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## **CBCT evaluation of buccal bone plate thickness following rapid maxillary expansion and semi rapid maxillary expansion: A comparative *in vivo* study**

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### **Abstract**

**Aim and Objectives:** The aim of the study was to determine and compare the effects of force delivered through rapid maxillary expansion and semi rapid maxillary expansion on the Buccal bone plate thickness using imaging.

**Material and Method:** The study was conducted among 20 patients reporting to the OPD of Orthodontics department, RUHS College of Dental Science, Jaipur with transverse maxillary deficiency requiring expansion of maxilla. The sample was then divided into two groups, RME and SRME with 10 subjects in each group. A hyrax expansion screw was customized and bonded with an acrylic splint on the maxillary first premolars and first molars in both the groups. The appliance activation protocol of 4-quarter turn per day was followed in RME group whereas protocol of 2-quarter turns per day for the first week, followed by one-quarter turn every other day was followed in SRME group. After completion of expansion process, the screws were stabilized by tying ligature wire in hyrax opening hole. The same hyrax expansion screw was used for retention for at least 3 months after expansion. CBCT scans of each subject were done prior to the delivery of the expander (T1) and 3 months after the last activation of the expansion appliance (T2). DICOM images were obtained & Image analysis was performed to measure the thickness of the buccal bone corresponding to the maxillary first molars on the mesiobuccal root for the left sides at 3- & 6-mm distance from CEJ. The change in buccal bone thickness is then evaluated in pre & post CBCT in both the groups. Data obtained was compiled on to a MS Office excel worksheet & subjected to statistical analysis using SPSS software. Paired t test was used for the comparisons between the groups. For all the statistical tests, P<0.05). In case of RME the mean difference in buccal bone plate thickness at 3mm was 0.66 ±0.12mm and at 6 mm it was 0.82 ±0.19 mm and the mean difference at 3mm and 6 mm point was found to be 0.16 mm which was statistically significant (P<0.05) was considered to be statistically significant.

**Result:** The result showed that the mean difference in buccal bone plate thickness before & after the treatment with SRME at 3mm was 1.05±0.12 mm and at 6 mm it was 1.09 ±0.16 mm and the mean difference at 3mm and 6 mm point was 0.04 mm, which was statistically insignificant (P>0.05). In case of RME the mean difference in buccal bone plate thickness at 3mm was 0.66 ±0.12mm and at 6 mm it was 0.82 ±0.19 mm and the mean difference at 3mm and 6 mm point was found to be 0.16 mm which was statistically significant (P<0.05). On comparing the mean difference between the buccal bone plate thickness after treatment with Semi RME and RME at 3 and 6 mm was found to be 0.12 mm which was statistically significant (p<0.05).

**Conclusion:** In case of RME the difference in buccal bone thickness before & after procedure at 3 & 6mm was non uniform suggestive of more tipping movement whereas in case of SRME the difference in buccal bone thickness before & after procedure at 3 & 6mm was more uniform suggestive of less tipping movement and more bodily movement. Thus, it can be concluded from the study that SRME can be a better alternative in adult patients with transverse discrepancies.

**Keywords:** Buccal bone plate thickness, 3D reconstruction, CBCT.

### **Introduction**

Maxillary or palatal expansions have been the most sought after treatment modality in transverse maxillary deficiency patients, accompanied by unilateral or bilateral posterior crossbites.

The treatment time for correction of transverse problem is before the correction of antero-posterior and vertical problems.

Rapid palatal expansion has been widely acclaimed as a treatment protocol for children with constricted arches & best results are obtained before peak growth spurts.

The mechanical stresses induced by RME results in the transmission of forces that produce tensile and compressive strains on the facial bones and the adjacent structures. Craniomaxillary suture system, which absorbs and transmit these forces, are likely to be modified by these mechanical forces.

