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3D Evaluation of Changes in A Point and Premaxilla after Maxillary Protraction with Rapid Maxillary Expansion by Voxel Superimposition Technique

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Abstract

Objective: To evaluate the changes of premaxilla and A point in the midsagittal plane after maxillary protraction with rapid maxillary expansion by voxel superimposition technique in Cone-Beam Computed Tomography (CBCT) in growing patients, and to investigate the possible correlations between premaxillary changes and A point advancement.

Materials and Methods: The CBCT records of 46 patients with skeletal Class III malocclusion characterized by maxillary hypoplasia were selected from our CBCT database. 23 patients (14 boys and 9 girls, 8.23 ± 11.46 years old) who underwent Maxillary Protraction with Rapid Maxillary Expansion (RME-MP). The CBCT scan was performed before (T1) and after treatment (T2), the interval is on average 8 to 10 months. 23 patients (11 boys and 12 girls, 8.67 ± 13.31 years old) who did not receive RME-MP served as the control group. Midsagittal slices of the CBCT images were used to evaluate the thickness, labial and palatal aspects, and cross-sectional area of the premaxilla. Paired samples were used for statistical comparison. Correlation between premaxillary changes and A point was analyzed by Pearson correlation coefficient.

Results: The PMMT and PMCSA were significantly decreased, and the PMPH was increased after RME-MP. The correlation analysis of the PMBT changes showed negative correlations with the IFA-AA changes (P<0.01). Negative correlations between the PMCSA changes and IFA-AA changes (P<0.05).

Conclusion: The changes in the thickness and cross-sectional area of the premaxilla were negatively correlated with the difference of the IF point Advancement (IFA) and the A point Advancement (AA).

Keywords: Premaxilla; A point; Maxillary protraction; Rapid maxillary expansion; Cone-beam computed tomography

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Introduction

Skeletal Class III malocclusion occurs due to maxillary hypoplasia, mandibular overgrowth, or the combination of the both. Previous studies [1-4] had reported that 25% to 57% of skeletal Class III malocclusion is associated with varying degrees of maxillary hypoplasia. It was recommended that Maxillary Protraction (MP) can be used as an effective treatment of skeletal Class III malocclusion [5,6]. MP promotes maxillary growth and advancement, and thus changes the relationship between the maxilla and mandible.

As an improvement of maxillary protraction, Maxillary Protraction with Rapid Maxillary Expansion (RME-MP) has been accepted by more and more clinical orthodontics physicians. The modified device consists of two parts: Face mask and rapid maxillary expansion appliance. Some studies suggested that RME can open the midpalatal suture and the circummaxillary sutures, activate the reconstruction of these sutures, further facilitate the effect of maxillary protraction.

The premaxilla (or praemaxilla) is one of a pair of small cranial bones at the very tip of the upper jaw of many animals, usually, but not always, baring teeth. In humans, they are fused with

Figure 1: Premaxilla and its boundary with maxilla.

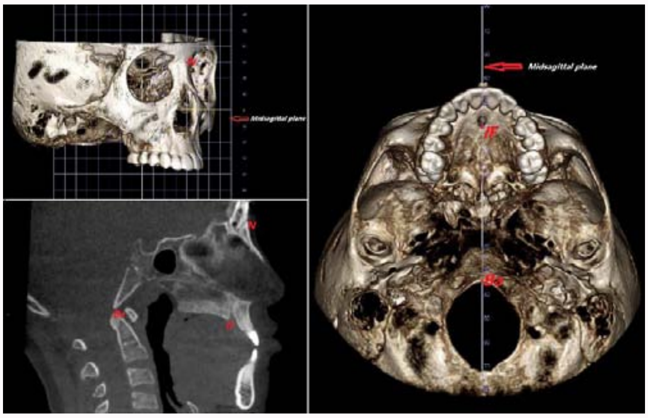

Figure 2: The orientation of the 3D model and the determination of the Midsagittal Plane (MSP).

