

Space closure in the maxillary posterior area through the maxillary sinus

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A common dilemma in adult orthodontic treatment is deciding how best to treat missing posterior teeth. One treatment option is to orthodontically close the space. But closure can be difficult, especially if the open space is in the maxillary posterior area, because tooth movement through the maxillary sinus is limited. The increased difficulty of moving teeth in the maxillary sinus is similar to moving a tooth in the atrophic posterior mandibular ridge. If space closure is selected as a treatment method, proper mechanics and light forces should be applied. In this article, we report movement of teeth through the maxillary sinus and discuss various implications related to orthodontic treatment in the maxillary sinus. (*Am J Orthod Dentofacial Orthop* 2014;145:95-102)

The maxillary sinus, located in the body of the maxilla, is the largest and the first of the paranasal sinuses to develop. The development of the maxillary sinus starts about the third month of fetal life and ends its growth around 20 years of age with the eruption of the third molars.^{1,2} The maxillary sinus is typically pyramidal in shape with the base of the pyramid being the nasal antral wall, and its apex extending into the zygoma. It can be considered as having 3 walls, a floor, and a roof. The roof of the sinus is the floor of the orbit, and its floor is the alveolar process of the maxilla.³ The floor of the maxillary sinus is similar to cortical bone because it is a layer of compact bone lined with the periosteum.⁴

In adults, the size of the maxillary sinus is variable in its extension. Its floor extends between adjacent teeth or individual roots in about half of the population, creating elevations in the antral surface or protrusions of root apices into the sinus.^{4,5} In these cases, the thickness of the sinus floor is noticeably reduced. According to a histologic study by Wehrbein and Diedrich,⁶ most roots

that protrude radiographically into the sinus are actually enveloped by a thin cortical layer with perforations in 14% to 28% of the cases.

Maxillary premolar, molar, and occasionally canine roots can project into the maxillary sinus.⁷ Kwak et al⁸ reported that the topographic anatomy of the root apices of the maxillary molars are located closer to the inferior wall of the sinus than the premolar root apices. The distance from the root apex to the inferior sinus wall is the shortest in the second molar area.^{8,9} In orthodontics, when tooth roots protrude into the maxillary sinus, they can cause moderate apical root resorption and greater tipping during intrusive or horizontal movement of teeth across the sinus floor.¹⁰

This case report presents a man, age 31 years 1 month, with maxillary sinus pneumatization from previous extractions. He was treated with bodily movement of teeth through the sinus floor.

CASE REPORT

A male patient, age 31 years 1 month, was referred to the clinic in Okayama, Japan, for evaluation of space closing of his missing teeth. He had a convex profile and a Class II skeletal pattern. He was in good general health and had no history of major systemic diseases or dental trauma. He reportedly had had 3 premolars extracted in preparation for orthodontic treatment when he was an adolescent but did not follow through with treatment because he could not afford it at that time.

He was missing 2 maxillary second premolars and the mandibular right first premolar. He had a deep overbite and a 5.5-mm overjet with a Class I molar relationship on the right side and a full Class II molar relationship on the left side, along with a mesiolingual rotation of his

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.

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Submitted, December 2011; revised and accepted, July 2012.

0889-5406/\$36.00

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<http://dx.doi.org/10.1016/j.ajodo.2012.07.020>



Fig 1. Pretreatment intraoral photographs.

maxillary first molars. He also had a Class II canine relationship on both sides (Fig 1).

A panoramic radiograph showed no caries, and all third molars were present except for the mandibular right third molar. Some areas demonstrated blunted and short root apices. The maxillary first molars were tilted mesially. There was postextraction sinus pneumatization in both maxillary second premolar areas (Fig 2).¹¹ The relationship between the roots of the maxillary posterior teeth and the maxillary sinus was assessed by using cone-beam computed tomography (CBCT) (Fig 3).

The treatment objectives were to obtain normal overbite and overjet, establish a Class I canine relationship, and close the spaces where the extracted teeth had been in the maxillary arch, with acceptable root parallelism.

After the initial orthodontic consultation, the patient was referred to an oral surgeon to extract all third molars. However, he wanted to have his third molars extracted after the leveling stage. Preadjusted appliances with 0.022-in self-ligating brackets (In-Ovation; GAC, Bohemia, NY) were bonded for leveling and alignment. The maxillary arch was leveled with continuous archwires, starting with 0.014-in nickel-titanium and working up to 0.019 × 0.025-in beta-titanium with 0.016 × 0.022-in titanium molybdenum alloy intrusion archwires (Fig 4).¹²

After 6 months of treatment, when the anterior bite was open, 0.022-in self-ligating brackets were bonded on the mandibular anterior segment. After 8 months of treatment, the patient chose skeletal anchorage system treatment to solve his dental problems.¹³⁻¹⁶ The skeletal anchorage system is composed of titanium anchor plates and monocortical screws that are temporarily placed in the jaw as absolute orthodontic anchorage.¹³⁻¹⁶ A Y-shaped anchor plate (Orthoanchor SMAP; Dentsply-Sankin, Tokyo, Japan) was bilaterally implanted at the zygomatic buttresses, and skeletal anchorage system mechanics were applied to upright the maxillary first molars and distalize the maxillary canines and first premolars.¹³⁻¹⁶ After approximately 1 year of skeletal anchorage system treatment, he finally



Fig 2. Pretreatment panoramic radiograph.

had all his third molars extracted. The remaining maxillary anterior teeth were retracted with a T-loop while maintaining maximum anchorage on the posterior segments with the skeletal anchorage system (Fig 5). During the finishing stage, final detailing of the occlusion was accomplished with 0.016 × 0.022-in steel archwires in conjunction with posterior up-and-down elastics (Fig 6).