After maxillary expansion the mandible can rotate forward and backward with any vertical change of the maxilla or if there is any correction taking place in the antero-posterior and transverse problems, the antagonistic mandible also shows changes and occlusal settlements. This change in position of the mandible, as an effect of Rapid Palatal Expansion may also change the size and volume of the oropharyngeal airway. In rapid maxillary expansion (RME) protocols, a twice daily activation schedule, which is most commonly proposed in the literature, was shown to produce residual loads during early treatment (Zimring and Isaacson, 1965)<sup>[16]</sup>. Iseri *et al.* (1998) reported that RME not only produced an expansion force at the intermaxillary suture but also caused high forces on various structures in the craniofacial complex. The retention of RME depends not only on bone formation in the intermaxillary suture but also on the creation of a stable relationship at the articulations of the maxilla and other bones of the facial skeleton (Isaacson and Ingram, 1964; Zimring and Isaacson, 1965)<sup>[14, 16]</sup>.

Therefore, relatively slower expansion is recommended to produce less tissue resistance in the nasomaxillary structures (Iseri *et al.*, 1998). Both Geran *et al.* (2006) and Sari *et al.* (2003) used a regimen of one activation per day in young patients and reported success with this protocol. However, Sari *et al.* (2003) stated that this regimen is not superior to the classic regimen of two-quarter turns per day and suggested evaluation of slower rhythms for RME in the mixed dentition. Iseri *et al.* (1998) suggested a slow expansion protocol immediately after the separation of the intermaxillary suture by RME in order to produce less tissue resistance. İseri and Özsoy (2004) used semirapid maxillary expansion (SRME) which is different to the SRME protocol described by Mew (1977, 1983, 1997). Mew (1983) and Sandikçioğlu and Hazar (1997) used an activation rhythm of 1 mm per week whereas İseri and Özsoy (2004) used a schedule of 2 turns per day for the first 5 – 6 days and 3 turns per week for the rest of the expansion in older adolescents and adults. While the effects of RME on adolescents and young adults are well documented, there is limited information on the outcome of Semi RME in adult subjects. Orthodontists, worldwide have increased the use of cone beam computed tomography (CBCT). The CBCT provides scanned images with much greater resolution and accuracy to obtain proper measurements of the suture system in and around nasomaxillary complex and buccal bone thickness.

The purpose of this study was to study and compare the effects of forces generated by rapid maxillary expansion and semi rapid maxillary expansion on buccal bone plate thickness in subjects with maxillary transverse deficiency using CBCT imaging.

## Materials and Methods

### Sample

Ethical clearance was sought from the Ethical Committee of

RUHS College of Dental Sciences (Govt. Dental College), Jaipur (Rajasthan) explaining the aim & importance of the study. The study was conducted among 20 patients in the age group of 15-25 years of North Indian origin who underwent orthodontic examinations and were diagnosed with transverse maxillary deficiency at the department of Orthodontics and Dentofacial Orthopaedics, RUHS College of Dental Sciences, Jaipur. Sample size was calculated using G Power Software (version 3.0.10). Based on the calculated effect size of 5, 5% level of precision, 95% confidence level and 80% power of the study, minimum sample size was calculated as 40. Sample was divided into two groups:

**Group A** - 10 patients with rapid maxillary expansion &

**Group B** - 10 patients with semi rapid maxillary expansion.

### The inclusion criteria's

1. Patients in the late transitional or permanent dentition stage in 15-25 years of age.
2. Almost fused mid palatal suture as seen in CBCT.
3. No craniofacial abnormalities or previous surgical or extraction treatment.
4. A transverse maxillary deficiency with unilateral or bilateral.
5. Patients with healthy periodontium

### The Exclusion Criteria for this study were as follows:

1. Previous history of RME or Semi Rapid Maxillary Expansion.
2. Any surgical intervention by oral surgeon or ENT surgeon.
3. Unhealthy periodontium.
4. History of cleft lip and palate.
5. History of maxillofacial trauma.
6. Any syndrome and systemic disease.
7. Previous history of orthodontic treatment.
8. Uncooperative patient for study purpose.