the maxilla and usually termed as the incisive bone (Figure 1). Some significant cephalometric landmarks, such as A point, ANS point, are located on the premaxilla. In particular, A point has been used clinically to assess the effect of maxillary protraction. In Shanker's study [7], they found that of A point advancement (2.4 mm), 75% was the result of skeletal maxillary advancement and 25% was attributed to local remodeling changes. They have distinguished the relative skeletal and local remodeling contributions to the total A point change by using the Björk and Skiller's "structural method" of maxillary superimposition technique. However, Shanker's study did not evaluated the effect of RME-MP on the premaxilla itself. Therefore, the aim of this study was to evaluate the changes of premaxilla and A point in the midsagittal plane after RME-MP using Cone-Beam Computed Tomography (CBCT) in growing patients, and to investigate the possible correlations between premaxillary changes and A point advancement.

Material and Methods

The material for this study consisted of pairs of CBCT scans of 46 children patients retrieved from ###. They were originally used to study craniofacial growth. The inclusion criteria were: (1) skeletal and dental Class III malocclusion characterized by maxillary hypoplasia (ANB angle <0°, Wit's appraisal < -2.0 mm); (2) vertically normal growth pattern (SNGoGn <40°); 3) no cleft lip and palate; 4) normal maxillary central incisors; 5) clear 3D images. The study protocol was approved by the Medical Ethical Commission of the ###. All patients were signed the informed consent. The selected patients were divided into 2 groups and 23 patients each.

In the first group (RME-MP), all of 23 patients (14 boys and 9 girls, 8.23 ± 11.46 years old) had undergone maxillary protraction with rapid maxillary expansion. The RME-MP lasted for 10 to 12 months. RME was performed (the screw expander was turned once each in the morning and evening respectively) in the first three weeks. The midpalatal suture was effectively opened. In order to retain the effect of the RME, the intraoral expansion appliance (Haas screw) was removed at the end of the RME-MP. The application of the MP had not been interrupted during the whole process. MP forces were standardized (400 g/each side; directed nearly 30° forward and downward with the occlusion plane). Patients wore the face mask for about 12 h to 16 h per day. The RME-MP stopped when positive overjet of anterior teeth achieved about 2 mm to 4 mm. Retaining and observation for 3 months after RME-MP finished. The first CBCT scan was performed before treatment (T1) while the second was taken after Retaining (T2), and the interval was averagely 13 to 15 months.

To distinguish the treatment changes from normal growth changes, the second group of 23 patients (11 boys and 12 girls, 8.67 ± 13.31 years old) who did not receive RME-MP served as the control group.

The CBCT scans were obtained by using the Dental Volumetric Tomograph KaVo 3D eXam (Imaging Sciences International LLC, Hatfield, PA, USA) and they range from geisioma to chin. Data from the CBCT were exported in Digital Imaging and Communications in Medicine (DICOM) format to InvivoDental software 5.1.3 (Anatomage, Inc, San Jose, USA). For each subject, a 3D virtual model was created in a three-dimensional coordinate system. For the fully automatic voxel-based rigid registration, the "Superimposition" module in *Invivo*Dental software was used. Data from the CBCT scans after treatment were exported in DICOM format to the module and initially superimposed with the image before treatment. After that, clicking on the "voxel registration" button in the top left corner, three white boxes will pop up on three different views of the scan (sagittal, coronal, axial). The boxes were used to select the anterior skull base [8]. Then, clicking on the "start" button and the automatic and voxel-based superimposition of 3D images before and after treatment

Table 1: Landmarks selected for the study.

