

Rapid Maxillary Expansion – An Overview

¹Dr. Piyush, PG, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

²Prof. Dr. Kuldeep DMello, HOD & Professor, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

³Dr. Omkar Singh Yadav, Reader, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

⁴Dr. Sayeri Hossain, PG, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

⁵Dr. Nibedita Biswas, PG, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

Corresponding Author: Dr. Piyush, PG, Department of Orthodontics and Dentofacial Orthopedics, K D Dental College and Hospital, Matura, India

Citation of this Article: Dr. Piyush, Prof. Dr. Kuldeep DMello, Dr. Omkar Singh Yadav, Dr. Sayeri Hossain, Dr. Nibedita Biswas, “Rapid Maxillary Expansion – An Overview”, IJDSIR- September - 2020, Vol. – 3, Issue - 5, P. No. 177 – 186.

Copyright: © 2020, Dr. Piyush, et al. This is an open access journal and article distributed under the terms of the creative commons attribution noncommercial License. Which allows others to remix, tweak, and build upon the work non commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Maxillary transverse deficiency usually requires expansion of the palate. Expansion of palate can achieved by rapid maxillary expansion devices, Slow or removable expansion devices, distraction osteogenesis and or by any other surgical methods. Expansion of arch does not only leads to change in the width of the arch but it also increases the arch perimeter which gives space for to relieve crowding or crossbite or any other abnormality present in the arch. This article reviews only on the maxillary expansion by the technique of rapid maxillary expansion and its effects on associated cranial structures

and some of the recent advances in maxillary expansion is also given in brief.

Keywords: Transverse deficiency, Expansion, Rapid maxillary expansion, Cranial structures, Recent advances

Introduction

Maxillary expansion treatments have been used for more than a century to correct maxillary transverse deficiency. The earliest common cited report is that of E.C. Angell published in *Dental Cosmos* in 1860[1]. The most effective orthopedic treatment that aims to increase the maxillary transverse width is rapid maxillary expansion

(RME) [2]. The first use of RME was described by Angell in 1860[3].

Transverse separation of the maxillae through rapid palatal expansion also has the potential for increasing arch perimeter by unravelling crowding in the maxillary arch and helps in correction of disharmonies in the transverse plane between maxillary and mandibular arches. This procedure which was used as a method of crossbite correction has now has its application for levelling the curve of Wilson, reducing the dark spaces in the buccal corridors and perhaps increase in airway patency[4,5].

Rapid Maxillary expansion occupies unique niche in orthodontic treatment. The elimination of transverse maxillary deficiency should include as an important part of an orthodontic treatment plan. Growth is normally complete by the age of 17 years and the mean transverse growth between the age of four years and adulthood is 6.9 mm. Maxilla will grow in small amount transversely throughout the life, it is more likely that a crossbite encountered in the permanent dentition will not get corrected by itself[6].

Anatomy

The tenacity of circummaxillary attachments due to buttressing is strong postero-supero-medially and postero-supero-laterally. A palatine bone forms an intimate relationship with maxilla to form complete hard palate (or) floor of nose and greater part of lateral wall of nasal cavity.

Maxilla articulates with the following bones[7].

Cranial –1. Frontal 2.Ethemoid

Facial–1. Nasal 2.Lacrimal 3.inferiornasal concha 4.vomer
5. Zygomatic6. Palatine 7.Opposite maxilla

Sutures

Mid Palatine Suture plays a key role in R.M.E [8].

- i. Infancy - Y-shape
- ii. Juvenile - T-shape

iii. Adolescence - Jigsaw puzz

The maxilla is connected to the cranium and cranial base by a number of sutures[9]

- 1.Nasomaxillary Suture
- 2.Frontomaxillary Suture
- 3.Zygomaticotemporal Suture
- 4.Lacrimomaxillary Suture
- 5.EthmoidomaxillarySuture
- 6.Vomeromaxillary Suture

It is important to know when does the suture closes by synostosis and on an average 5%of suture in closed by age 25 years. Earliest closure occurs in girls aged 15 yrs. Greater degree of obliteration occurs posteriorly than anteriorly. Ossification comes very late anterior to incisive foramen, this is important when planning surgical freeing in late instances of RME[6].