### Radiographic Examination

Cone beam computed tomography scans were taken with standard protocol using Carestream CS9300 imaging system (CS 3D Imaging v3.5.7; Carestream Health Inc New York, USA) using FOV of 17x11 cm. Image Volume was reconstructed with isotropic isometric 300x300x300 um voxels. The tube voltage ranged from 68-90 Kvp, tube current was 4 mA, and an exposure time of 11.30 seconds was used. This resulted in exposure which ranged from 697-1585 mGy.cm<sup>2</sup>. Patient was positioned in a standing posture, the head upright and teeth closed together with lips relaxed, in the natural head position, standing in front and looking at the eyes of self-mirror image. Patient is positioned so that the intersection lines were straight horizontal and vertical through the centre of the region of interest to construct a three-dimensional (3D) computer model.

### 3D Assessment

Buccal bone plate thickness measurement done by using 3D-DOCTOR software developed by Able Software Corp. 5 Appletree Lane Lexington, MA 02420-2406, US.

The PC workstation used Windows@ 7 Home Premium 64-bit (Microsoft Corporation, Remond, WA, USA). Measurements were made on monitor of Dell 24" nonglossy (1920x1200 pixels resolution) with a Dell precision workstation using CS3D software (v.3.5.7).

Each subjects was scanned at two different time points: T0 and T1. The first image (T0) was obtained prior to the delivery of the expander and represented the subject’s baseline condition prior to expansion. The second time point (T1) was taken at the appointment 3 months following the last activation of the expansion appliance.

Landmarks for measurements of buccal bone plate thickness for left mesiobuccal root, 3 dental landmarks were placed: CEJ, cementoenamel junction; RP3, root point 3, intersection of a 3-mm radius circle (black circle) with the center corresponding to the CEJ landmark and the buccal root profile; and RP6, root point 6, intersection of a 6-mm radius circle (green circle) with the center corresponding to the CEJ landmark and the buccal root profile.

Image analysis was performed to measure the thickness of the buccal bone corresponding to the maxillary first molars on the mesiobuccal root for the left sides. First, image orientation was changed to create a plane passing through the long axis of the maxillary permanent first molar defined with 3 landmarks:

1. The more coronal point of the buccal furcation
2. The apex of the palatal root
3. The center of pulp chamber floor

**Statistical Analysis**

Data obtained was compiled on a MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States). Data was subjected to statistical analysis using Statistical package for social sciences (SPSS v 24.0, IBM).

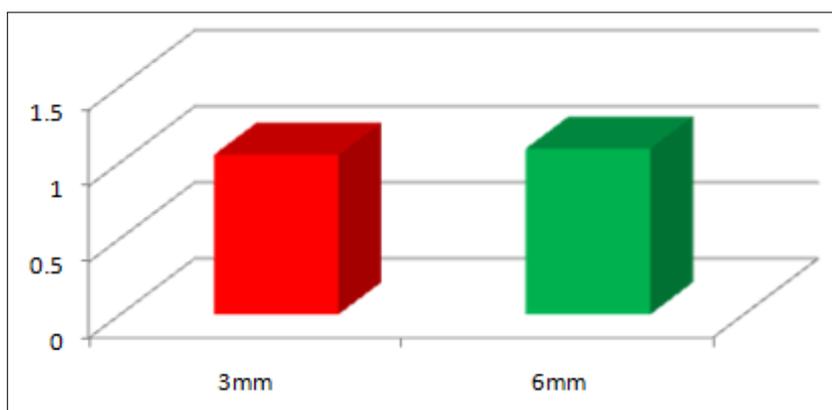
Descriptive statistics like frequencies and percentage for categorical data, Mean & SD for numerical data has been depicted. Since the outcome data was on a numerical discrete scale, also Normality of numerical data was checked using Shapiro-Wilk test & was found that the data followed a normal curve; hence parametric tests have been used for comparisons. Independent t test, were used to validate the consistency of both groups at T0 in terms of age and to compare the outcome variables at T1. Paired sample t tests were used to compare changes from T0 to T1. For all the statistical tests,  $P < 0.05$  was considered to be statistically significant, keeping  $\alpha$  error at 5% and  $\beta$  error at 20%, thus giving a power to the study as 80%.