Landmarks for MSP	Anatomic region	Lateral view	Axial view	Anteroposterior view
1. Nasion (N)	Frontonasal suture	Anterior-most point	Middle-anterior–most point on the anterior contour	Middle point
2. Basion (Ba)	The anterior margin of the foramen magnum	Inferior-posterior most point	Anterior-most point	Middle point
3. Incisive foramen (IF)	Incisive foramen	Posterior-inferior–most point	Posterior-most point	Middle point
Landmarks for Maxillary incisors				
4. Upper right incisal edge (UR1Ed)	Maxillary central incisors	Posterior-inferior–most point	Middle point	Middle-inferior–most point
5. Upper left incisal edge (UL1Ed)	Maxillary central incisors	Posterior-inferior–most point	Middle point	Middle-inferior–most point
6. Upper right incisal apex (UR1Ap)	Maxillary central incisors	The top point	Middle point	The top point
7. Upper left incisal apex (UL1Ap)	Maxillary central incisors	The top point	Middle point	The top point
Landmarks for premaxilla	**Anatomic region**	**Midsagittal view**		
8.Anterior nasal spine (ANS)	Median, sharp bony process of the maxilla	Anterior-most point		
9. A point (A)	Premaxilla	Posterior-most point on the curve of the maxilla between the anterior nasal spine and supradentale		
10. Premaxilla labial alveolar ridge (Ar)	Premaxilla alveolar	Anterior-inferior–most point		
11. Incisive foramen (IF)	Incisive foramen	Posterior-inferior–most point		
12. ANS* point (ANS*)	The posterior margin of the premaxilla	The intersection of palatal plane and posterior margin of the premaxilla		
13. A* point (A*)	The posterior margin of the premaxilla	The closest point on the posterior margin of the premaxilla from A point		
14. Premaxilla palatal alveolar ridge (Ar*)	Premaxilla alveolar	Posterior-inferior–most point		

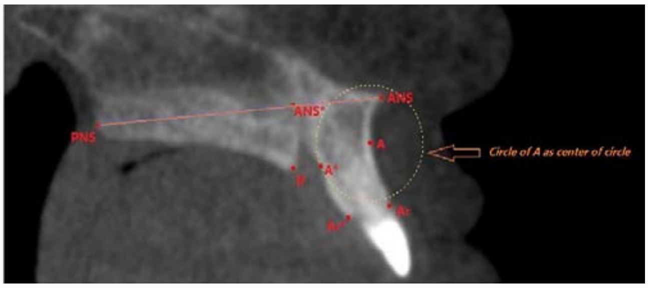

Figure 3: Landmarks displayed in the midsagittal plane.

begins. The superimposition process took approximately 4 min.

The N-Ba-IF definition of the Midsagittal Plane (MSP) was used (Table 1 and Figure 2) for 3D model orientation9. The position and orientation of the 3D model in the coordinate system depended on the head position of the patient when the CBCT scanned. In the "section" module, using axial, coronal, and sagittal views on the left side, the 3D virtual model on the right side was oriented. A total of 7 landmarks were selected (Table 1 and Figure 3) and defined criteria were established for each landmark.

The items (Figure 4) were measured as follows.

1. Premaxillary tip thickness (PMTT): The distance between Ar and Ar*
2. Premaxillary middle thickness (PMMT): The distance between A and A*
3. Premaxillary bottom thickness (PMBT): The distance between ANS and ANS*
4. Premaxillary labial height (PMLH): The distance between Ar and ANS
5. Premaxillary palatal height (PMPH): The distance between Ar* and ANS*
6. Premaxillary cross-sectional area (PMCSA): Cross-sectional area of the premaxillary below the palate plane
7. IF point advancement (IFA): The distance between IF before RME-MP and IF after RME-MP
8. A point advancement (AA): The distance between A before RME-MP and A after RME-MP

In addition, the position of the maxillary incisors in the premaxilla was also measured in our study. Four landmarks for maxillary incisors were selected (Table 1). The following items were used in our study: 1. U1-PP: angle formed by the intersection of the long axis of the maxillary central incisors and the palate plane; 2. IF-U1Ed(x,y,z): The three-dimensional position of the maxillary central incisor crown relative to the IF point. 3. IF-U1Ap(x,y,z): The three-dimensional position of the maxillary central incisor root apex relative to the IF point.