Factors to be considered prior expansion[6]

Important factors to be considered in Rapid Maxillary Expansion:

1. Rate of Expansion: Active expansion of 0.3 -0.5 mm is completed in 2-4 weeks, with sometime for the cellular response of osteoclasts and osteoblasts cells.
2. Form of Appliance: expansion must reach to the basal portions of maxilla when the thrust come to the teeth. According to its rigidity or flexibility, appliance will play an important role i.e. anchorage or control of tipping.
3. Age and Sex of the patient: expansion differs in both the sexes because of increasing rigidity of facial skeletal with age.
4. Difference between maxillary and mandibular first molars & bicuspid width is 4mm or more indicated for rapid expansion.
5. Severity of cross bite i.e. number of teeth involved.
6. Initial angulations of molars or premolars: When the maxillary molars are buccally inclined, expansion will help to tip them further into the buccal musculature and

also help to upright the lower molars if they are lingually inclined.

7. Assessment of roots of deciduous tooth. 8. Physical availability of space for expansion.

8. Nasal Obstruction: Before orthodontic treatment, patient should examine for nasal obstruction. If obstruction is present then the patient should refer to an otolaryngologist.

9. Medical history: maxillary expansion depends on suture opening, lack of obstruction and the resiliency of craniofacial complex to adapt to biomechanical changes. So the medical conditions should be considered.

10. Metabolic disorders: Many metabolic disorders are associated with suture synotoses which include hyperthyroidism, hypophosphatemic vitamin D-resistant rickets and mucopolysaccharidoses and mucopolipidoses. These disorders are mostly associated with bone metabolism. Maxillary expansion will be affected even in young patients if they are suffering from any of these diseases.

11. Periodontal Type: Gingival condition is also important as periodontal condition because a thin and delicate gingiva might be prone to recession after surgical trauma or injury.

12. Mucogingival Health: Health of the mucogingival tissue is also important as periodontal and gingival condition, so it should be assessed before expansion.

Indications [10]

- Patients who have lateral discrepancies that result in either unilateral or bilateral posterior crossbites involving several teeth are candidates for RME. The constriction may be skeletal (narrow maxillary base or wide mandible), dental, or a combination of both skeletal and dental constriction.[10,11]
- Patients with Class III malocclusions, and patients with borderline skeletal and pseudo Class III problems

are candidates if they have maxillary constriction or posterior crossbite.[10,12]

- In cleft palate patients with sagittal and transverse discrepancies caused by primary surgeries, RME can be used with a facemask to obtain effective maxillary protraction and improve class III skeletal pattern.[13,14]
- To gain arch length in patients who have moderate maxillary crowding.[5,15]
- Cases of inadequate nasal capacity exhibiting chronic nasal respiratory problems.[12,16]
- According to Bell, the enhanced skeletal response that accompanies RME redirects the developing posterior teeth into normal occlusion and corrects asymmetries of condylar position.[17]
- RME treatment is known to cause relief for the enuretic children, although the long-term success rate is questionable.[18]
- RME is used in the treatment of conductive hearing loss since this procedure aid in improving hearing due to a more normal functioning of the pharyngeal ostia of the Eustachian tubes as a result of the effect of maxillary expansion on the palatal and nasopharyngeal tissues.[19]

Contraindications

- Noncompliant individuals
- Individuals who have a single tooth crossbite

Individuals who have anterior open bites, steep mandibular planes, and convex profiles are generally not well suited to RME.

Individuals who have skeletal asymmetry of the maxilla or mandible, and adults with severe anteroposterior and vertical skeletal discrepancy are not good candidates for RME.[20]

Hazards of RME[7]

1. Difficulty with oral hygiene
2. Length of fixation
3. Chances of dislodgement and breakage
4. Tissue trauma
5. Infection (acute ulcerative gingivitis-most common)
6. Sometime failure of suture to open

Types of Rapid maxillary expansion

1. Tissue borne: Haas type expansion.
2. Tooth borne: Banded – Hyrax or Biedermann type.
3. Bonded maxillary expansion.
4. Minne Expander or Isaacson type.