**Results**

The data was tabulated in Microsoft excel software and analyzed with SPSS V.24 software. Paired t test and independent t test were used for the comparisons. The  $p$  value  $\leq 0.05$  was considered as statistically significant.

**Table 1:** Comparison of buccal bone plate thickness difference before and after treatment with Semi RME

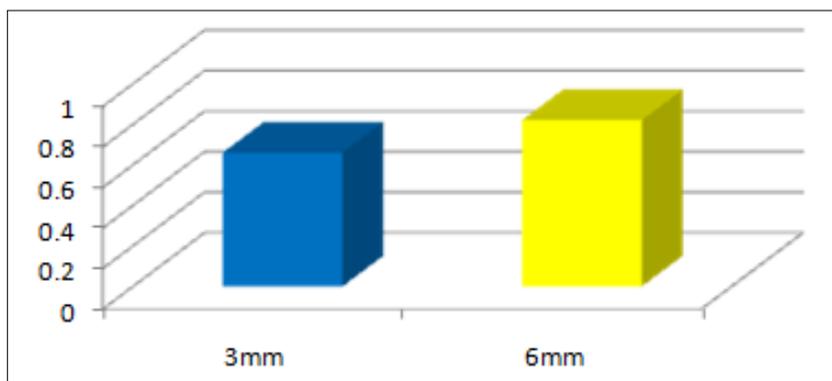
Distance	Mean difference between before & after	SD	Mean difference at 3 and 6	T value	P value
3mm	1.05	0.12	0.04	2.63	0.324*
6mm	1.09	0.16			



**Fig 1:** Comparison of buccal bone plate thickness difference before and after treatment with Semi RME

**Table 2:** Comparison of buccal bone plate thickness difference before and after treatment with RME

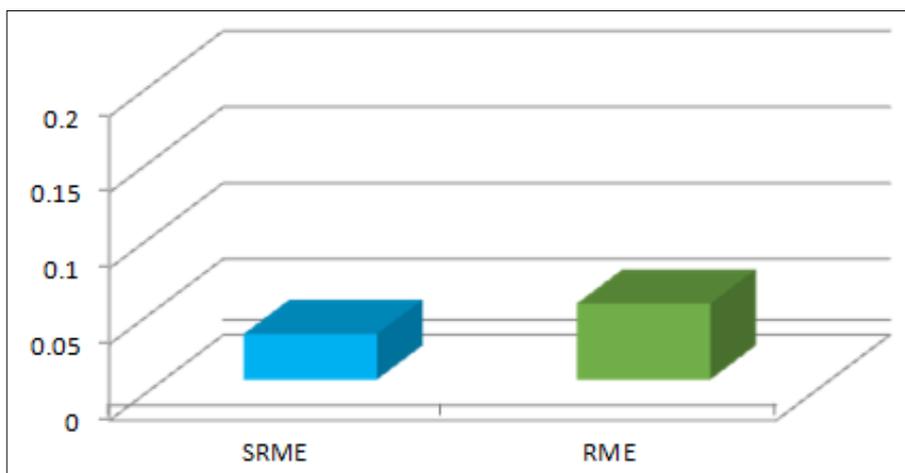
Distance	Mean difference between before & after	SD	Mean difference at 3 and 6mm	T value	P value
3mm	0.66	0.12	0.16	9.249	0.0001*
6mm	0.82	0.19			



**Fig 2:** Comparison of buccal bone plate thickness difference before and after treatment with RME

**Table 3:** Comparison of buccal bone plate thickness difference after treatment with Semi RME and RME

Distance	Mean	SD	Mean difference at 3 and 6	T value	P value
Semi RME	0.04	0.02	0.12	13.721	0.0001*
RME	0.16	0.10			



**Fig 3:** Comparison of buccal bone plate thickness difference after treatment with Semi RME and RME

**Observations**

**1. Treatment with Semi RME**

The buccal bone plate thickness mean difference at 3mm was  $1.05 \pm 0.12$  mm and at 6 mm it was  $1.09 \pm 0.16$  mm and the mean difference at 3mm and 6 mm point was 0.04 mm after the treatment with Semi RME. Difference between the buccal bone plate mean thickness before and after treatment with Semi RME was statistically insignificant ( $P > 0.05$ ). Table 1 and Figure 1 show the comparison of the buccal bone plate mean thickness difference before and after treatment with Semi RME.