Statistical analyses were done by using the Statistical Package for the Social Sciences (version 21.0; SPSS, Chicago. IL, USA). Paired t-test was used to evaluate the changes of two groups during treatment or observation period. An independent sample t-test was performed

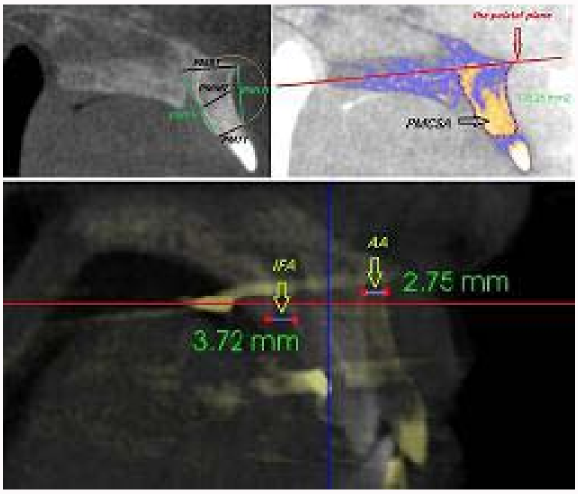

Figure 4: The measurement of the thickness, labial and palatal aspects, and cross-sectional area of the premaxilla, A point Advancement (AA) and IF point Advancement (IFA).

to compare T1 and T2 and T2 to T1 changes between two groups. The changes were statistically significant at P<0.05. Pearson correlation coefficient was used to analyze the relationships between the changes of maxillary central incisor position and the premaxillary changes, and to investigate the relationships among the premaxillary changes, IFA and AA. 15 randomly selected CBCT records were measured twice, at intervals of 3 weeks. Paired samples t-test and intraclass correlation coefficients were used to evaluate the reliability of the measurements. There was no significant statistical difference between the two measurements. The ICC scores of all measurements were above 0.943, indicating that the measurements were fairly reliable.

Results

All 23 patients in the RME-MP group were successfully treated. There was no significant difference between groups in age distribution, treatment or observation duration, and sex distribution, as presented in Table 2, 3.

After RME-MP, the SNA angle increased by 2.69° ± 0.58° (P<0.01). The differences in SNA changes were significant between RME-MP group and untreated group (P<0.01; Table 4).

The premaxilla measurements and statistical comparison between before and after treatment were presented in Table 4. The PMMT (P<0.05) was significantly decreased in RME-MP group, whereas the change was not significant in the untreated group. A significant difference was presented in the PMPH (P<0.01) and PMCSA (P<0.05): The PMPH and PMCSA were increased after RME-MP. The differences in PMPH (P<0.01) and PMCSA (P<0.05) changes were significant between RME-MP group and untreated group.

UR1-PP, UL1-PP, IF-UR1Ed(x), and IF-UR1Ap(x) showed significant decreases (P<0.05; Table 4) in RME-MP group. However, IF-UR1Ed(y), IF-UL1Ed(x), IF-UL1Ed(y), and IF-UL1Ap(x) showed significant increases (P<0.05; Table 4) in the treated group. The differences in the changes were significant between RME-MP group and untreated group (P<0.01; Table 4).

The measurements and statistical comparison between IFA and AA were presented in Table 4. There were significant differences in IFA and AA (P<0.05). On average, the IFA-AA was 0.97 mm in

Table 2: Comparisons of ages and treatment and observation durations between the groups.

	Treated patients		Untreated patients		
	Mean (range)	SD	Mean (range)	SD	P
T1 (y)	9.76 (8.23-11.46)	0.78	10.54 (8.67-13.31)	0.96	0.094
T2 (y)	10.53 (8.92-12.37)	0.83	11.36 (9.48-14.15)	0.97	0.115
Duration (mo)	9.18 (8.00-10.00)	0.68	9.87 (8.00-11.00)	0.8	0.063

Table 3: Sex distributions in the groups.