Clinical Management of RME

The patient/parent should be informed in advance about the upper midline diastema during the expansion phase. This is likely to close spontaneously during the retention period. Patients should be instructed to turn the expansion screw one-quarter turn twice a day (am and pm). This may be associated with minor discomfort. Force levels tend to accumulate following multiple turns and can be as high as 10 kg following many turns. Patients should be reviewed weekly and some clinicians recommend that an upper occlusal radiograph be taken one week into treatment to ensure that the midpalatal suture has separated. If there is no evidence of this, it is important to stop appliance activation as there is a risk of alveolar fracture and/or periodontal damage. Active treatment is usually required for a period of 2-3 weeks, after which a retention period of three months is recommended to allow for bony infilling of the separated suture[21].

Effects of RME on Circummaxillary Sutures

An examination of occlusal films showed that the opening of the midpalatal suture extends through the horizontal plates of the palatine bones, but the distance between the two expanded halves is very narrow. Kudlicin a study on a

human dry skull that simulated in vivo response of RME, concluded the following:

- (1) all craniofacial bones directly articulating with the maxilla were displaced except the sphenoid bone,
- (2) the cranial base angle remained constant,
- (3) displacement of the maxillary halves was asymmetric, and
- (4) the sphenoid bone, not the zygomatic arch: was the main buttress against maxillary expansion.

Gardner and Kronman, in a study on RME in rhesus monkeys, found that the lambdoid, parietal and midsagittal sutures of the cranium showed evidence of disorientation, and in one animal these sutures split 1.5 mm. Therefore, RME could affect relatively remote structures and is not limited to the palate. [22]

Effect of RME on periodontal ligament

The width of the PDL is 0.18 –0.25mm. The screw when turned 90 degrees, the midpalatal suture will open by 0.2 mm and narrows the periodontal membrane by 0.1mm on each side. It has been argued that such a mild reduction in space in the periodontal width would not interrupt the circulation of blood and will facilitate an ideal orthodontic condition for the transformation of bone. Also, Ziebe in 1930 has mentioned that the expansion should not exceed 0.2 –0.5mm/ day which would lead to PDL compression and rupture of blood vessels[7].

Effects of RME on the maxillary complex

The heavy applied pressure acts as an orthopedic force compresses the periodontal ligament, bends the alveolar processes, tips the anchor teeth, and gradually opens the midpalatal suture. According to —Ekstriim, Henrickson, and Iensen the mineral content within the suture rose rapidly during the first month after the completion of suture opening which involves tissue injury followed by a hemorrhage, proliferation and repair phenomenon that ultimately leads to regeneration of the suture. From the

frontal view, the maxillary suture is found to separate superoinferiorly in a nonparallel manner. The separation is pyramidal in shape with the base of the pyramid located at the oral side of the bone.[23]

1. Maxillary Halves: Krebs showed that the two halves of the maxilla rotated in both the sagittal and frontal planes. Haas and Wertz found the maxilla to be more frequently displaced downward and forward. The final position of the maxilla, after completion of expansion, is unpredictable and it has been reported to return, partially or completely to its original position, In the frontal plane, the fulcrum of rotation for each of the maxillae is said to be approximately at the frontomaxillary suture.[23]
2. Palatal Vault: Fried and Haas reported that there was lowering of palatine processes of the maxilla as a result of the outward tilting of the maxillary halves. Davis and Kronman reported that the palate dome remained at its original height[23]
3. Alveolar processes: Because bone is resilient, bending of the alveolar processes occurs laterally initially during expansion. Most of the applied forces tend to dissipate within 5 to 6 weeks. After stabilization is terminated, any remaining forces in the displaced tissues will react on the maxillary alveolar processes causing them to bounce back. So the overcorrection is required to compensate the subsequent rebound[23].
4. Maxillary Anterior Teeth Appearance of diastema between the maxillary central incisors is estimated as a active sign of suture opening. Following this separation, the incisor crowns converge and establish proximal contact caused by the elastic recoil of the transseptal fibers. This generally takes about 4 months. The maxillary central incisors tend to be extruded relative to the S-N plane and in 76% of the cases they upright or tip lingually. [23]