**2. Treatment with RME**

The buccal bone plate thickness mean difference at 3mm was  $0.66 \pm 0.12$ mm and at 6 mm it was  $0.82 \pm 0.19$  mm and the mean difference at 3mm and 6 mm point was 0.16 mm after the treatment with RME. Difference between the buccal bone plate mean thickness before and after treatment with RME

was statistically significant ( $P < 0.05$ ). Table 2 and Figure 2 show the comparison of the buccal bone plate mean thickness difference before and after treatment with RME.

**3. Comparison of Semi RME and RME**

The buccal bone plate mean thickness difference at 3mm and 6mm after the treatment with Semi RME was  $0.04 \pm 0.02$  mm and the buccal bone plate thickness difference at 3mm and 6mm after the treatment with RME was  $0.16 \pm 0.10$  mm. The mean difference between them clearly shows that reduction of th buccal bone plate thickness while treating with semi RME in comparison to RME. The mean difference between the buccal bone plate thickness after the treatment with Semi RME and RME at 3 and 6 mm was statistically significant ( $p \leq 0.05$ ). Table 3 and Figure 3 show the comparison of the buccal bone plate thickness after treatment with Semi RME and RME.



**Fig 4:** Coronal View Measurement of Buccal Bone Plate Thickness before RME at point 3

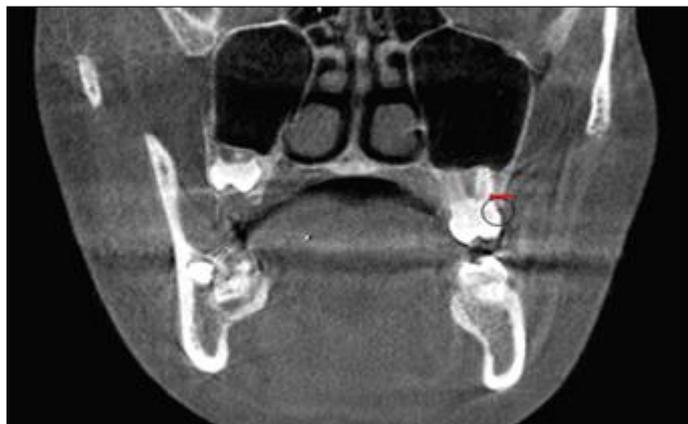


Fig 5: Coronal View Measurement of Buccal Bone Plate Thickness after RME at point 3



Fig 6: Coronal View Measurement of Buccal Bone Plate Thickness before RME at point 6



Fig 7: Coronal View Measurement of Buccal Bone Plate Thickness after RME at point 6

**Discussion**

In our present study, CBCT was used to determine and compare the effects of forces delivered through rapid maxillary expansion and semi rapid maxillary expansion on Buccal bone plate thickness.

The results of our study showed that the mean difference in thickness of the buccal bone plate at 3mm was  $1.05 \pm 0.12$  mm and at 6 mm it was  $1.09 \pm 0.16$  mm and also the mean difference between 3mm and 6 mm point was 0.04 mm after the treatment with Semi RME. Difference between the buccal bone plate mean thickness before and after treatment with Semi RME was statistically insignificant ( $P > 0.05$ ). Table 1 and Figure 1 show the comparison of the buccal bone plate mean thickness difference before and after treatment with Semi RME.

Şefika Ruzin Gönüldaş *et al.* studied the changes in the buccal bone plate and palatal bone in patients undergoing SRME using CBCT and that there is significant decrease in buccal bone thickness and increase in palatal bone. This is concordance with our present study.

