Original Article

Short-term skeletal and dentoalveolar effects of overexpansion: *A pilot randomized controlled trial*

Arun K. Bala[a]; Phillip M. Campbell[b]; Larry P. Tadlock[c]; Emet D. Schneiderman[d]; Peter H. Buschang[e]

ABSTRACT

Objectives: To evaluate whether the amount of rapid maxillary expansion differentially affects the skeletal and dentoalveolar changes that occur.

Materials and Methods: This randomized controlled trial included 23 patients who had rapid maxillary expansion (RME). Subjects were randomly assigned to a conventional expansion control group ($n = 12$) or an overexpansion group ($n = 11$), who started treatment at 13.2 ± 1.5 and 13.8 ± 1 years of age, respectively. Cone beam computed tomography scans (11 cm) were obtained prior to rapid maxillary expander (RME) delivery and approximately 3.7 months later. Initial hand-wrist radiographs were used to determine the participants' skeletal maturity.

Results: The RME screws were activated 5.6 ± 1.2 mm and 10.1 ± 0.6 mm in the conventional and overexpansion groups, respectively. Overexpansion produced significantly greater expansion of the nasal cavity (2.1X–2.5X), maxillary base (2.3X), buccal alveolar crest (1.4X), and greater palatine foramina (1.9X). Significantly greater intermolar width increases (1.8X) and molar inclination (2.8X) changes were also produced. The nasal cavity and maxillary base expanded 23%–32% as much as the screws were activated. Skeletal expansion was positively correlated with RME screw activation ($R = 0.61$ to 0.70) and negatively correlated ($R = -0.56$ to -0.64) with the patients' skeletal maturation indicators (SMIs). Together, screw activation and the patients' SMI scores explained 48%–66% of the variation in skeletal expansion.

Conclusions: This pilot study shows that overexpansion produces greater changes than conventional expansion, with greater skeletal effects among less mature patients. (*Angle Orthod.* 2022;92:55–63.)

KEY WORDS: RME; RCT; Humans; Overexpansion; CBCT

INTRODUCTION

Rapid maxillary expansion (RME) has been used as an adjunct to traditional orthodontic treatment for over 150 years.[1] It has been advocated for posterior crossbites, transverse and anteroposterior maxillary deficiencies, and mild-to-moderate crowding.[2–6] RME is often preferred to slow expansion because it maximizes the skeletal corrections.[3,7] The effects of RME include, in order, compression of the periodontal ligament, bending of the alveolar processes, tipping of the maxillary posterior teeth, and separation of the midpalatal suture.[3,7]

Cone beam computed tomography (CBCT) provides an accurate three-dimensional visualization of RME effects.[8] Based on reported CBCT averages, the maxillary skeletal base expands 19%–58% as much as the molars (Table 1).[6,9,10] Relative to screw activation, the skeletal base expands 22%–50% as much.[11–18] There is no clear pattern of differences between or within sites, possibly due to the lack of

[a] Private Practice, Austin, TX, USA.
[b] Professor Emeritus, Department of Orthodontics, Texas A&M University College of Dentistry, Dallas, TX, USA.
[c] Associate Professor, Department of Orthodontics, Texas A&M University College of Dentistry, Dallas, TX, USA.
[d] Professor, Department of Biomedical Sciences, Texas A&M University College of Dentistry, Dallas, TX, USA.
[e] Regents Professor and Director of Orthodontic Research, Department of Orthodontics, Texas A&M University College of Dentistry, Dallas, TX, USA.
Corresponding author: Peter H. Buschang, PhD, Professor and Director of Orthodontic Research, Orthodontic Department, Texas A&M University College of Dentistry, Dallas, TX 75246, USA
(email: phbuschang@tamu.edu)

Accepted: July 2021. Submitted: March 2021.
Published Online: August 13, 2021

Table 1. Skeletal Expansion as a Percent of Molar Expansion and Screw Activation

References	Amount (mm)	Skeletal Location	Skeletal Expansion (mm)	% Skeletal Expansion
Molar expansion				
Cross et al.[13]	5.50	Nasal cavity	1.06	19.3
Silva Fihlo et al.[8]	5.47	Nasal cavity	2.08	38.0
Cross et al.[13]	5.50	Maxillary base	1.11	20.2
Kartalian et al.[14]	5.35	Maxillary base	2.25	42.1
Silva Fihlo et al.[8]	5.47	ANS	2.66	48.6
Cross et al.[13]	5.50	ANS	3.19	58.0
Screw activation				
Chung et al.[15]	7.58	Nasal cavity	1.75	23.1
Kanomi et al.[19]	5.00	Nasal cavity	1.28	25.6
Baratiera et al.[16]	7.00	Nasal cavity	2.11	30.1
Garrett et al.[18]	5.08	Nasal cavity	1.89	37.2
Pereira et al.[20]	8.00	Maxillary base	1.76	22.0
Podesser et al.[21]	7.00	Maxillary base	1.70	24.3
Chung et al.[15]	7.58	Maxillary base	2.28	30.1
Garib et al.[17]	7.00	Maxillary base	2.60	37.1
Weissheimer et al.[22]	8.00	Maxillary base	3.10	38.8
Podesser et al.[21]	7.00	Midpalatal suture	1.60	22.9
Weissheimer et al.[22]	8.00	Midpalatal suture	3.14	39.3
Garrett et al.[18]	5.08	Midpalatal suture	2.55	50.2

variability in the amounts of expansion performed. The relationship between the amount of maxillary expansion and the skeletal response provides the basis for understanding the stability of dental and skeletal components.[5,19,20] To address possible post-retention relapse associated with dental tipping and dentoalveolar bone bending, 2 to 4 mm of overexpansion has been recommended.[3,6,10] Haas[4] advocated substantially more overexpansion, suggesting that the mandibular arch should be completely contained by the maxillary arch. He proposed an average 12 mm of expansion, and a minimum of 10 mm.[5]

The objective of the present study was to determine how the amount of expansion is related to the amounts of dental and skeletal responses that occur. The null hypothesis was that greater amounts of screw activation have no effect on the relative (skeletal vs dental) amounts of expansion that occur. To date, the skeletal effects of overexpansion have not been objectively evaluated. Overexpansion is planned to gain greater amounts of skeletal changes, with the dental and dentoalveolar aspect of overexpansion being corrected during fixed appliance therapy.

