

Orthodontic Movement through the Maxillary Sinus

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ABSTRACT

The maxillary sinus (MS) , the largest of the paranasal sinuses, begins to develop at the ethmoidal infundibulum in the third month of fetal life. The maxillary sinus floor (MSF) consists of a thin bony plate covered with a layer of mucosa. Intrusion or bodily movement of the teeth across the sinus floor by orthodontic treatment have been shown to cause moderate apical root resorption and higher degree of tipping. Therefore, the aim of this review was to investigate orthodontic tooth movement through the maxillary sinus.

Keywords: Orthodontics, Tooth movement , Maxillary Sinus, Maxillary Sinus Floor

INTRODUCTION

The maxillary sinus (MS) , the largest of the paranasal sinuses, begins to develop at the ethmoidal infundibulum in the third month of fetal life.¹ After birth, it undergoes rapid growth, extending both laterally and inferiorly, during the first 3 years and from 7 to 12 years of age. Its dimension is approximately 3*6*8 mm, and ends its growth in a pyramid shape in adults. The maxillary sinus floor (MSF) consists of a thin bony plate covered with a layer of mucosa.²⁻⁵ With pneumatization and aging, the floor extends into the posterior alveolar process and forms the alveolar recess, creating protrusions of root apices into the sinus. Generally, the MSF is at the level of nasal floor at puberty and in approximately 50% of the adult population, the sinus invades the maxillary alveolar process, coming in close proximity to the roots of the second premolar and the first and second permanent molars. Occasionally, the sinus floor can extend as far as the region of the canine root. Tooth roots that protrude into the maxillary sinus can cause complications in extractions, implantation, endodontic procedures, and orthodontic mechanics. Orthodontic intrusion and bodily movement of teeth across the sinus floor have been found to cause moderate apical root resorption and variable degrees of tipping in experimental and clinical studies. To date, the interaction of maxillary sinus development and posterior tooth axial inclinations has not been assessed longitudinally in orthodontic patients. An anatomical description and relationship between the root apex of the maxillary tooth and the inferior wall of the maxillary sinus are essential for diagnosing sinus pathoses and planning a proper dental implantation. Therefore identifying the degree of proximity as well as the cortical thickness between the root apex and the inferior wall of the sinus is useful for surgical procedures.⁵⁻¹⁰

Tooth roots that protrude into the maxillary sinus can have various implications, including the following:¹¹⁻¹⁵

1. Implants

Wehrbein and diedrich described a positive correlation between the length of the root projection on the maxillary sinus in panoramic radiograph and the amount of pneumatization after extraction. Sinus expansion after extraction can greatly decrease the bone height available for the implant placement.

2. Extraction complication

Oroantral fistulae or root displacement into the sinus cavity are a frequent complications after extraction of the first and second molars.

3. Endo antral syndrome

In endoantral syndrome, the spread of pulpal disease beyond the confines of the dental supporting tissues into the maxillary sinus causing sinusitis may be present.

4. Orthodontics

Intrusion or bodily movement of the teeth across the sinus floor by orthodontic treatment have been shown to cause moderate apical root resorption and higher degree of tipping. Therefore, the aim of this review was to investigate orthodontic tooth movement through the maxillary sinus.

Size of The Maxillary Sinus In Orthodontic Treatment

When it comes to the clinical significance, the size of the maxillary sinus is closely linked to the orthodontic movement of the posterior teeth and the placing of mini-screws because of the maxillary sinus and the posterior teeth are adjacent.¹⁵⁻²⁰ Therefore, the size of the maxillary sinus has a specific impact on clinical orthodontic treatment. If the average volume of the maxillary sinus is larger in low angle patients, we should be more careful in moving the posterior maxillary teeth, especially when treating without CBCT. Besides, the extended development of the mandible can continue until 18 to 20 years old,¹⁶ which became the leading cause of relapse of non-surgical masking therapy of Class III. On the other hand, the maxillary sinus of adolescents aged 12 to 15 have approximately grown to the size of an adult. So if the maxillary sinus is correlated with mandible, it can be used to predict the growth trend and increment of the mandible to some extent, and it has specific clinical significance for such Class III patients.¹⁷⁻¹⁹