Fixed retainers were placed from canine to canine in the mandible and from lateral incisor to lateral incisor in the maxilla after debonding. Wraparound removable retainers were also delivered to secure the stability of both arches. Total treatment time for this patient was 30 months.

The posttreatment records indicate that the treatment objectives were achieved. A Class I canine relationship was established with a canine-protected occlusion, and acceptable overbite and overjet were achieved. The posterior spaces were successfully closed (Fig 7).

The posttreatment panoramic radiograph shows proper space closure and acceptable root parallelism. There were no significant signs of bone resorption compared with pretreatment. However, some areas showed signs of apical root resorption (Fig 8).

At the 1-year follow-up, the patient had a stable occlusion, and the orthodontic treatment results were maintained (Fig 9). A 3-dimensional radiograph shows fairly stable results (Fig 10).

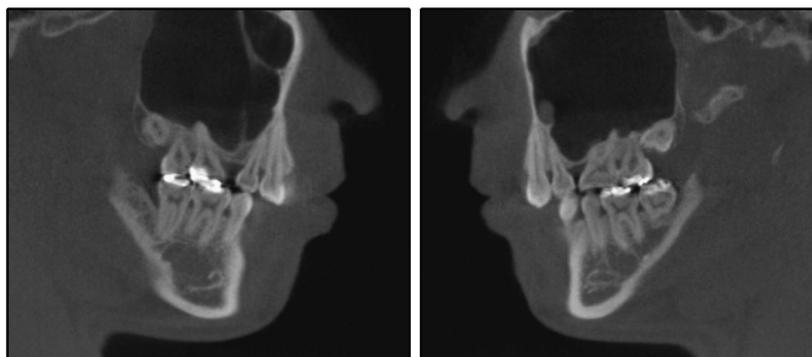


Fig 3. CBCT images showing postextraction maxillary sinus pneumatization in both maxillary second premolar areas.



Fig 4. Intraoral photographs showing the maxillary intrusion arch in place.



Fig 5. The maxillary arch space was closed with T-loops while maintaining maximum anchorage on the posterior segments with a skeletal anchorage system.

DISCUSSION

The shape and size of the maxillary sinuses can change because of many factors. One of the most common causes is when maxillary posterior teeth are extracted. This causes an inferior expansion of the maxillary sinus and leads to pneumatization of the sinus.¹¹

Pneumatization is a physiologic process that occurs in all paranasal sinuses during the growth period, causing them to increase in volume.^{17,18} Pneumatization of the sinus after extractions is an important consideration for diagnosis and treatment planning for dental implants, endodontic procedures,

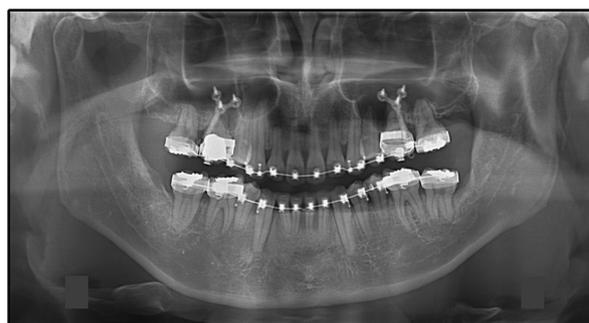


Fig 6. Panoramic radiograph showing the detailing stage of treatment.



Fig 7. Posttreatment intraoral photographs.



Fig 8. Posttreatment panoramic radiograph.

and orthodontic treatment.⁸ Wehrbein and Diedrich⁶ described a positive correlation between the length of root projection into the maxillary sinus as observed on panoramic radiographs and the amount of pneumatization after extraction. Sharan and Madjar¹¹ reported that extraction of the maxillary second molars led to greater expansion than did extraction of the maxillary first molars. They also reported that extractions of 2 or more adjacent posterior teeth caused greater sinus expansion.

Pneumatization of the maxillary sinus also occurs when mandibular posterior teeth have been missing for a long time, resulting in overeruption of the opposing maxillary posterior teeth. In such situations, orthodontic molar intrusion with temporary anchorage devices might prevent invasive prosthodontic reduction with root canal treatment or posterior segmental osteotomy and thereby successfully intrude the maxillary posterior teeth through the maxillary sinus cortical floor.¹⁹⁻²²

The relationship between the roots of the maxillary posterior teeth and the maxillary sinus can be assessed by various techniques such as panoramic radiography and CBCT. Panoramic radiography is a commonly used imaging technique in dentistry because it allows visualization of various anatomic structures, is low cost, and has wide availability. It does have disadvantages that include convoluted images caused by superimposed anatomic structures, horizontal and vertical

magnification, and a lack of cross-sectional information.^{1,23,24} CBCT overcomes these limitations by providing multiplanar images with uniform low magnification, but it has disadvantages that include higher doses of radiation, high cost, and limited availability.^{25,26} In our case study, the anatomic correlation between the dental roots and the alveolar bone was examined with both panoramic radiography and CBCT.