MATERIALS AND METHODS

A randomized controlled trial was designed to evaluate the effects of overexpansion among orthodontic patients. The study included patients recruited at Texas A&M College of Dentistry. All data were collected and maintained at the College of Dentistry. This trial was not registered.

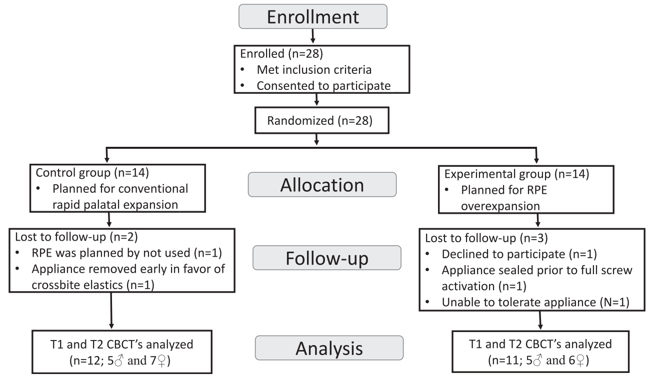

Figure 1. Patient flow through the study.

To be eligible for the study, patients had to be in the late mixed or early permanent dentition stages, less than 16 years old, require at least 4 mm of palatal expansion to treat transverse deficiencies, and be in good periodontal health (ie, pocket depths $<$ 2 mm; attached gingiva; no more than localized gingivitis). Patients were excluded if they had pre-treatment hypodontia, craniofacial anomalies or were being treated with any other appliances.

A power analysis, assuming a power of 90%, a type I error of 5%, and an effect size of 1.2 (based on reported dentoalveolar changes),[12] indicated that 12 patients per group were required. A total of 28 patients were recruited between August 2018 and April 2019, with four additional subjects to account for dropouts (Figure 1). The study was approved by the Institutional Review Board at Texas A&M University College of Dentistry (2017-0585-CD-FB). Stratified by sex, the subjects were randomly allocated to a conventional expansion control group ($n = 14$) or an overexpansion experimental group ($n = 14$) using the Microsoft Excel (version 16.0, Microsoft Corporation, Redmond, WA, USA) randomization function. The conventional and overexpansion groups were 13.2 $\pm$ 1.5 and 13.8 $\pm$ 1 years of age at the start of treatment, respectively. Chi-square analysis indicated that there was no significant ($P = 0.292$) between-group difference with regard to the sex distribution. There were no changes to the trial after it commenced. To determine whether the treatment response was related to the participants' skeletal maturity, Fishman's skeletal maturity indicators (SMI) were used.[21]

Appliance Design and Expansion Protocol

Hyrax expander screws (either 10 or 12 mm) were used, with bands on the maxillary first molars and metal arms extending anteriorly to the second and first premolars, or deciduous molars when applicable. The conventional group was expanded until the palatal cusps of the posterior maxillary teeth were positioned

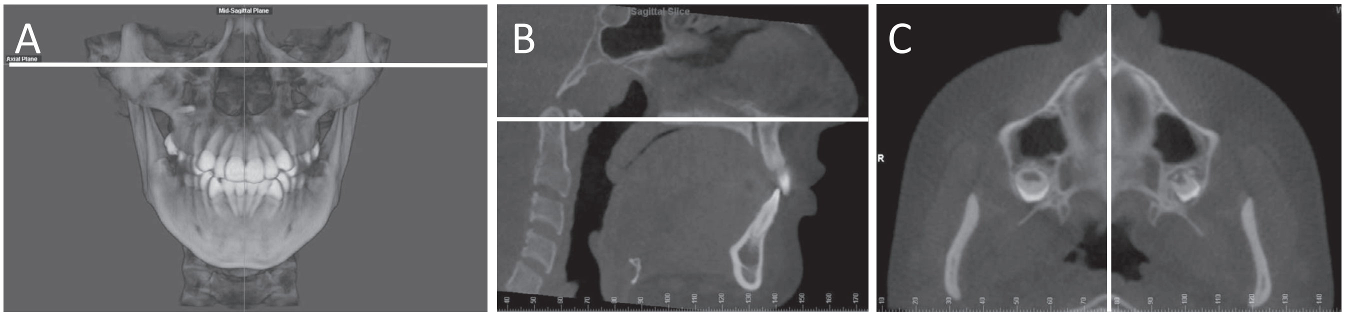

Figure 2. Orientation of (A) coronal view on the orbits, (B) sagittal view on ANS and PNS, and (C) axial view on midpalatal suture.

along the lingual incline of the buccal cusps of the posterior mandibular teeth. Subjects in the overexpanded group were expanded to the limits of the RME screws (5 with the 10 mm and 6 with the 12 mm screws). All participants were instructed to turn the expansion screw one turn (0.25 mm) per day and to record their turns. When expansion was completed, screw activation was measured twice intraorally using digital calipers, and averaged for the analyses.