Lengths and Widths Of The Maxillary Sinus In Orthodontic Treatment

Okşayan¹¹ found that the maxillary sinus lengths and widths were shorter in patients with a high angle, but there was no significant correlation between the volume and vertical growth patterns. However, our research found that the maxillary sinus length, width, and volume of high angle patients were smaller than those of low angle patients. Therefore, the conclusions of these two studies are basically the same, and the discrepancy is perhaps due to the age range of the patients included. The average age of patients enrolled by Okşayan was 29.90 ± 10.91 , which was much wider. Although, in general, the development of the maxillary sinus has reached the size of an adult at the age of 15, many physiological and pathological factors affect the volume of maxillary sinus over time.²⁰⁻²⁵ Considering that the growth of the mandible lasts 18 to 20 years¹⁶, the age of the patients included in this study was 15 to 20 years old, in order to match the longitudinal growth of the mandible and its correlation with the maxillary sinus. Therefore, the ages of included patients probably lead to the support of distinction in the results of these studies. For the sagittal analyses between the craniofacial bones and maxillary sinus, previous studies were controversial. Oktay⁹ found that the maxillary sinuses of females with Class II were relatively larger. Moreover, Weng Jiahua²¹ and Dah-Jouonzo²⁴ also found that the maxillary sinus is larger in patients with skeletal Class II. Traditional two-dimensional planar radiographic pictures lose much information, omitting the perspective from the third dimension.²⁵ However, three-dimensional digital cone-beam CT (CBCT) has many advantages compared with previous technologies, such as lower radiation, shorter imaging time, low cost,^{26, 27} and relatively complete maxillary sinus information. Meanwhile, the prediction of mandibular growth is intractable, but quite a crucial issue. Because in clinical practice, the cause of recurrences in many adolescents with skeletal Class III is the continued growth of the mandible after orthodontic treatment.¹⁷ At present, even the most classic prediction of the mandibular growth using the wrist radiograph is not effective enough.²⁸ Hand-wrist radiographs can predict the peak of growth and development, but there is no significant correlation with the quantity of mandibular growth.²⁹ The cervical vertebral maturation (CVM) method could not validly predict the mandibular growth peak.³⁰ Research indicate that the maxillary sinus is larger in low

angle patients. Therefore, low angle patients need a more careful evaluation of the shape and size of the maxillary sinus when implanting mini-screws in the maxilla or moving the posterior maxillary teeth to avoid penetrating the maxillary sinus.³¹ At the same time, some study results indicate that the volume of the maxillary sinus is positively correlated with the length of mandible. Therefore, for adolescent patients who are skeletal Class III with larger maxillary sinus volume, the possibility of further development of the mandible after orthodontic treatment is higher, and the possibility of recurrence is correspondingly increased. These possibilities mean that orthognathic surgery for this type of skeletal Class III patient might be more appropriate as a treatment selection.

Magnitude Of Forces

For tooth movement in the sagittal direction, all authors reported distal or mesial bodily movement of the target teeth. Cacciafesta et al.³², Re et al.³³, Oh et al.³⁴, Park et al.³⁵ and Kuroda et al.³⁶ revealed that the overall translation consisted of processes of initial tipping followed by up-righting. Saglam et al.³⁷ and Carvalho et al.³⁸ described distal bodily movement of the second premolars, but no details were provided in their reports. For molar intrusion into the MS, Yao et al. reported intrusion of tooth numbers 26 and 27 with slight distal tipping³⁹, while Kravitz et al. reported intrusion of tooth number 16 with palatal crown tipping⁴⁰.

Duration And Rate Of Tooth Movement

For tooth movement in the vertical direction, 3-mm intrusion in 5 months and 4.4-mm intrusion in 6 months for molars were reported by Yao et al. and Kravitz et al., respectively.^{39,40} Overall, for molar intrusion into the MS, the individual cases showed a rate of 0.6–0.7 mm/month, and for distal-mesial movement, rates of 0.16–1.17 and 0.05–0.16 mm/month were reported for premolars and molars, respectively.