	Male	Female	Total	χ^2	*P*
Treated patients	14	9	23		
Untreated patients	11	12	23	0.789	0.375
Total	25	21	46		

the treated group. The differences between IFA and AA were not significant in the untreated group. The differences in IFA-AA were significant between RME-MP group and untreated group (P<0.05) (Table 5).

Pearson correlation coefficient analysis between the maxillary central incisal positional changes and the premaxilla changes were illustrated in Table 6. Due to significant differences of the UR1-PP, UL1-PP, IF-UR1Ed(x), IF-UR1Ed(y), IF-UR1Ap(x), IF-UL1Ed(x), IF-UL1Ed(y), IF-UL1Ap(x), IF-UL1Ap(y), IF-UL1Ap(z), PMBT, PMPH, and PMCSA between before and after treatment, those were selected as variables. The correlation analysis of the IF-UR1Ed(x) changes showed positive correlations with the PMBT and PMCSA changes (P<0.01). Negative correlations between the IF-UR1Ed(x) changes and PMPH changes (P<0.05). The correlation analysis of the IF-UL1Ed(x) changes showed negative correlations with the PMBT and PMCSA changes (P<0.01). Positive correlations between the IF-UL1Ed(x) changes and PMPH changes (P<0.05).

Correlation coefficient analysis between the premaxilla changes and advancement were listed in Table 7. The correlation analysis of the PMBT changes showed negative correlations with the IFA-AA changes (P<0.01). Negative correlations between the PMCSA changes and IFA-AA changes (P<0.05). However, there were no significant correlations between the PMPH and IFA-AA changes.

Table 4: Changes from T1 to T2 in the treated patients and untreated subjects and comparisons between the 2 groups.