Similarly in our study, CBCT showed that the buccal bone plate thickness mean difference at 3mm and 6mm was  $0.66 \pm 0.12$ mm and  $0.82 \pm 0.19$  mm respectively. And the mean difference at 3mm and 6 mm point was 0.16 mm after the treatment with RME. Difference between the buccal bone plate mean thickness before and after treatment with RME was statistically significant ( $P < 0.05$ ). Table 2 and Figure 2 show the comparison of the buccal bone plate mean thickness difference before and after treatment with RME.

Joshua Luebbert *et al.* found that the greatest expansion

occurs in the transverse direction in the posterior maxilla and is less in the anterior between incisors. This is consistent with previous studies which indicate that mechanical loading in the anterior results in suture separation, whereas in the posterior, there is greater skeletal resistance resulting in mostly dental expansion. This expansion corresponds to the distance between pulp chambers, which is greater than the expansion between mesial buccal root apices indicating that the RME resulted in tipping of the teeth buccally. Clinically, this is significant as to prevent the buccal roots from communicating through the cortical plate of bone.

Kitichai Rungcharassaeng *et al.* assessed the immediate effects of RME include dental tipping, reductions of alveolar bone height, and bone dehiscence and found that with significant dental expansion, buccal crown tipping, and loss in Buccal bone plate thickness of maxillary posterior teeth occurs (within 3 months) after RME ( $P < .05$ ).

Buccal crown tipping occurred in about 80% of the posterior teeth in his study and this closely corresponded to the 75% of the sample measured immediately after expansion reported by Thorne.

Significant buccal bone losses was observed in both horizontal (BBT) and vertical (BMBL) dimensions in all posterior teeth (P1, P2, and M1) after RME. Although the bone losses (BBT, BMBL) around P1 (-1.14, -4.42 mm) and M1 (-1.24, -2.92 mm) were not significantly different from each other ( $P > .05$ ), they were statistically significantly greater than the bone losses observed around P2 (-0.84, -1.37 mm). Garib *et al.* reported similar results; they found significantly more buccal bone losses (BBT, BMBL) around P1 (-0.6, -7.1 mm) and M1 (-0.7, -3.8 mm) than P2 (-0.2, -0.2 mm) ( $P < .05$ ).

In our present study the buccal bone plate mean thickness difference at 3mm and 6mm after the treatment with Semi RME was  $0.04 \pm 0.02$  mm and the buccal bone plate thickness difference at 3mm and 6mm after the treatment with RME was  $0.16 \pm 0.10$  mm. The mean difference between them clearly shows the reduction of the buccal bone plate thickness while treating with semi RME in comparison to RME. The mean difference between the buccal bone plate thickness after the treatment with Semi RME and RME at 3 and 6 mm was statistically significant ( $p \leq 0.05$ ). Table 3 and Figure 3 show the comparison of the buccal bone plate thickness after treatment with Semi RME and RME.

Mauricio Brunetto *et al.* studied the correlation between rapid maxillary expansion and slow maxillary expansion procedures with the loss of buccal alveolar bone height and thickness of the anchorage teeth. The same changes represented by variations in CEJ 3, and CEJ 5 were observed in both groups of this study.

Patients in the slow maxillary expansion group suffered major periodontal consequences 9 patients had signs of dehiscence. Of this total, 6 had CEJ 3 reduced to zero, and 3 had both CEJ 3 and CEJ 5 reduced to zero. The highest rates of periodontal bone loss, which occurred in the slow maxillary expansion group, can be attributed to the greater bodily movement of the first permanent molars combined with lower flexion of the alveolar processes and the possibility of major orthodontic movement in the slow maxillary expansion group. All of these 3 factors facilitate the approximation of the roots to the buccal alveolar bone, allowing the onset of periodontal changes.

The tested rapid and slow maxillary expansion procedures caused significant buccal displacement of the maxillary first permanent molars, with a significant difference in the degree of inclination between the groups. The rapid maxillary

expansion group had higher inclinations, and the results suggest greater bodily movement of the teeth in the slow maxillary expansion group. Loss and reduction of height and thickness of bone were detected in both groups, with greater intensity and significance in the slow maxillary expansion group.

