

Rapid Palatal Expansion and Airway – Controversy, Consensus, and The Role Of 3D Imaging

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Abstract. The aim of this article is to evaluate the effect of expansion appliance on airway by analyzing the studies that used cone beam computed tomography (CBCT). CBCT can help to analyze the effects of orthodontic treatment such as expansion appliances on nasal cavity, oral and pharyngeal airway volume. Rapid maxillary expansion can be used with conventional design (RME) or with the contemporary design with mini screws (MARPE). The effect of the different designs of expansion appliances will be covered in this article. This article will also cover the effects of the different protocols on evaluating the airway dimensions on CBCT.

Keywords: Rapid maxillary expansion, Cone beam computed tomography, three dimensional imaging, airway.

1 INTRODUCTION

Orthodontics has evolved from conventional plane radiographs to the contemporary cone beam computed tomographs (CBCT) (Linder-Aronson et al., 1979). The transition to CBCT has happened gradually over the years. From conventional plane radiographs, the magnetic resonance imaging (MRI) and computed tomography (CT) were the next big innovations in medical imaging (Al-Saleh et al., 2016). This was adapted to dental field by the innovation of cone beam computed tomography. Currently, CBCT is the popular option for three dimensional radiographs in dentistry and orthodontics (Scarfe et al., 2017). As compared to the previous radiographs like MRI and CT, CBCT requires less radiation and thus the exposure dose to the patient is less. The overall cost of CT scan machine is higher than that of CBCT. These are the reasons why CBCT has become more popular (Saccucci et al., 2015).

2 EMERGENCE OF 3D IMAGING

The three dimensional radiographs such as CBCT provide valuable information regarding the airway dimensions in addition to the regular information regarding the skeletal and dental relationships (van Vlijmen et al., 2012). Different CBCT reconstruction software are available in the market that can help to manipulate the CBCT in three planes (Bianchi et al., 2019). These tools can be used for identification of abnormalities in upper airway and also help to measure the upper airway volume. One of the important applications of such tools is the measurement of upper airway volume and its relation with craniofacial growth, orthognathic surgery, and different orthodontic treatment options.

For this purpose, rapid maxillary expansion (RME) has been evaluated on its dental and skeletal effects with the help of plaster models, to cephalometric radiographs. In many instances, posterior-anterior (PA) cephalometric radiograph has also been used for investigating the effects of rapid maxillary expansion (Sicurezza et al., 2012). The accuracy of lateral cephalograms and PA cephalograms is questionable due to position errors during the recording of the radiographs (Mehta et al., 2020). In a recent study, it was shown that the rotations of the head in pitch, roll and yaw can lead to overestimations of the length of maxilla, mandible, and cervical vertebrae maturation on assessment on plane radiographs. As these radiographs project the structures in two dimensional format, the structures from right and left superimpose onto each other for lateral cephalogram and structures from anterior and posterior superimpose onto each other for PA cephalogram (Mehta et al., 2020). Due to such effects, the assessment of the effects of rapid maxillary expansion on nasal cavity cannot be performed effectively. Whereas, such rotations do not affect CBCT as CBCT projects the structures in three dimensional format..

3 OBSTRUCTIVE SLEEP APNEA (OSA) AND ORTHODONTICS

In orthodontic practice, many patients present with constricted maxilla. This type of malocclusion has been shown to be linked with obstructive sleep apnea (OSA). OSA in children has a rising prevalence (Senaratna et al., 2017). However, OSA is found to result due to a multitude of factors such as obesity, enlargement of adenoids or tonsils, or due to allergic rhinitis. RME is typically used for the treatment of constricted maxilla in preadolescent population (Mehta et al., 2021 a). However, it has some adverse reactions if used in more mature individuals. Consequently, there is a rising interest in mini screw supported rapid maxillary expansion (MARPE) and its effects on maxillary expansion in adolescent or older individuals (Li et al., 2020; Mehta et al., 2021 a). Li et al. have shown that expansion with RME or MARPE can lead to an increase in the airway dimensions and airway volume (Li et al., 2020). This has been proposed to occur due to the higher nasal cavity volume that occurs with expansion by either RME or MARPE as measured on CBCT. It has also been suggested that such rapid expansion of maxilla can help the patients to reposition the tongue in a better manner and this results in a higher volume of oropharynx (Kushida et al., 1997).

4 WHY IS THE FOLLOW UP PERIOD CRITICAL FOR ASSESSMENT OF RESULTS OF EXPANSION ON AIRWAY.

The question is whether expansion with RME or MARPE can cause a higher oral and nasal dimensions and are these changes in the dimensions stable.