CBCT Methodology

To quantify the skeletal and dental effects of expansion, 11-cm CBCT scans were obtained prior to RME delivery (T1) and after expansion/retention was complete (T2). The CBCT scans were taken using an i-CAT FLX unit (Imaging Sciences International, Hatfield, PA, USA) at 0.3-mm voxel size, with a pulsed scan time of 8.9 seconds. The CBCTs were evaluated using Dolphin 3D software (version 11.9, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). The patients continued into fixed orthodontic treatment after the T2 CBCT had been taken.

The floors of the right and left orbits were oriented along the true horizontal in the coronal plane (Figure 2); in the sagittal plane, ANS and PNS were oriented along the true horizontal. In the axial plane, the midpalatal suture was oriented along the true vertical. Seven measurements were made on the coronal slice passing through the centers of the maxillary first molar palatal roots (Table 2).[10,12–14,16–18] Anterior nasal width was measured on the coronal slice passing through the center of the incisive foramen (Figure 3).[22] To determine skeletal expansion posterior to the first molars, greater palatine foramina width was measured as the distance between the lateral margins of the greater palatine foramina on the axial slice passing through the center of the hard palate.[22] Molar and alveolar bone inclinations were measured bilaterally and averaged (Figure 4). All measurements were made by one blinded operator. The CBCTs of 10 randomly selected subjects were re-oriented and re-measured. No statistically significant systematic differences were found; method error ranged from 0.3 to 0.4 mm for linear, and from 0.2° to 1.2° for angular measurements.

Table 2. Measures, Their Abbreviations (Abbr), Units, and Definitions. All Measurements Except ANW and GPFW Were Made on the Coronal Slice Taken Through the Center of the Maxillary First Molar Palatal Roots

Measure	Abbr	Units	Definitions
Anterior nasal width	ANW	mm	The widest portion of the nasal aperture on slice take at the center of the incisive foramen (Figure 3A)
Posterior nasal width	PNW	mm	The widest portion of the nasal aperture (Figure 3B)
Maxillary width at nasal floor	Mx_NF	mm	Distance between the maxillary cortical plates at the level of the nasal floor (Figure 3C)
Maxillary width at alveolar crest	Mx_AC	mm	Distance between the maxillary cortical plates at the levels of the buccal alveolar crest (Figure 3C)
Greater palatine foramina width	GPFW	mm	Distance between the lateral margins of the greater palatine foramina taken on an axial slice through the center of the hard palate (Figure 3D)
Inner molar width	IMW	mm	Distance between the palatal cusp tips of the maxillary first molars (Figure 4A)
Molar inclination	MInc	°	Average of right and left angles formed by the intersections of the lines connecting the palatal cusp tips and root apices of the maxillary first molars and the true horizontal (Figure 4A)
Inner alveolar bone inclination	ABInc_I	°	Average of right and left angles formed by the intersections of the lines tangent to the inner cortical plates of alveolar bone and the true horizontal (Figure 4B)
Outer alveolar bone inclination	ABInc_O	°	Average of right and left angles formed by the intersection of the lines tangent to the outer cortical plate of alveolar bone and the true horizontal (Figure 4C)

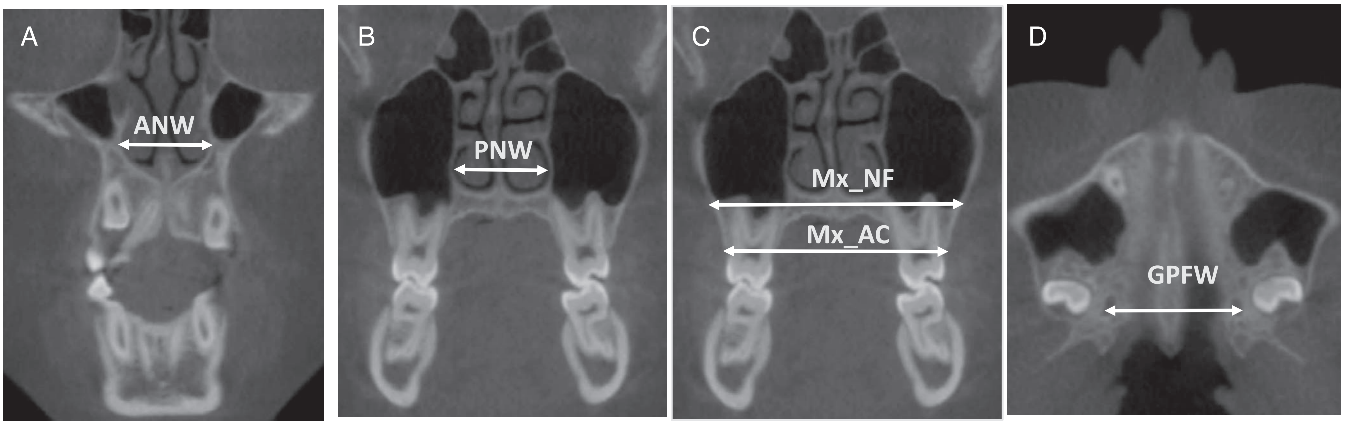

Figure 3. (A) anterior nasal width (ANW), (B) posterior nasal width (PNW), (C) maxillary nasal floor (Mx_NF) and alveolar crest (Mx_AC), and (D) greater palatine foramina width (GPFW) measured on the coronal slice.

Statistical Analyses

All analyses were performed using IBM SPSS Statistics software (version 25.0, IBM Corporation, Armonk, NY, USA). The significance level was set at 0.05. Because the continuous outcome variables were normally distributed, independent sample *t*-tests were used to compare the groups, with Bonferroni corrections. Linear and multiple regressions were used to evaluate the relationships.