5. Maxillary Posterior Teeth With the initial alveolar bending and compression of the periodontal ligament, there is a definite change in the long axis of the posterior teeth. Hicks found that the angulation between the right and left molars increased from 1° to 24° during expansion. [23]

Effects of RME on the Mandible

Due to disruption of occlusion caused by extrusion and tipping of maxillary posterior teeth along with alveolar bending there is a tendency for the mandible to swing downward and backward which causes the opening of the mandibular plane .[23]

Effects of RME on the Mandibular Teeth

In a study done by Gryson there was a mean increase in the mandibular intermolar width of 0.4 mm but there was no correlation between the change in mandibular intercanine and intermolar distances with respect to the increase in maxillary intercanine and intermolar distances. RME can influence the mandibular dentition, but it is unpredictable.[23]

Effects of RME on adjacent facial structures

Kudlick, in a study on a human dry skull that simulated in vivo response of RME, concluded the following[23]1.Directly attached bones of craniofacial region were moved except sphenoid bone.2.No change in cranial base angle.3.Displacement of the maxillary halves was asymmetric.4.Sphenoid bone was the main uphold against expansion of maxilla not the zygomatic arch.

Effects of RME on nasal airway resistance

In 1902, Brown described the first case in which nasal blockage was eliminated by the rapid palatal expansion by separating the palatal halves along with opening of midpalatine suture. There is increase in volume of nasal cavity immediately following expansion, particularly at the floor of nose adjacent to midpalatal suture. The nasal cavity width gain averages 1.9 mm, but can widen as

much as 8 -10mm at the level of inferior turbinates. The effect ranges from no change to marked improvement of nasal airflow.

Effect of RME on soft tissue

Tip of the nose and soft tissue point A follows the anterior movement of the maxilla and maxillary incisors. Nihat, Kilicet al, concluded in their study that the soft tissue facial angle decrease, the H angle and profile convexity increases after RME[24].

Activation schedule

1.Schedule by Timms[7]

Patients \leq 15 yrs: 45 degree activation 4 times per day.

Patients \geq 20 yrs: 45 degree rotation in morning and evening.

2.Schedule by Zimring and Isaacson.[23]

Young growing patients: Two turns perday for 4-5 days, followed by one turn per day till expansion is achieved.

Non growing adults: Two turns per day for 2 days, then one turn per day for 5-7 days, followed by one turn every alternate day, till expansion is achieved.

3.McNamara and Brudon[5] once per day activation schedule till expansion is obtained.

4.Semi-rapid Maxillary Expansion (SRME)

As suggested by Iseri activation included two turns per day for the first 5 to 6 days followed by three turns per week for the remainder of the SRME treatment. This stimulates the adaptation process in nasomaxillary complex, thereby minimizing relapse in post-retention period in young and adult patients[25,26]

5.Alternate rapid maxillary expansion and constrictions

In 2005, the Alt-RAMEC protocol was introduced by Liou; it enables sutural mobilization with the opening and closing of the RME screw for 7–9 consecutive weeks without unnecessary expansion [27]. Its rationale is similar to that of simple tooth extraction in which we

repeatedly rock the tooth buccally and lingually until the tooth is “disarticulated” out of the alveolar socket [28].

In the Alt-RAMEC protocol, the maxilla is expanded by 7 mm on week 1 through an expansion device that expands 1 mm/day, and then the screw is closed at a rate of 1 mm/s on week 2. In the remaining weeks, the screw of the expansion device is turned on for 1 week and closed for 1 week, and the Alt-RAMEC protocol is completed at the end of the 9-week cycle. Following completion of this protocol, protraction force is applied to move the maxillae forward[28].