Zimmerman et al. have reported that CBCT can be used for accurately measuring the airway dimensions of the patient (Zimmerman et al., 2017). However, there is a lack of follow up in the studies regarding the evaluation of the changes in the airway dimensions following expansion with most studies having a follow up period of 6 months or less (Li et al, 2020; Christovam et al., 2016). A longitudinal study by Mehta et al. in 2021 is the only study that consists of an adequate follow up of 2 years and 8 months (Mehta et al., 2021 b). This study shows that the nasal cavity volume in control group is not different from the patients with RME after follow up period (Mehta et al., 2021 b). The only difference was observed at the end of follow up period was in the MARPE group. The authors in this study concluded MARPE group showed a higher nasopharyngeal volume than RPE group and control group at the end of follow up period (Mehta et al., 2021 b). This study gives us important insights regarding the effects of expansion at long follow up. This means that expansion with MARPE may be better than RME for airway dimensions at follow up.

4.1 does the design of expansion appliances affect airway differently?

Different designs of expansion appliances have been introduced in the orthodontic community. The conventional rapid maxillary expansion design consists of an expander cemented to the maxillary teeth with a bonding agent (Conroy-Piskai et al., 2016). If acrylic covering is performed on the occlusal surfaces of the teeth, then it is known as bonded rapid maxillary expander (Conroy-Piskai et al., 2016; Biondi et al., 2017). The design of expansion appliances with mini screws in the maxillary palate is known as mini screw supported rapid palatal expansion (MARPE or MARME) appliance (Abu Arquib et al., 2021). Such appliances can be designed as pure bone anchored expansion appliance which are connected only to mini screws and not to teeth (Mehta et al., 2021 b). Mini screw supported expansion appliances can also be designed with a combination of bone anchorage and tooth anchorage with expander cemented on the mini screws and the maxillary teeth (Li et al, 2020; Park et al., 2017). Such appliances are known as hybrid bone-tooth borne expansion appliances. Mini screw supported expansion appliances can also be designed to expand the maxillary arch unilaterally (U-MARPE) which are cemented on mini screw on one side of the mid palatal suture and to the maxillary teeth on the other side (Dzingle et al., 2020). All these designs can influence the airway dimensions. As the expansion appliances with diverse designs exert different amount and type of forces on the maxilla, the changes on airway will also be altered (Wang et al., 2017). This should be taken into consideration when evaluating the results of the studies on expansion appliances and their effects on airway.

5 APPLICATION OF CBCT MEASUREMENTS ACROSS THE STUDIES

The assessment of airway volume in a CBCT requires a careful approach of patient positioning, recording the CBCT, reconstruction of CBCT data and measurement of airway volume (Kamaruddin et al., 2019). Head positioning is critical in patients as differences in yaw, pitch, and roll rotations can lead to errors in measurements. In addition, it has been reported that with more severe rotation of head, there is greater errors (Mehta et al., 2020). Thus, the head position used for the acquisition of CBCT is important when evaluating the airway dimensions.

CBCT allows the investigator to measure the three-dimensional airway space and analyze it volumetrically as well identify the minimal cross-sectional area in the airway. Because of this reason, a major consideration for reliability and accuracy of airway measurements is the thresholding. Thresholding and segmentation of the different parts of the airway is critical while observing the changes due to orthodontic treatment interventions. Some studies have used static thresholding for measurement of airway volume. However, such thresholding has not been found to be accurate. Dynamic thresholding, even though required more time, has been reported to be more accurate in the current literature (Alves et al., 2011; Alves et al., 2012; Iannetti et al., 2011; Iwasaki et al., 2011; Mehta et al., 2021 b; Yamashina et al., 2008).

Another effect of rapid maxillary expansion on airway is the positioning of tongue. Iwasaki et al. observed that after RME, the position of tongue was lower compared to before RME (Iwasaki et al., 2013). The authors concluded that these effects contributed to improvement in the nasal airway ventilation with RME. Thus, RME leads to multiple effects on the oropharyngeal structures and the effects on airway are a combination of these factors.

6. CONCLUSION

The use of CBCT for the measurement of airway can be done effectively if proper thresholding and head positioning is performed. Dynamic thresholding can help in identifying the airway dimensions accurately and reliably. The effects of expansion on airway can be influenced by the design of expansion appliances whether conventional design of RME or contemporary design of MARPE. With just one study investigating the effects of expansion on airway in long follow up, more studies are required that can provide results on stability of expansion. Based on limited number of studies, it can be concluded that MARPE can influence airway for longer follow up time than conventional RME design.

2.6 References

The References section lists books, articles, and reports that are cited in the paper. This section does not have a section number. The references are formatted according to APA Style. Examples of the format to be followed are given at the end of this template.