RESULTS

There was no statistically significant ($P = 0.372$) pre-treatment difference in SMI scores between the experimental and control groups (7.64 $\pm$ 3.1 vs 6.4 $\pm$ 3.3, respectively). Independent *t*-tests showed no statistically significant between-group pre-treatment morphological differences (Table 3). The screws were activated 1.8X more in the experimental (10.1 $\pm$ 0.6 mm) than control (5.6 $\pm$ 1.2 mm) group (Table 4). Anterior nasal width (Δ ANW; 2.1X), posterior nasal width (Δ PNW; 2.5X), maxillary width at the nasal floor (Δ Mx_NF; 2.3X), greater palatine foramina width (Δ GPFW; 1.9X), and intermolar width (Δ IMW; 1.8X) all increased significantly more in the overexpansion group. The between-group difference in maxillary alveolar crest width (Δ Mx_AC) was not statistically significant after Bonferroni adjustment. Changes in molar inclination (Δ MInc; 2.8X) were also significantly greater in the overexpansion than conventional expansion group. Outer and inner alveolar bone inclinations (Δ ABInc_I and Δ ABI_O) showed no statistically significant between-group treatment differences.

Nasal widths and nasal floor width increased 23%–32% of screw activation among the experimental group, which was 5.5%–7.6% greater than the increases among the conventional group (Figure 5). The Mx AC increased 9.1% more in the conventional than the

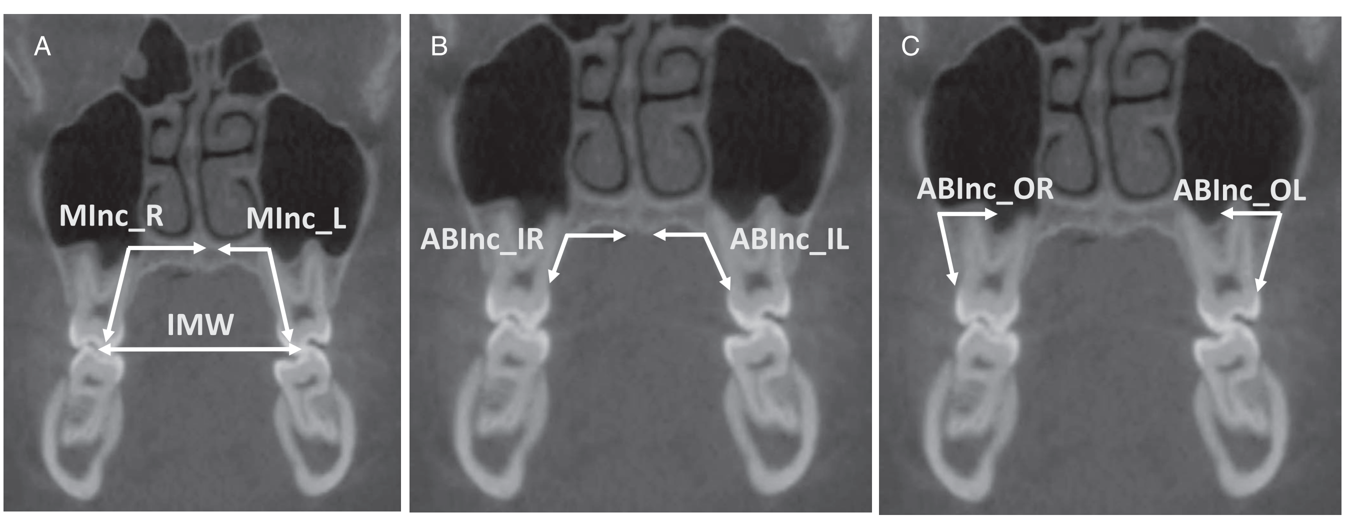

Figure 4. (A) Intermolar width (IMW) and molar inclination (Minc), (B) inner alveolar bone inclination (ABInc_I), and (C) outer alveolar bone inclination (ABInc_O) measured on the coronal slice.

Table 3. Comparisons of the Conventional Expansion and Overexpansion Groups at T1

		Conventional Expansion		Overexpansion		
	Units	Mean	SD	Mean	SD	Probability
ANW	mm	21.8	1.7	22.9	1.6	.135
PNW	mm	27.6	3.5	27.1	1.0	.630
Mx_NF	mm	63.6	4.7	64.1	2.5	.782
Mx_AC	mm	57.7	3.5	59.6	2.5	.157
GPFW	mm	30.3	2.5	30.5	1.6	.853
IMW	mm	39.7	3.1	39.8	1.5	.946
MInc	°	102.5	4.5	101.0	2.2	.326
ABInc_I	°	107.1	4.9	104.5	1.2	.113
ABInc_O	°	88.1	11.3	92.8	4.1	.194

overexpanded group (Figure 5). None of the between-group differences were statistically significant. Skeletal and dentoalveolar changes as a percent of molar expansion showed similar between-group differences, with none attaining statistical significance (Figure 6).

Relationships Among Skeletal Changes, Age and Screw Activation

The amounts of expansion were not significantly correlated with chronological age (Table 5). While absolute amounts of expansion were unrelated, patients' SMI scores were negatively correlated with the percent increases in ANW, PNW, and GPFW. After Bonferroni adjustments, the absolute increases in ANW, PNW, Mx_NF, Mx_AC, GPFW, and MInc were all positively related to screw activation (Table 6). For every mm of screw activation, the maxilla expanded approximately 0.4 mm, with slightly greater amounts of expansion at the alveolar crest and slightly lesser amounts distal to the molar. The association between ΔIMW and screw activation was linear, with slightly greater amounts of molar expansion with every mm of activation (Figure 7).

