when referred to the MP, but with lower values.

The small number of observed patients is a limit of the present study. Moreover, a difficulty in the comparative analysis with previous studies arose; the recent literature used for each publication had different landmarks for skeletal and dental evaluation, which created a problem when different treatment options had to be evaluated and compared. A norm should be defined for all CBCT maxillary studies to have an acceptable level of quality and a standard of reference. In the present study, the percentage of dental and skeletal expansion was not reported. The examination of previously published articles showed different interpretations, and this could be confusing. This important information should have a standardized definition and should take into account all the components of the maxillary complex.

CONCLUSIONS

1. The use of bone-borne maxillary expansion was effective in generating a palatal widening in both growing and young adult patients.
2. Bone-borne expansion was effective with negligible dental effects.
3. No significant skeletal or dental changes were observed between groups.
4. In younger patients, the amount of expansion was slightly greater than in older patients but showed the same geometry of expansion and differences.

AUTHOR CREDIT STATEMENT

Fabio Annarumma: conceptualization, investigation; Marco Posadino: resources and software; Anna De Mari: resources, visualization; Sara Drago: data curation, formal analysis, writing; Hussein Aghazada: investigation; Giovanni Manes Gravina: conceptualization; Erda Qorri: supervision; Armando Silvestrini Biavati: supervision, review; Marco Migliorati: project administration, methodology, writing, reviewing, and editing.

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