Alveolar Bone Formation and Remolding Of the Sinus Floor

Re et al.³³, Saglam et al.³⁷, and Carvalho et al.³⁸ moved the second premolars distally through the MS with pneumatization into the alveolar bone. Alveolar bone formation occurred in the moving direction, along with direct remolding of the sinus lamina dura and sinus lift, and implants were subsequently inserted in the previous positions of the second premolars. Likewise, alveolar bone formation was observed in the studies of Cacciafesta et al.³² and Oh et al.³⁴, and signs of sinus wall modeling were also observed in Oh et al.'s study. In terms of molar intrusion, Yao et al. and Kravitz et al. found that the lamina dura followed the course of molar intrusion, and bone remolding during intrusion was achieved in Yao et al.'s case.^{39,40}

Safety and Side Effects

First, radiographically evident OIRR was reported by Cacciafesta et al.³², Park et al.³⁵ and Carvalho et al.,³⁸ whereas no apparent OIRR was reported by Kravitz et al., Oh et al.^{39,40} Second, no perforation of the sinus floor or loss of pulp vitality was reported in the 9 cases. Third, standard periodontal control measures were adapted by Cacciafesta et al.,³² Re et al.,³³ Oh et al.,³⁴ and Saglam et al.³⁷, and they reported that bone support and periodontal health were maintained.

Discussion

This review intended to determine the feasibility, safety and stability of current interventions for orthodontic movement through the maxillary sinus. However, the difficulty of the moving process varied substantially, possibly indicating the heterogeneity among clinical measures and internal anatomic structures and the inherent bias of case reports. The key biomechanical objective is uniform distribution of orthodontic forces along the Periodontal Ligament (PDL) and the line of the active force passing through the centre of resistance^{29,30}. Considering the anatomic variability of the MSF, techniques for better control in three dimensions should be developed, especially for patients with primarily regional complaints. To achieve tooth movement by frontal resorption, mild and constant forces (35–60 g, 70–120 g and 10–20 g for tipping, bodily and intrusion movement, respectively) are recommended. However, considering the amount of resistance in sliding mechanics^{9,30} the decay rate of forces and the root numbers of the posterior teeth, the magnitude of 50–200 g of force applied in the included cases seems safe. Most cases showed initial stages

of tipping through the MS, which is consistent with a previous study . Deviation from ideal bodily movement may reflect expression of a well-designed pure Newtonian mathematical force system applied on the in vivo PDL. Orthodontic forces are derived from deformation of some parts of existing appliances; however, each appliance has a particular load deflection rate, and the decay rates of the counterparts (i.e., the moment of force and the moment of couple) in the equilibrium system are not equal, and consequently, the moment to force ratio constantly changes, resulting in constant changes in the center of rotation and difficulty in maintaining translation. Moreover, in the MS, the distribution of bone density along the axis of a tooth must be considered.^{8,15} The coronal part of the root is more likely to move against cancellous bone while the apical part is more likely to move against cortical bone. Therefore, the tooth is easily tipped toward the moving direction. Furthermore, for molar intrusion, the accompanying tipping may reflect different resistances among roots. Moving at low speeds is a prerequisite for compensatory bone regeneration.¹⁷⁻²² Therefore, applying light and continuous forces is the best strategy to achieve the ideal speed for moving teeth. In the past few decades, the development of implant sites with the help of orthodontic tooth movement has been shown to be practical,³⁶ and in several cases, this technique was successfully applied in the MS area. One major concern, however, is maintaining the intact membrane of the sinus floor. First, in surgical sinus augmentation procedures, the floor is mechanically and instantaneously lifted by applying graft materials or alveolar bone blocks. This shows the endurance and reparability of the sinus floor as it may adapt to slow and mild tooth movement. Second, recent studies have revealed that under stressful stimulation, bone deposition on the sinus side preceded resorption on the PDL side, and the amount of bone in the sinus wall was maintained or increased. This mechanism may partially account for bone remodeling of the sinus floor. For retention,³⁰⁻⁴⁰ wrap-around or bonded retainers were mainly used for the maxillary teeth, and implants and subsequent prosthetic crowns were installed adjacent to or opposing the moved teeth.

Conclusion

Lastly, during orthodontic tooth movement, some side effects such as severe root resorption, osseous perforation, and sinus perforation may be beyond orthodontists' control. These cannot be macroscopically or radiologically detected but can be verified histologically. Clinicians should determine accurate diagnoses with consideration of anatomical structures before treatment, execute careful protocols, and conduct progress evaluations throughout treatment

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