Multiple regression analyses showed that, in combination, the patients' SMIs and the amount of screw

Table 4. Comparisons of Changes From T1 to T2 for the Conventional Expansion and Overexpansion Groups

		Conventional Expansion		Overexpansion		
	Units	Mean	SD	Mean	SD	Probability
Screw activation	mm	5.6	1.2	10.1	0.6	$<.001$
Δ ANW	mm	1.5	0.9	3.2	1.3	.001
Δ PNW	mm	1.3	0.9	3.2	1.2	$<.001$
Δ Mx_NF	mm	1.3	1.1	3.0	1.3	.002
Δ Mx_AC	mm	3.4	1.5	4.9	1.6	.027
Δ GPFW	mm	1.5	0.9	2.8	1.1	.006
Δ IMW	mm	5.7	1.4	10.4	1.0	$<.001$
Δ MInc	°	2.8	3.2	7.8	3.9	.003
Δ ABInc_I	°	4.2	3.5	6.9	3.4	.073
Δ ABInc_O	°	5.3	6.0	6.0	2.9	.756

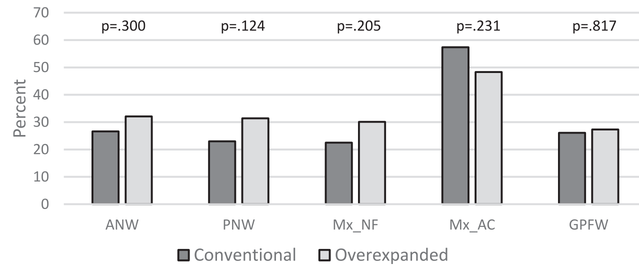

Figure 5. Skeletal expansion as a percent of screw activation.

activation explained 49%–67% of the individual differences in skeletal expansion and inclination changes (Table 7). Each unit increase of the SMIs decreased the amount of skeletal expansion and increased the amount of molar inclination. Skeletal age was approximately 0.5 to 0.7 times as important as screw activation in determining the changes that occurred.

DISCUSSION

As expected, overexpansion produced greater absolute skeletal increases than conventional expansion, but the actual amounts have not been previously established. While screw activation was approximately 1.8X greater among the overexpansion group, skeletal expansion was 2.1–2.5X greater (Figure 8). These differences were expected because more screw activation necessitates longer application of transverse forces, resulting in greater overall effects. At the level of the nasal floor, the amount of skeletal changes produced with overexpansion was similar to the amount produced with miniscrew-supported RME.[23] As such, overexpansion provides orthodontists with a way to obtain greater skeletal expansion without miniscrews; both produce a wider skeletal base for more stable long-term treatment results. The dental and dentoalveolar aspects of overexpansion must be corrected during subsequent orthodontic treatment to prevent relapse.

Skeletal increases expressed as a percent of screw activation showed no statistically significant between-group differences. However, there was a consistent trend of 5.5%–7.6% greater changes among the overexpansion group and post-hoc power analyses

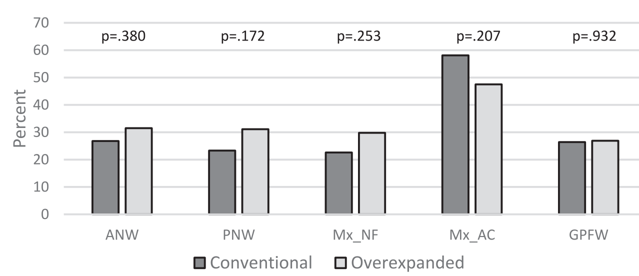

Figure 6. Skeletal expansion as a percent of molar expansion.

Table 5. Correlations of Chronological Age and SMI With Skeletal Expansion (Absolute and as a Proportion of Screw Activation)

	Chronological Age		SMI	
	R	Probability	R	Probability
Absolute skeletal expansion				
Δ ANW	−0.15	.486	−0.32	.141
Δ PNW	−0.02	.945	−0.30	.172
Δ Mx_NF	−0.11	.606	−0.32	.140
Δ Mx_AC	0.05	.837	−0.23	.292
Δ GPFW	−0.16	.462	−0.38	.750
Δ MInc	0.20	.365	0.17	.434
Skeletal expansion as a percent of screw activation				
Δ ANW %	−0.39	.067	−0.57	.005*
Δ PNW %	−0.17	.436	−0.56	.005*
Δ Mx_NF %	−0.26	.225	−0.52	.010
Δ Mx_AC %	−0.17	.440	−0.45	.032
Δ GPFW %	−0.39	.065	−0.64	.001*
Δ MInc_%	0.37	.083	0.43	.039

* Indicates statistical significance after Bonferroni correction.

confirmed insufficient sample size to rule out possible type II errors. Since differences between expansion and overexpansion relative to screw activation have not been previously evaluated, more research with larger samples is needed. Greater orthopedic effects with increasing amounts of screw activation might be expected if dentoalveolar changes are the primary goals at the start of RME.[3,4,7] This could explain the difference in dentoalveolar expansion in the present study (47.5% and 57.4% in the overexpansion and conventional groups, respectively), which fell within the range reported previously.[12,13,16–18]

The amount of skeletal expansion achieved with RME depended on the amount of appliance activation. The present study showed that 30% to 42% of the variation in skeletal expansion was explained by the amount of screw activation. Similar associations have been reported for nasal width and nasal floor changes.[14] Weaker statistical relationships have also been reported.[22] Importantly, the association between screw activation and skeletal expansion was not strong, implicating other possible explanatory factors.