	Control group				Treated group				Differences between groups					
	T1	T2	Change	P	T1	T2	Change	P	T1		T2	P	Change	P
	Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	P	Mean ± SD		Mean ± SD	
Dentofacial morphology														
SNA (°)	81.2 ± 2.84	80.49 ± 2.46	-0.71 ± 0.42	*	80.09 ± 3.05	83.59 ± 2.24	2.69 ± 0.58	**	-1.11 ± 1.94	NS	3.1 ± 1.85	*	3.4 ± 0.67	**
Premaxilla														
PMTT (mm)	6.28 ± 1.28	6.05 ± 1.44	-0.23 ± 0.99	NS	6.68 ± 0.92	6.26 ± 1.04	-0.42 ± 1.15	NS	0.4 ± 1.25	NS	0.21 ± 1.57	NS	-0.19 ± 0.85	NS
PMMT (mm)	8.14 ± 1.02	8.38 ± 0.89	0.24 ± 0.67	NS	8.31 ± 1.28	7.65 ± 1.25	-0.66 ± 0.52	*	0.17 ± 1.02	NS	-0.73 ± 0.63	*	-0.9 ± 0.57	*
PMBT (mm)	13.1 ± 2.14	12.29 ± 2.71	-0.81 ± 1.91	NS	13.6 ± 1.95	12.84 ± 2.32	-0.76 ± 1.71	NS	0.5 ± 2.26	NS	0.55 ± 2.43	NS	0.05 ± 1.67	NS
PMLH (mm)	15.55 ± 1.92	15.52 ± 1.62	-0.03 ± 1.56	NS	14.42 ± 1.79	14.21 ± 1.93	-0.21 ± 1.28	NS	-1.13 ± 1.68	NS	-1.31 ± 0.99	NS	-0.18 ± 1.34	NS
PMPH (mm)	17.6 ± 2.32	17.46 ± 2.57	-0.14 ± 2.14	NS	17.83 ± 2.14	18.92 ± 2.27	1.09 ± 0.42	**	0.23 ± 1.92	NS	1.42 ± 0.68	**	1.23 ± 0.49	**
PMCSA (mm^2)	139.5 ± 24.7	142.9 ± 18.21	3.41 ± 8.23	NS	149.1 ± 27.45	140.1 ± 26.2	-9 ± 9.12	*	9.6 ± 21.54	NS	-2.8 ± 16.79	NS	-12.41 ± 9.41	*
Maxillary incisors														
UR1-PP (°)	60.04 ±4.16	59.27 ± 4.53	-0.77 ±3.42	NS	61.35 ± 5.01	56.26 ± 4.64	-5.09 ± 4.64	*	1.31 ± 4.58	NS	-3.01 ± 2.32	*	-4.32 ± 1.44	**
UL1-PP (°)	59.38 ± 3.9	57.49 ± 3.24	-1.89 ± 2.69	NS	60.59 ± 5.35	54.98 ± 3.88	-5.61 ± 3.5	*	1.2 ± 5.84	NS	-2.51 ± 2.08	*	-3.72 ± 1.21	**
IF-UR1Ed (x)	-4.54 ± 0.72	-4.42 ± 0.65	0.12 ± 0.51	NS	-4.21 ± 0.78	-4.56 ± 0.68	-0.35 ± 0.26	*	0.33 ± 0.77	NS	-0.14 ± 0.74	NS	-0.47 ± 0.45	*
IF-UR1Ed (y)	13.26 ± 2.1	13.54 ± 1.78	0.28 ± 1.59	NS	13.11 ± 1.91	14.52 ± 2.05	1.41 ± 1.16	*	-0.15 ± 1.63	NS	0.98 ± 1.37	*	1.13 ± 1.04	*
IF-UR1Ed (z)	-14.6 ± 1.25	-14.81 ± 1.73	-0.21 ± 1.46	NS	-15.16 ± 2.28	-15.11 ± 2.38	0.05 ± 1.83	NS	-0.56 ± 0.99	NS	-0.3 ± 1.16	NS	-0.09 ± 1.25	NS
IF-UR1Ap (x)	-3.67 ± 0.79	-3.66 ± 0.74	0.01 ± 0.53	NS	-3.38 ± 0.67	-3.79 ± 0.69	-0.41 ± 0.34	*	0.29 ± 0.52	NS	-0.13 ± 0.47	NS	-0.42 ± 0.38	*
IF-UR1Ap (y)	5.41 ± 1.68	5.32 ± 1.43	-0.09 ± 1.24	NS	4.55 ± 1.52	5.64 ± 1.77	1.09 ± 1.43	NS	-0.86 ± 1.79	NS	0.32 ± 1.71	NS	1.18 ± 1.04	NS
IF-UR1Ap (z)	5.34 ± 1.96	4.47 ± 1.83	-0.87 ± 1.7	NS	4.51 ±1.57	4.4 ±1.58	-0.12 ± 1.51	NS	-0.83 ± 1.85	NS	-0.07 ± 1.62	NS	0.75 ± 1.48	NS
IF-UL1Ed (x)	4.48 ± 1.16	4.59 ± 1.45	0.11 ± 0.58	NS	4.75 ± 0.99	5.36 ± 0.6	0.61 ± 0.54	*	0.27 ± 0.79	NS	0.77 ± 0.52	*	0.66 ± 0.34	*
IF-UL1Ed (y)	13.33 ± 2.06	13.36 ± 2.16	0.03 ± 1.07	NS	13.12 ± 2.11	14.5 ± 1.69	1.37 ± 1.06	*	-0.21 ± 1.92	NS	1.14 ± 1.36	NS	1.34 ± 0.86	*
IF-UL1Ed (z)	-14.5 ± 1.18	-14.81 ± 1.54	-0.31 ± 2.1	NS	-15.03 ± 1.87	-14.8 ± 2.37	0.23 ± 1.91	NS	-0.53 ± 1.42	NS	0.01 ± 1.69	NS	0.54 ± 1.7	NS
IF-UL1Ap (x)	3.24 ± 0.9	3.48 ± 0.66	0.24 ± 0.71	NS	3.16 ± 0.68	3.63 ± 0.67	0.48 ± 0.37	*	-0.08 ± 0.74	NS	0.15 ± 0.46	NS	0.24 ± 0.26	*
IF-UL1Ap (y)	4.39 ± 1.09	4.67 ± 1.11	0.28 ± 1.32	NS	4.55 ± 1.6	4.8 ± 2.06	0.26 ± 1.81	NS	0.16 ± 1.49	NS	0.13 ± 0.86	NS	-0.02 ± 1.04	NS
IF-UL1Ap (z)	4.16 ± 1.12	3.86 ±1.37	-0.3 ± 1.54	NS	4.32 ± 1.85	4.03 ± 1.69	-0.29 ± 1.76	NS	0.16 ± 1.53	NS	0.17 ± 1.27	NS	0.01 ± 0.93	NS