References

- Abu Arqub, S., Mehta, S., Iverson, M. G., Yadav, S., Upadhyay, M., & Almuzian, M. (2021). Does Mini Screw Assisted Rapid Palatal Expansion (MARPE) have an influence on airway and breathing in middle-aged children and adolescents? A systematic review. *International orthodontics*, 19(1), 37–50.
<https://doi.org/10.1016/j.ortho.2021.01.004>.
- Al-Saleh, M. A., Alsufyani, N. A., Saltaji, H., Jaremko, J. L., & Major, P. W. (2016). MRI and CBCT image registration of temporomandibular joint: a systematic review. *Journal of otolaryngology - head & neck surgery = Le Journal d'oto-rhino-laryngologie et de chirurgie cervico-faciale*, 45(1), 30. <https://doi.org/10.1186/s40463-016-0144-4>
- Alves, M., Jr, Baratieri, C., Mattos, C. T., Brunetto, D., Fontes, R., Santos, J. R., & Ruellas, A. C. (2012). Is the airway volume being correctly analyzed?. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, 141(5), 657–661. <https://doi.org/10.1016/j.ajodo.2011.11.019>
- Alves, M., Jr, Baratieri, C., Nojima, L. I., Nojima, M. C., & Ruellas, A. C. (2011). Three-dimensional assessment of pharyngeal airway in nasal- and mouth-breathing children. *International journal of pediatric otorhinolaryngology*, 75(9), 1195–1199. <https://doi.org/10.1016/j.ijporl.2011.06.019>.
- Bianchi, J., Gonçalves, J. R., Ruellas, A., Vimort, J. B., Yatabe, M., Paniagua, B., Hernandez, P., Benavides, E., Soki, F. N., & Cevdanes, L. (2019). Software comparison to analyze bone radiomics from high resolution CBCT scans of mandibular condyles. *Dento maxillo facial radiology*, 48(6), 20190049. <https://doi.org/10.1259/dmfr.20190049>
- Biondi, E., Bandini, A., Lombardo, L., Orlandi, S., Siciliani, G., & Manfredi, C. (2017). Phonetic analysis during treatment with rapid maxillary expander. *Orthodontics & craniofacial research*, 20(1), 21–29. <https://doi.org/10.1111/ocr.12136>

- Christovam, I. O., Lisboa, C. O., Ferreira, D. M., Cury-Saramago, A. A., & Mattos, C. T. (2016). Upper airway dimensions in patients undergoing orthognathic surgery: a systematic review and meta-analysis. *International journal of oral and maxillofacial surgery*, 45(4), 460–471. <https://doi.org/10.1016/j.ijom.2015.10.018>
- Conroy-Piskai, C., Galang-Boquiren, M. T., Obrez, A., Viana, M. G., Oppermann, N., Sanchez, F., Edgren, B., & Kusnoto, B. (2016). Assessment of vertical changes during maxillary expansion using quad helix or bonded rapid maxillary expander. *The Angle orthodontist*, 86(6), 925–933. <https://doi.org/10.2319/112315-799>
- Dzingle, J., Mehta, S., Chen, P. J., & Yadav, S. (2020). Correction of Unilateral Posterior Crossbite with U-MARPE. *Turkish journal of orthodontics*, 33(3), 192–196. <https://doi.org/10.5152/TurkJOrthod.2020.20034>
- Iannetti, G., Polimeni, A., Pagnoni, M., Fadda, M. T., Ramieri, V., Tecco, S., & Festa, F. (2011). Upper airway volume after Le Fort III advancement in subjects with craniofacial malformation. *The Journal of craniofacial surgery*, 22(1), 351–355. <https://doi.org/10.1097/SCS.0b013e3181f7e11b>
- Iwasaki, T., Saitoh, I., Takemoto, Y., Inada, E., Kakuno, E., Kanomi, R., Hayasaki, H., & Yamasaki, Y. (2013). Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: a cone-beam computed tomography study. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, 143(2), 235–245. <https://doi.org/10.1016/j.ajodo.2012.09.014>
- Iwasaki, T., Saitoh, I., Takemoto, Y., Inada, E., Kanomi, R., Hayasaki, H., & Yamasaki, Y. (2011). Evaluation of upper airway obstruction in Class II children with fluid-mechanical simulation. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*, 139(2), e135–e145. <https://doi.org/10.1016/j.ajodo.2010.08.014>
- Kamaruddin, N., Daud, F., Yusof, A., Aziz, M. E., & Rajion, Z. A. (2019). Comparison of automatic airway analysis function of Invivo5 and Romexis software. *PeerJ*, 7, e6319. <https://doi.org/10.7717/peerj.6319>
- Kushida, C. A., Efron, B., & Guilleminault, C. (1997). A predictive morphometric model for the obstructive sleep apnea syndrome. *Annals of internal medicine*, 127(8 Pt 1), 581–587. https://doi.org/10.7326/0003-4819-127-8_part_1-199710150-00001
- Li, Q., Tang, H., Liu, X., Luo, Q., Jiang, Z., Martin, D., & Guo, J. (2020). Comparison of dimensions and volume of upper airway before and after mini-implant assisted rapid maxillary expansion. *The Angle orthodontist*, 90(3), 432–441. <https://doi.org/10.2319/080919-522.1>
- Linder-Aronson S. (1979). Respiratory function in relation to facial morphology and the dentition. *British journal of orthodontics*, 6(2), 59–71. <https://doi.org/10.1179/bjo.6.2.59>
- Mehta, S., Dresner, R., Gandhi, V., Chen, P. J., Allareddy, V., Kuo, C. L., Mu, J., & Yadav, S. (2020). Effect of positional errors on the accuracy of cervical vertebrae maturation assessment using CBCT and lateral cephalograms. *Journal of the World federation of orthodontists*, 9(4), 146–154. <https://doi.org/10.1016/j.ejwf.2020.09.006>
- Mehta, S., Chen, P. J., Vich, M. L., Upadhyay, M., Tadinada, A., & Yadav, S. (2021). Bone-anchored versus tooth-anchored expansion appliances: Long-term effects on the condyle-fossa relationship. *Journal of the World federation of orthodontists*, S2212-4438(21)00031-X. Advance online publication. <https://doi.org/10.1016/j.ejwf.2021.07.001>
- Mehta, S., Wang, D., Kuo, C. L., Mu, J., Vich, M. L., Allareddy, V., Tadinada, A., & Yadav, S. (2021). Long-term effects of mini-screw-assisted rapid palatal expansion on airway. *The Angle orthodontist*, 91(2), 195–205. <https://doi.org/10.2319/062520-586.1>
- Park, J. J., Park, Y. C., Lee, K. J., Cha, J. Y., Tahk, J. H., & Choi, Y. J. (2017). Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion in young adults: A cone-beam computed tomography study. *Korean journal of orthodontics*, 47(2), 77–86. <https://doi.org/10.4041/kjod.2017.47.2.77>
- Saccucci, M., Cipriani, F., Carderi, S., Di Carlo, G., D'Attilio, M., Rodolfo, D., Festa, F., & Polimeni, A. (2015). Gender assessment through three-dimensional analysis of maxillary sinuses by means of cone beam computed tomography. *European review for medical and pharmacological sciences*, 19(2), 185–193.