Table 6. Relationships Between the Amount of Screw Activation and Changes of the Skeletal and Dentoalveolar Measurements

	Intercept	Slope	R	Probability
Δ ANW	−0.627	0.382	0.67	<.001*
Δ PNW	−0.922	0.401	0.70	<.001*
Δ Mx_NF	−0.970	0.399	0.66	.001*
Δ Mx_AC	0.843	0.415	0.61	.002*
Δ GPFW	−0.239	0.299	0.61	.002*
Δ IMW	−0.108	1.037	0.95	<.001*
Δ MInc	−3.234	1.087	0.62	.002*
Δ ABInc_I	−0.199	0.731	0.49	.018
Δ ABInc_O	2.491	0.406	0.21	.333

* Indicates statistical significance after Bonferroni correction.

The present study found greater (5°) molar inclination changes in the overexpansion group, a positive correlation between screw activation and molar inclination changes, and a positive association between inclination changes and the patients' SMIs. The positive associations between the patients' SMIs and inclination changes demonstrated that older (more skeletally mature) patients exhibited greater dental changes than younger patients. Controlling for the amount of screw activation, the multiple regression indicated that molar inclination increased 0.5° for every unit increase of SMI; patients starting with an SMI of 11 would have 4.5° greater inclination changes than patients starting with an SMI of 2.

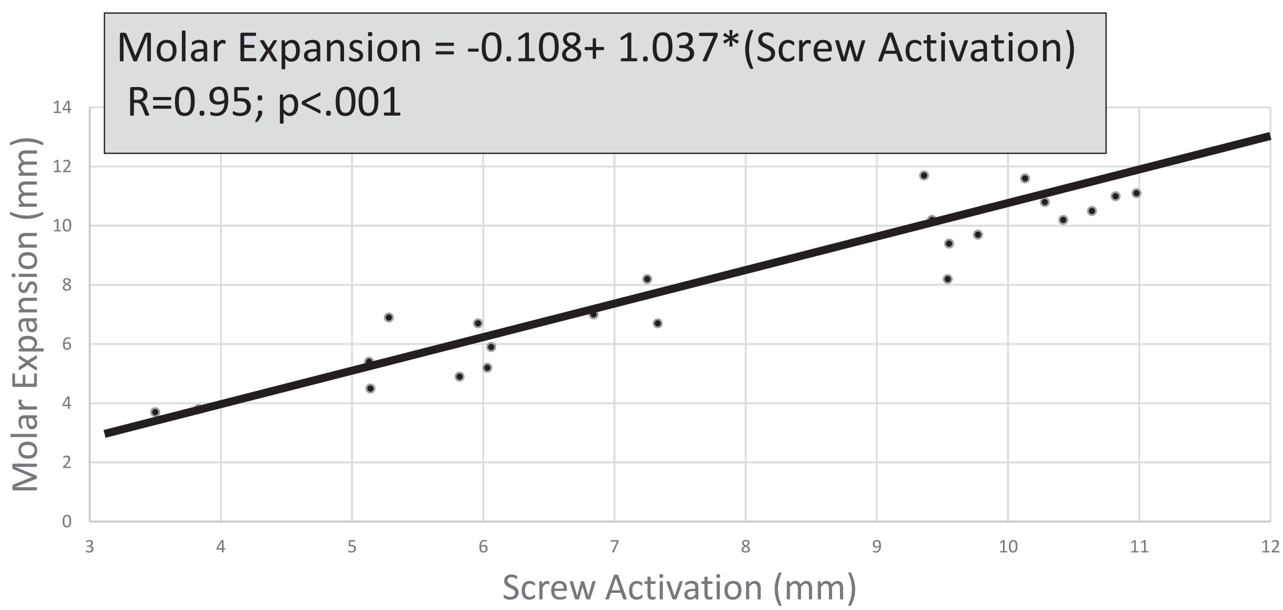

Figure 7. Association between molar expansion (ΔIMW) and screw activation.

Table 7. Multiple Regression Relating SMI and Screw Activation Performed to Changes of the Skeletal and Dentoalveolar Measurements, With Unstandardized (Beta) and Standardized Beta (Stand B) Coefficients

		SMI		Screw Activation			
	Constant	Beta	Stand B	Beta	Stand B	R	Probability
Δ ANW	0.384	−0.187	−0.431	0.420	0.741	0.80	<.001
Δ PNW	0.056	−0.180	−0.414	0.437	0.766	0.81	<.001
Δ Mx_NF	0.102	−0.198	−0.430	0.439	0.729	0.79	<.001
Δ Mx_AC	1.782	−0.173	−0.331	0.450	0.657	0.69	.002
Δ GPFW	0.743	−0.181	−0.485	0.336	0.686	0.78	<.001
Δ MInc	−5.780	0.469	0.347	0.992	0.561	0.70	.001

Alveolar bone bending did not appear to be related to the amount of RME activation. In the present study, alveolar bone inclination changes did not show any between-group differences or associations with screw activation. They compared closely to changes previously reported.[10] Alveolar bone bending is an initial response to the transverse forces delivered by the RME appliance[3,4,7] and is essentially complete within the first week of screw activation.[24] This could explain why alveolar bone inclination changes and midpalatal suture separation are not closely related. The lack of continual alveolar bone bending in the present study may have been related to the design of the appliance used, which applied forces to the dentition rather than the alveolus.

Except for the youngest patients, less than one-third of screw expansion was expressed at the skeletal level. Previous studies have reported 23%–30% of nasal cavity expansion, 22%–39% of the maxillary base expansion, and 23%–50% of midpalatal suture expansion (Table 1). Percentages that were greater than those reported in the present study pertained to younger samples.[12,13,18] RME prior to or during the pubertal growth spurt has been shown to produce greater skeletal expansion than RME after the spurt.[2,3,7,20] The present study showed that, given the same amount of skeletal expansion, individuals who are 5 SMI units less mature will experience almost 1 mm more skeletal expansion at the nasal floor.