NS: Not Significant; *P<0.05; **P<0.01

Table 5: Measurements and statistical comparison between AA and IFA.

Control group				Treated group				Differences between groups					
AA	IFA	IFA-AA	P	AA	IFA	IFA-AA	P	AA		IFA	P	IFA-AA	P
Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	Mean ± SD	Mean ± SD		Mean ± SD	P	Mean ± SD		Mean ± SD	
0.23 ± 0.12	0.27 ± 0.09	0.04 ± 0.07	NS	3.38 ± 0.4	4.36 ± 0.43	0.97 ± 0.47	*	3.15 ± 0.63	**	4.1 ± 0.56	**	0.95 ± 0.42	*

NS: Not Significant; *P<0.05; **P<0.01

Discussion

In this study, the initial aim was to evaluate premaxilla and A point changes in the midsagittal plane after RME-MP, and to find out the relationship between the both. The Incisive Foramen (IF) point was introduced into the study as a reference point and compared with the A point. The IF point is located in the anterior palate proved to be a stable structure of the maxilla in RME-MP [10,11]. In previous studies [9,12,13], the IF point Advancement (IFA) was used to represent the maxillary advancement after treatment, and the A point Advancement (AA) represented the maxillary change, including the maxillary position advancement and the reconstruction of the premaxilla. Theoretically, the difference between IFA and AA may be related to changes in the premaxilla. Therefore, we finally decided to analyze the relationships among the premaxilla changes, IFA and AA.

In the current study, the 3D models before and after treatment were superimposed to analyze the effect of maxillary protraction. The anterior cranial base that has completed growth by age 7 [14-17] was used to register the 3D models. So, the Midsagittal Plane (MSP) of the superimposed 3D models is consistent. This also means that the assessment of premaxillary changes in the MSP is feasible and reliable in the study. It should be noted that the "premaxilla" in this study is not the anatomical premaxilla, it is only part of the premaxilla. The limits were: Posterior limit - incisive foramen, superior limit - the palatal plane. Compared to the anatomical premaxilla, the boundaries of the new "premaxilla" are more clear and include the common cephalometric landmarks. In addition, the Premaxillary Middle Thickness (PMMT) does not represent the thickness of the middle of the premaxilla, but the thickness of the premaxilla at the A point level. The purpose is to clarify the local changes of the premaxilla at the A point level.

In the literature, it has been showed that the change of the position of the upper incisor root directly affects the position of the A point. In Chen's study [17], they proclined the upper incisor by 15.25 degrees

Table 6: Pearson correlation coefficient analysis between the maxillary incisal positional changes and the Premaxilla Changes (n=23).

Variable*		PMMT (T2–T1)	PMPH (T2–T1)	PMCSA (T2–T1)
UR1-PP (T2–T1)	*r*	-0.292	-0.114	0.116
	P	0.256	0.662	0.656
UL1-PP (T2–T1)	*r*	-0.109	0.152	0.181
	P	0.677	0.56	0.486
IF-UR1Ed (x) (T2–T1)	*r*	0.556*	-0.625**	0.681**
	P	0.02	0.007	0.003
IF-UR1Ed (y) (T2–T1)	*r*	0.162	-0.093	-0.117
	P	0.534	0.722	0.655
IF-UR1Ap (x) (T2–T1)	*r*	-0.054	-0.136	0.276
	P	0.838	0.602	0.283
IF-UL1Ed (x) (T2–T1)	*r*	-0.556*	0.567*	-0.67**
	P	0.02	0.018	0.003
IF-UL1Ed (y) (T2–T1)	*r*	-0.228	-0.318	-0.255
	P	0.378	0.214	0.323
IF-UL1Ap (x) (T2–T1)	*r*	-0.213	-0.19	-0.214
	P	0.412	0.465	0.409

**: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed)

Table 7: Pearson correlation coefficient analysis between the premaxilla changes and advancement (n=23).