Repetitive weekly protocol of Alternate rapid maxillary expansions and constrictions(Alt-RAMEC) has the advantage of displacing the maxilla more anteriorly and disarticulating the circumaxillary sutures more effectively than a single course of RME.[27]

Upto what expansion should be done?

Kerbs (1964) Stockfisch (1976) and Linder Aronson et al (1979) found that one third to one half of the expansion, was lost before achieving permanent stability[29].

A general and convenient guideline for expansion- Stop expansion when the palatal cusps of maxillary posterior teeth reach up to the level of buccal cusps of the mandibular teeth[30,31].

Estimation of Expansion

- Measure the distance between the mesiobuccal cusp tips of maxillary 1stmolars.
- Buccal groves at the middle of the buccal surfaces of mandibular 1stmolars.
- Subtract the mandibular measurement from maxillary measurement.

The average differences in persons with normal occlusion are + 1.6 mm for males and + 1.2 mm for females. The discrepancy between the maxillary and mandibular measurements is a good estimate of how far the maxillary molars must be expanded. One should overexpand the

molars 2 to 4 mm beyond the required distance to allow for the expected post fixation relapse. The expansion screw should provide at least the calculated amount of expansion.[23]

Treatment Timing for RME

Generally, the suggested time of treatment is between the ages of 6 and 8 years after the maxillary permanent first molars and incisors have erupted. Treating at such an early age is reported to remove factors that inhibit growth and development. Studies reveal that treatment during early mixed dentition or prepubertal age is found to have significant and more effective long-term changes at the skeletal level in both maxillary and circummaxillary structures. When RME treatment is performed after the pubertal growth spurt, maxillary adaptations to expansion therapy was more of dentoalveolar than skeletal.[32,33]

Cellular Midpalatal Suture Changes after Rapid Maxillary Expansion in Growing Subjects[38]

Histological

7-Days

Mature bone with small marrow spaces and trabecular bone with the peculiar storiform appearance inside the soft tissue was observed. The bone margins of the suture were characterized by inter-digitations, where the newly-formed osteoid matrix undergoing mineralization directly was also observed. Inside the suture, newly-formed trabecular bone was detected. In the suture gap a blood clot was present. The trabecular newly formed bone had a parallel trend and was surrounded by osteoid matrix undergoing mineralization. In a few areas of the blood clot numerous red blood cells were present. Newly-formed spicules close to large and small vessels were observed.

30 Days

The newly-formed bone trabeculae were oriented perpendicularly to the long axis of the suture and run parallel to each other. A small portion of the bone margins

of the palatal suture was evident, lined by osteoblasts producing osteoid matrix. In the marrow spaces, several small blood vessels in the vicinity of not yet mineralized osteoid matrix were present.

Polarized Light

7 Days

Under polarized light, newly-formed bone and collagen fibers with a storiform orientation were observed.

30 Days

Under polarized light, newly-formed bone undergoing mineralization could be observed. Not yet organized newly-formed bone trabeculae were also evident.

Recent Advances in RME

1. Surgically Assisted RME (SARME)

1. Surgically Assisted RME(SARME) Without Pterygoid Osteotomy (Local Anesthesia)

2. SARME With Pterygoid Osteotomy (General Anesthesia)

Hyrax appliance is placed by the orthodontist prior to surgery. Patient undergoes surgery under local anesthesia or general anesthesia. After surgery Hyrax appliance is activated. Activation time varies according to individual needs. The retention period usually lasts for 6 months to prevent recurrence.[33,34] In a study on the effect of low level laser therapy (LLLT) on bone regeneration in midpalatal anterior suture after SARME it was found that there was accelerated bone regeneration and increased mineralisation[34]

2. Microimplant Assisted Rapid Palatal Expansion (MARPE)

Recently, microimplant-assisted RPE (MARPE) appliances have become available for treatment of transverse maxillary constriction in older patients that can localize the lateral forces to the midpalatal suture while minimally using the dentition.[35]

3. Segmental Maxillary Surgery[21]:

To expand the maxilla, Le fort 1 osteotomy technique should be performed simultaneously with surgical cut along the Midpalatal suture. The maxillary halves are then parted and positioned in the new place. Expansion is limited due to the relative inelasticity of palatal mucoperiosteum. Maxillary incisor roots can be separated with fixed orthodontic treatment, to ease to make surgical midline cut like SARPE.