- Scarfe, W. C., Azevedo, B., Toghyani, S., & Farman, A. G. (2017). Cone Beam Computed Tomographic imaging in orthodontics. *Australian dental journal*, 62 Suppl 1, 33–50. <https://doi.org/10.1111/adj.12479>
- Senaratna, C. V., Perret, J. L., Lodge, C. J., Lowe, A. J., Campbell, B. E., Matheson, M. C., Hamilton, G. S., & Dharmage, S. C. (2017). Prevalence of obstructive sleep apnea in the general population: A systematic review. *Sleep medicine reviews*, 34, 70–81. <https://doi.org/10.1016/j.smrv.2016.07.002>
- Sicurezza, E., Greco, M., Giordano, D., Maiorana, F., & Leonardi, R. (2012). Accuracy of landmark identification on postero-anterior cephalograms. *Progress in orthodontics*, 13(2), 132–140. <https://doi.org/10.1016/j.pio.2011.10.003>
- van Vlijmen, O. J., Kuijpers, M. A., Bergé, S. J., Schols, J. G., Maal, T. J., Breuning, H., & Kuijpers-Jagtman, A. M. (2012). Evidence supporting the use of cone-beam computed tomography in orthodontics. *Journal of the American Dental Association* (1939), 143(3), 241–252. <https://doi.org/10.14219/jada.archive.2012.0148>.
- Wang, M. H., Ge, Z. L., Tian, L., Li, P. R., & Che, Y. Q. (2017). *Zhonghua kou qiang yi xue za zhi* = *Zhonghua kouqiang yixue zazhi* = Chinese journal of stomatology, 52(11), 678–683. <https://doi.org/10.3760/cma.j.issn.1002-0098.2017.11.006>
- Yamashina, A., Tanimoto, K., Sutthiprapaporn, P., & Hayakawa, Y. (2008). The reliability of computed tomography (CT) values and dimensional measurements of the oropharyngeal region using cone beam CT: comparison with multidetector CT. *Dento maxillo facial radiology*, 37(5), 245–251. <https://doi.org/10.1259/dmfr/45926904>.
- Zimmerman, J. N., Lee, J., & Pliska, B. T. (2017). Reliability of upper pharyngeal airway assessment using dental CBCT: a systematic review. *European journal of orthodontics*, 39(5), 489–496. <https://doi.org/10.1093/ejo/cjw079>