Variable*		IFA (T2–T1)	AA (T2–T1)	IFA–AA (T2–T1)
PMMT (T2–T1)	*r*	-0.04	0.363	-0.833**
	P	0.879	0.152	0
PMPH (T2–T1)	*r*	-0.036	0.128	-0.342
	P	0.892	0.625	0.18
PMCSA (T2–T1)	*r*	-0.186	0.064	-0.540*
	P	0.475	0.808	0.025

**: Correlation is significant at the 0.01 level (2-tailed); *: Correlation is significant at the 0.05 level (2-tailed)

in a group of Class II div 2 non-growing cases and they demonstrated that point A follows the apex of the upper incisors, as much as half; apex moved 2.95 mm backward and point A moved 1.24 mm backward after alignment. It is known that maxillary incisors procline to somewhat degree due to the anteriorly directed forces applied to the dentition. So, our manuscript also includes the maxillary central incisor position change after RME-MP treatment in order to interpret the results of the study in a more proper way.

The PMMT was significantly decreased after RME-MP, average 0.66 mm. Positive correlations between the IF-UR1Ed(x) changes and PMMT changes. Negative correlations between the IF-UL1Ed(x) changes and PMMH changes. It is known that the RME opens and activates the palatal suture, resulting in diastema of maxillary central incisors. Therefore, this suggested that the reduction of the PMMT may be related to the RME. The PMPH was significantly increased after RME-MP, average 1.09 mm. And there were no significant differences in the PMLH between before and after treatment. This phenomenon may be explained that the premaxilla rotated counterclockwise after RME-MP. This resulted in a longer distance from the ANS* point to the Ar* point after treatment than before treatment. Unlike the ANS* point, ANS point is relatively stable, so there is little difference in the PMLH between before and after RME-MP. A significant reduction in the PMCSA is a direct result of the reduced PMMT, with an average reduction of 9.00 mm^2.

The result of the measurements and comparison between IFA and AA showed that the IFA-AA was 0.97 mm in the treated group. The differences were negatively correlated with the PMBT and the PMCSA. The premaxilla is located between the IF point and the A point, so the correlation among the three is not difficult to understand. The changes in the premaxilla, especially the reduction in the thickness and the area, caused the IF point advanced more than the A point.

In summary, the premaxilla after RME-MP changed. The changes were related to the IF-UR1Ed(x) and IF-UL1Ed(x). The PMMT and the PMCSA were reduced, while the PMPH increased. This caused the IF point advanced more than the A point. The greater the amount of this reduction, the greater the difference of the IFA and the AA. So now a problem arises: Whether the maxillary advancement represented by the advancement of the A point underestimates the effect of the maxillary protraction with rapid maxillary expansion? The decrease of the PMMT and the PMCSA resulted in the decrease of the A point advancement relative to the IF point advancement after RME-MP, but this change occurred only at the A point level of the maxilla, not the entire premaxilla, nor the maxilla. Our follow-up study will further clarify this question.

Conclusion

1. Maxillary protraction with Rapid Maxillary Expansion (RME-MP) can increase the Premaxillary Palatal Height (PMPH), decrease the Middle Thickness (PMMT) and the Cross-Sectional Area (PMCSA) of the premaxilla.

2. The changes in the thickness and cross-sectional area of the premaxilla were negatively correlated with the difference of the IF point Advancement (IFA) and the A point Advancement (AA). In other words, when the PMMT and the PMCSA decreased after RME-MP, the IFA-AA increased.

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