Retention

Retention appliance typically used is simple palatal plate that has ball clasps between upper first and second deciduous molars and the upper first permanent molars. The patient is instructed to wear the appliance on fulltime basis. It is advisable to maintain the achieved expansion for at least one year, if not longer in order to facilitate changes that might be occurring in the mandibular dentition or in the maxillomandibular relationships.[5] Hicks observed that the amount of relapse is related to the method of retention after expansion. With no retention, the relapse can amount to 45% as compared with 10% to 23% with fixed retention and 22% to 25% with removable retention. [36]. Bell concluded that slow expansion is less disruptive to the sutural systems. Slow expansion that maintains tissue integrity apparently needs 1 to 3 months of retention, which is significantly shorter than the 3 to 6 months recommended for rapid expansion. Mew advocates a total retention period of 1 ½ to 4 years, depending on the extent of expansion.[37]

According to timms[7]

3 months – fixed retention

4-6 months – full time removable retention

2 years – half time removable retention

Conclusion

The application of RME has favoured orthodontic fraternity since its advent from 18th century. RME is a technique of choice in several cases like moderate to

severe transverse discrepancy. This helps us to increase the arch length in moderate crowding cases where arch length is deficient. Orthopedic transverse correction can be done by tipping of posterior teeth buccally along with separation of midpalatal suture. Overcorrection is required to compensate the relapse. Apart from achieving arch expansion it also has its effect on oral, nasal and pharyngeal tissues so as to benefit respiration.

Abbreviations – RME – Rapid Maxillary Expansion

References

1. Timms DJ .The dawn of rapid maxillary expansion. Angle Orthod. 1999 Jun; 69(3):247-50
2. Haas, A.J. (1965) The treatment of maxillary deficiency by opening the midpalatal suture. Angle Orthodontist, 35, 200–217.
3. Angell, E. (1860) Treatment of irregularity of the permanent or adult teeth. Dental Cosmos, 1, 540–544.
4. McNamara JA, Maxillary transverse deficiency, Am J OrthodDentofacialOrthop 2000;117:567-70.
5. James A Mcnamara, William Brudon, Rapid maxillary expansion appliances, Orthodontics and dentofacial orthopaedics (Needham Press).
6. Kumar SA, Gurunathan D, Muruganandham SS. Rapid Maxillary Expansion: A Unique Treatment Modality in Dentistry. Journal of Clinical and Diagnostic Research. 2011 August, Vol-5(4):906-911.
7. Rapid maxillary Expansion – Donald J. Timmis.
8. Melson B. Palatal growth study on human autopsy material: A histologic micro radiographic study. Am J Orthod 1975 ; 68: 42-54.
9. Leonardi R, Sicurezza E, Cutrera A, Barbato E. Early post-treatment changes of circumaxillary sutures in young patients treated with rapid maxillary expansion. The Angle Orthodontist. 2011 Jan; 81(1):36-41