Our findings supported those of Mauricio Brunetto *et al.* which was in concordance with our study.

### Conclusion

The following conclusions were derived from the CBCT measurements and comparison of the buccal bone plate thickness under the effects of force delivered through rapid maxillary expansion and semi rapid maxillary expansion.

1. In case of RME the difference in buccal bone thickness before & after procedure at 3 & 6mm is non uniform suggestive of more tipping movement.
2. In case of SRME the difference in buccal bone thickness before & after procedure at 3 & 6mm is more uniform suggestive of less tipping movement and more bodily movement.
3. On comparing RME & SRME – it can be concluded that SRME can be a better alternative in adult patients with transverse discrepancies.

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### References

1. Timms DJ. A study of basal movement with rapid maxillary expansion. *Am J Orthod.* 1980;77:500-507.
2. Bishara SE, Jakobsen JR, Treder J, Nowak A. Arch width changes from 6 weeks to 45 years of age. *Am J Orthod Dentofacial Orthop.* 1997;111:401-409.
3. Wertz RA. Changes in nasal airflow incident to rapid maxillary expansion. *Angle Orthod.* 1968;38:1-11.
4. Ahmed Ghoneima, Ezzat Abdel-Fattah, James Hartsfield, Ashraf El-Bedwehi, Ayman Kamel, and Katherine Kulaf Effects of rapid maxillary expansion on the cranial and circummaxillary sutures. *Am J Orthod Dentofacial Orthop.* 2011;140:510-9.
5. Sabri Ilhan Ramoglu and Zafer Sari maxillary expansion in the mixed dentition: rapid or semi-rapid 2009.
6. White JD. Expanding the jaw. *Dental Cosmos.* 1860;1:21- 22.
7. Angell EH. Treatment of irregularity of the permanent or adult teeth. *Dental Cosmos.* 1860;1:540-544/599-600.
8. Goddard. Separation of the superior maxilla at the symphysis. *Dental Cosmos.* 1893;35:880-884.
9. Brown GVI. The application of orthodontia principles to the prevention of nasal disease, *Dent. Cosmos.* 1993;45:765-775.
10. Landsberger R. Indications for the expansion of the maxilla, *Dent. Cosmos.* 1910;52:121.
11. Mesnard L. Immediate separation of the maxilla as a treatment for nasal impermeability, *Dent. Record.* 1929;49:371-372.
12. Thorne NAH. Expansion of maxilla, spreading the midpalatal suture; measuring the widening of the apical base and the nasal cavity on serial roentgenograms. *Am J Orthod,* 1960, 46.

13. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. *Angle Orthod.* 1961;31:73-90.
14. Isaacson RJ, Wood JL, Ingram AH. Forces produced by rapid maxillary expansion. *Angle Orthod.* 1964;34:256-260.
15. Cleall JF, Bayne DI, Posen JM, Subtelny JD. Expansion of the midpalatal suture in the monkey. *Angle Orthod.* 1965;35:23-35.
16. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion. *Angle Orthod* 1965;35:178-186.
17. Biederman W. A hygienic appliance for rapid expansion. *J Clinical Orthod.* 1968;2:67-70.
18. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. *Am J Orthod.* 1970;58:41-66.
19. Melsen B. Palatal growth studied on human autopsy material. *Am J Orthod.* 1975;68:42-54.
20. Wertz RA, Dreskin M. Midpalatal suture opening: A normative study. *Am J Orthod.* 1977;71:367-381.
21. Robin A, Sandstrom, Lewis Klapper and Stavros Papaconstantinou, Expansion of the lower arch concurrent with rapid maxillary expansion *Am J Orthod.* 1988;94:296-302.
22. Gryson JA. Changes in mandibular interdental distance concurrent with rapid maxillary expansion. *Angle Orthod.* 1977;47:186-92.
23. Noel Reed. Comparison of treatment outcomes with banded and bonded RPE appliances.