The amount of orthopedic expansion obtained with RME was inversely related to the patient's skeletal maturity. Skeletal expansion percentages, as calculated in the present study, were significantly and negatively correlated with the patients' SMIs. For example, greater palatine foramina width (GPFW), as a percentage of screw activation, decreased approximately 5% for every two units of SMI increase (Figure 9). Patients' maturity has been previously associated with skeletal expansion,[7] with patients treated during cervical vertebral maturation (CVM) stages 1–3 demonstrating greater long-term skeletal changes than those treated during CVM stages 4–6.[2] This association was due to the increased complexity of the midpalatal suture with age.[25] Skeletal maturity and midpalatal suture maturation have been shown to be strongly correlated.[26] It has been suggested that the ideal time to begin expansion is between SMI 1 to 4, and that it should be completed by SMI 9 for separation of the midpalatal suture.[27] The present study showed that the relationship is linear (ie, there is no cut-off age), with skeletal separation still possible, albeit more limited, after SMI 9.

RME produced greater inferior than superior, and greater anterior than posterior expansion. The treat-

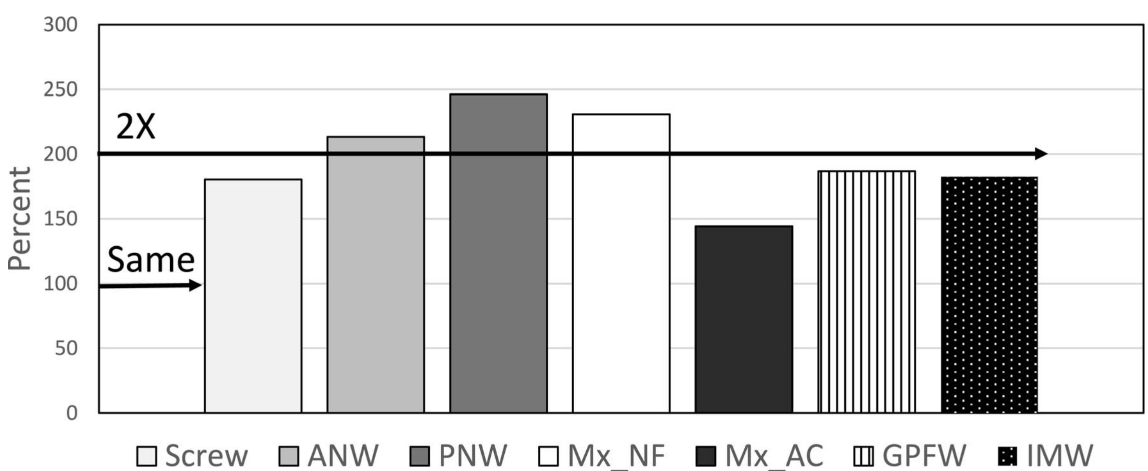

Figure 8. Overexpansion change as a percentage of conventional expansion change.

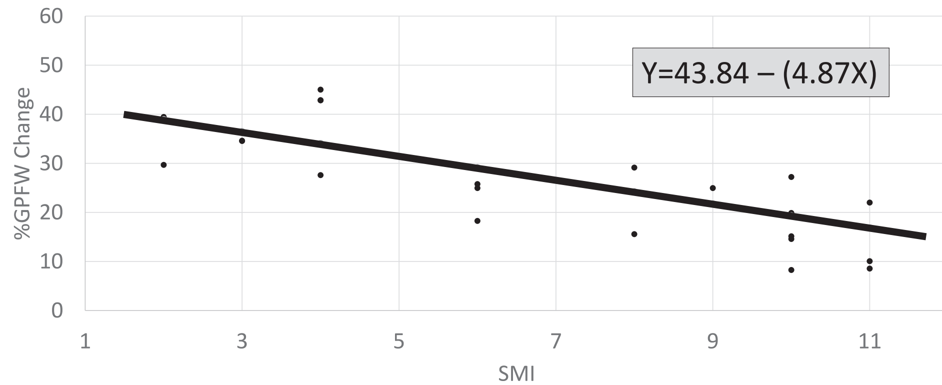

Figure 9. The effect of skeletal age (SMI) on greater palatine foramina width (GPFW) changes, as a percentage of screw activation.

ment effects in both groups were greater at the alveolar crest than at the nasal cavity, as previously reported.[6,7,9,10] This triangular pattern of expansion gives the false impression that substantial amounts of skeletal expansion occurred, when true expansion of the maxillary base and nasal cavity were limited. Greater inferior expansion was probably due to increased superior resistance to the applied force associated with the bony articulations.[3] Resistance also explains the greater anterior than posterior expansion observed.

The results of this study provide important clinical takeaways. First, conventional expansion produces only limited (1–2 mm) amounts of skeletal change above the alveolar crest. Cases with true basal discrepancies and complete posterior crossbites undoubtedly require overexpansion. Clinicians should also be aware that sutural expansion is a major procedure involving distraction osteogenesis. As such, it should be performed with care and consideration. Lastly, the present study underscores the importance of treating early in order to maximize the amount of skeletal expansion. It is possible to obtain twice as much skeletal expansion when treatment starts at SMI 2 (10.6 and 11.7 for females and males, respectively) than at SMI 11 (16.1 and 17.4 for females and males, respectively).