10. Michel.C.Alpernetal ,Rapid palatal expansion in adults with and without surgery. Angle orthodontist july 1987
11. Mugesandikcioglu,Skeletal and dental changes after maxillary expansion in the mixed dentition.Am J Orthod1997;111:321-7.
12. Andrew J Hass,Rapid palatal expansion of the maxillary dental arch and nasal cavity by opening midpalatal suture. Angle Orthod,vol.31,no.2.
13. Robert j isaacsonetal,Some effects of rapid maxillary expansion in cleft lip and palate patients.Angle orthod 1964.
14. Omar Gabriel da Silva Filhoetal, Rapid Maxillary Expansion After Secondary Alveolar Bone Grafting in Patients With Alveolar Cleft The Cleft Palate. Craniofacial Journal. 2009;46(3):331-338
15. Sabrina Mutinelli et al,Anchorage onto deciduous teeth: effectiveness of early rapid maxillary expansion in increasing dentalarch dimension and improving anterior crowding. Progress in Orthodontics (2015) 16:22.
16. Robert A. Wertz et-al,Changes in Nasal Air Flow Incident to Rapid Maxillary Expansion.Angle orthodontist ,vol 52,no 9.
17. Bell RA. A review of maxillary expansion in relation to rate of expansion and patient's age. AM J Orthod1982;81:32-7.
18. SerdarUsumezaD ,Effect of Rapid Maxillary Expansion on Nocturnal Enuresis.Angle Orthod 2003;73:532-538.
19. Theodore Laptook, Williston Park, N. Y,Conductive hearing loss and rapid maxillary expansionAm J Orthod1981Vol 80 No.3,325-331
20. Samir EBishara ,Maxillary expansion :clinical implications Am J Orthodontofacorthop 1987,91, 3-14.
21. Gill D, Naini F, McNally M, Jones A. The management of transverse maxillary deficiency. Dent Update. 2004 Nov;31(9):516-523
22. Wertz RA, Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod1970;58:41-66.
23. Samir EBishara ,Maxillary expansion :clinical implications Am J Orthodontofacorthop 1987,91, 3-14.
24. Kiliç N, Kiki A, Oktay H, Erdem A. Effects of rapid maxillary expansion on Holdaway soft tissue measurements. The European Journal of Orthodontics. 2008 Jun 1;30(3):239-43.
25. Iseri H, Ozsoy S, Semirapid maxillary expansion--a study of long-term transverse effects in older adolescents and adults. Angle Orthod ,2004,74(1):71-78.
26. SabriihanRamoglu ,Maxillary expansion in mixed dentition rapid or semi rapid ,Euro JOrthod,2010
27. Liou EJ, Tsai WC. A new protocol for maxillary protraction in cleft patients: repetitive weekly protocol of alternate rapid maxillary expansions and constrictions. Cleft Palate Craniofac J. 2005;42:21-7.
28. Liou EJ. Effective maxillary orthopedic protraction for growing Class III patients: a clinical application simulates distraction osteogenesis. Prog Orthod. 2005;6:154-71.
29. Buddee, David Robert. "Some comparisons of slow and rapid maxillary expansion." (1984).
30. Isaacson RJ, Ingram AH. Forces produced by rapid maxillary expansion: II. Forces present during treatment. The Angle Orthodontist. 1964 Oct;34(4):261-70.
31. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion: III. Forces present during

- retention. *The Angle orthodontist*. 1965 Jul;35(3):178-86.
32. TizianoBaccetti ,Treatment timing for rapid maxillary expansion.*Angle Orthod*2001,71,343-350
33. Lorenzo Franchi, TizianoBaccetti,Postpubertal assessment of treatment timing for maxillary expansion and protraction therapy followed by fixed appliances. *Am J OrthodDentofacialOrthop* 2004;126:555-68
34. PierangeloAngeletti ,Effect of low level laser therapy on bone regeneration in midpalatal anterior sutureafter surgically assisted rapid maxillary expansion. *OOOOE* 2010,109,e38-e46.
35. Chuck Carlson,a Jay Sung,b Ryan W. McComb ,Microimplant-assisted rapid palatal expansion appliance to orthopedically correct transverse maxillary deficiency in an adult. *Am J OrthodDentofacialOrthop* 2016;149:716-28
36. Preston Hicks,Slow maxillary expansionA clinical study of the skeletal versus dentalresponse to low-magnitude force,*American journal of orthodontics*, Vol 73, No 2,1978.
37. John Mew,Relapse following maxillary expansion A study of twenty-five consecutive cases. *Am J Orthod*,vol 83,No 1
38. Caprioglio A, Fastuca R, Zecca PA, et al. Cellular Midpalatal Suture Changes after Rapid Maxillary Expansion in Growing Subjects: A Case Report. *Int J Mol Sci*. 2017;18(3):615.