CONCLUSIONS

- Overexpansion leads to significantly greater amounts of skeletal and dental expansion than conventional expansion.
- Nasal cavity and maxillary base widths typically increase 20%–33% of RME screw activation, with slightly greater percentages with overexpansion than conventional expansion.
- Together, the amount of screw activation and the patients' skeletal maturation explain 48%–65% of the variation in skeletal expansion that occurs.
- The effects of RME treatment are triangular from a coronal perspective and greater inferiorly than superiorly.

REFERENCES

1. Angle EH. Treatment of irregularity of the permanent or adult teeth. *Dent Cosmos*. 1860;1:540–544.
2. Baccetti T, Franchi L, Cameron CG, McNamara JA. Treatment timing for rapid maxillary expansion. *Angle Orthod*. 2001;71:343–350.
3. Bishara S, Staley R. Maxillary expansion: Clinical implications. *Am J Orthod Dentofacial Orthop*. 1987;91:3–14.
4. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *Angle Orthod*. 1961;31:73–90.
5. Haas AJ. Long-term posttreatment evaluation of rapid palatal expansion. *Angle Orthod*. 1980;50:189–217.
6. Silva Filho OG, Prado Montes LA, Torelly LF. Rapid maxillary expansion in the deciduous and mixed dentition evaluated through posteroanterior cephalometric analysis. *Am J Orthod Dentofacial Orthop*. 1995;107:268–275.
7. Bell RA. A review of maxillary expansion in relation to rate of expansion and patient's age. *Am J Orthod*. 1982;81:32–47.
8. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. *Am J Orthod Dentofacial Orthop*. 2009;136:19–25.
9. Cross DL, McDonald JP. Effect of rapid maxillary expansion on skeletal, dental, and nasal structures: a postero-anterior cephalometric study. *Eur J Orthod*. 2000;22:519–528.
10. Kartalian A, Gohl E, Adamian M, Enciso R. Cone-beam computerized tomography evaluation of the maxillary dentoskeletal complex after rapid palatal expansion. *Am J Orthod Dentofacial Orthop*. 2010;138:486–492.
11. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. *Am J Orthod Dentofacial Orthop*. 2004;126:569–575.
12. Baratiera CL, Alves M, Jr., Mattos CT, Lau GWT, Nojma LI, de Souza MMG. Transverse effects on the nasomaxillary complex one year after rapid maxillary expansion as the only intervention: a controlled study. *Dental Press J Orthod*. 2014;19:79–87.

13. Garib DG, Castanha Henriques JF, Janson G, Freitas MR, Coelho RA. Rapid maxillary expansion - tooth tissue-borne versus tooth-borne expanders: a computed tomography evaluation of dentoskeletal effects. *Angle Orthod*. 2005;75: 548–557.
14. Garrett BJ, Caruso JM, Rungcharassaeng K, Farrage JR, Kim JS, Taylor GD. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2008;134:8–9.
15. Kanomi R, Deguchi T, Kakuno E, Takano-Yamamoto T, Roberts WE. CBCT of skeletal changes following rapid maxillary expansion to increase arch-length with a development-dependent bonded or banded appliance. *Angle Orthod*. 2013;83:851–857.
16. Pereira JDS, Jacob HB, Locks A, Brunetto M, Ribeiro GLU. Evaluation of the rapid and slow maxillary expansion using cone-beam computed tomography: a randomized clinical trial. *Dental Press*. 2017;22:61–68.
17. Podesser B, Williams S, Crismani AG, Bantleon HP. Evaluation of the effects of rapid maxillary expansion in growing children using computer tomography scanning: a pilot study. *Eur J Orthod*. 2007;29:37–44.
18. Weissheimer A, de Menezes LM, Mezomo M, Dias DM, de Lima EMS, Rizzatto SMD. Immediate effects of rapid maxillary expansion with Haas-type and hyrax-type expanders: a randomized clinical trial. *Am J Orthod Dentofacial Orthop*. 2011;140:366–376.
19. Gurel HG, Memili B, Erkan M, Sukurica Y. Long-term effects of rapid maxillary expansion followed by fixed appliances. *Angle Orthod*. 2010;80:5–9.
20. Krebs A. Midpalatal suture expansion studied by the implant method over a seven-year period. *Rep Congr Eur Orthod Soc*. 1964;40:131–142.
21. Fishman LS. Radiographic evaluation of skeletal maturation: a clinically oriented method based on hand-wrist films. *Angle Orthod*. 1982;52:88–112.
22. Grunheid T, Larson CE, Larson BE. Midpalatal suture density ratio: a novel predictor of skeletal response to rapid maxillary expansion. *Am J Orthod Dentofacial Orthop*. 2017; 151:267–276.
23. Celenk-Koca T, Ertan Erdinc A, Hazar S, Harris L, English JD, Akyalcin. Evaluation of miniscrew-supported rapid maxillary expansion in adolescents: a prospective randomized clinical trial. *Angle Orthod*. 2018; 88:702–709.
24. Starnbach HKB, Bayne D, Cleall J, Subtelny JD. Facioskeletal and dental changes resulting from rapid maxillary expansion. *Angle Orthod*. 1966;36:152–164.
25. Korbmacher H, Schilling A, Puschel K, Amling M, Kahl-Nieke B. Age-dependent three-dimensional microcomputed tomography analysis of the human midpalatal suture. *J Orofac Orthop*. 2007;68:364–376.
26. Angelieri F, Franchi L, Cevidanes LHS, McNamara Jr JA. Diagnostic performance of skeletal maturity for the assessment of midpalatal suture maturation. *Am J Orthod Dentofacial Orthop*. 2015;148:1010–1016.
27. Revelo B, Fishman LS. Maturational evaluation of ossification of the midpalatal suture. *Am J Orthod Dentofacial Orthop*. 1994;105:288–292.