The topography of the inferior wall with the maxillary root apices varies according to a patient's age, size, amount of pneumatization of the maxillary sinus, and status of dental retention.³ The thickness of the inferior wall of the sinus and its relationship with the adjacent teeth is crucial for orthodontic tooth movement.^{8,10} This information provides a basis for the application of appropriate forces in orthodontic tooth movement and predicting the amount of tooth movement through the maxillary sinus.

Knowledge of the cortical thickness of the buccal and palatal alveolar plates plus the inferior wall thickness of the maxillary sinus is important in periapical surgery or dental implantation. Kwak et al⁸ reported that the distance between the apex of the buccal root and the buccal alveolar plate was shortest in the maxillary first premolar area and longest on the mesiobuccal root in the maxillary second molar area.

Considering the topographic anatomy of the maxillary sinus, it is still debatable whether orthodontic movement can be done through the dense cortical bone of the maxillary sinus. Wehrbein et al¹⁰ reported that orthodontic movement through the maxillary sinus was limited, but other authors reported that teeth can move through the anatomic limitations such as cortical bone, suture, or sinus.^{27,28}

From our study, the representative CBCT scans showed the following: the axial section images were obtained by making a cut at the maxillary first molar cemento-enamel junction level. Red and blue color images show pretreatment and posttreatment, respectively. Tooth movement was demonstrated by



Fig 9. One-year posttreatment intraoral photographs.

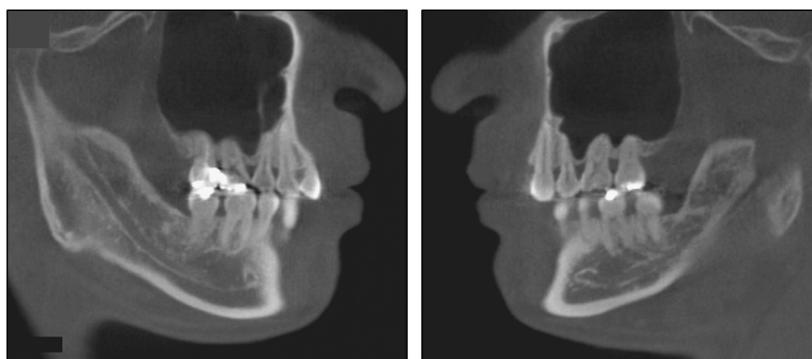


Fig 10. One-year posttreatment CBCT images showing space closure in the maxillary posterior area through the maxillary sinus.

superimposing the pretreatment and posttreatment images.²⁹⁻³¹ According to this, the first molars rotated mesially and moved slightly forward through the maxillary sinus, whereas the first premolars moved distally (Fig 11, A-C).

The coronal section images were obtained at the center of the maxillary first molars. The differences between first molar root and crown positions are the result of changes in inclination and rotation. According to the superimposition, the first molars were rotated mesially and uprighted (Fig 11, D-F).²⁹⁻³¹ As for the maxillary first premolars, a clear difference between before and after could not be seen in the CBCT images.

From the volume-rendering 3-dimensional sagittal images, the maxillary first premolars were uprighted slightly and moved distally. Also, the first molar moved mesially and was uprighted. Since we are showing just 1 patient, we are definitely not in the position to conclude one way or the other; yet in this case, from our CBCT observation, the floor of the sinus did not displace coronally during orthodontic approximation of these teeth (Fig 11, G-I).

Bone is a complex mineralized tissue that is constantly adapting to structural and metabolic changes. Roberts et al³² stated that modeling changes

the size and shape of bones in response to mechanical loading, whereas remodeling is the turnover of bone that is related to bone maturation and mineral metabolism. Therefore, orthodontic tooth movement occurs by a bone modeling phenomenon, and the biologic balance of bone structures occurs by bone remodeling as a physiologic process.

Tooth movement through the maxillary sinus is another example of tooth movement through bone. In orthodontically induced tooth movement, the moving root is displaced in the cortical bone by frontal and undermining resorption. In this process, there is a balance between bone resorption and apposition in response to orthodontic forces. The modeling and remodeling mechanisms can readily adapt to changes in the mechanical loading of the alveolar bone.³³

Orthodontic tooth movement causes a coordinated bone modeling and remodeling reaction in both trabecular and cortical bone.³³ Generally, osteoclasts open resorption cavities, and osteoblasts fill them with new bone. In orthodontic treatment, the efficiency of bone resorption dictates the rate of tooth movement, and bone remodeling can substantially contribute to resorption efficiency.³³ Reitan^{34,35} demonstrated that during orthodontic tooth movement, bone around the

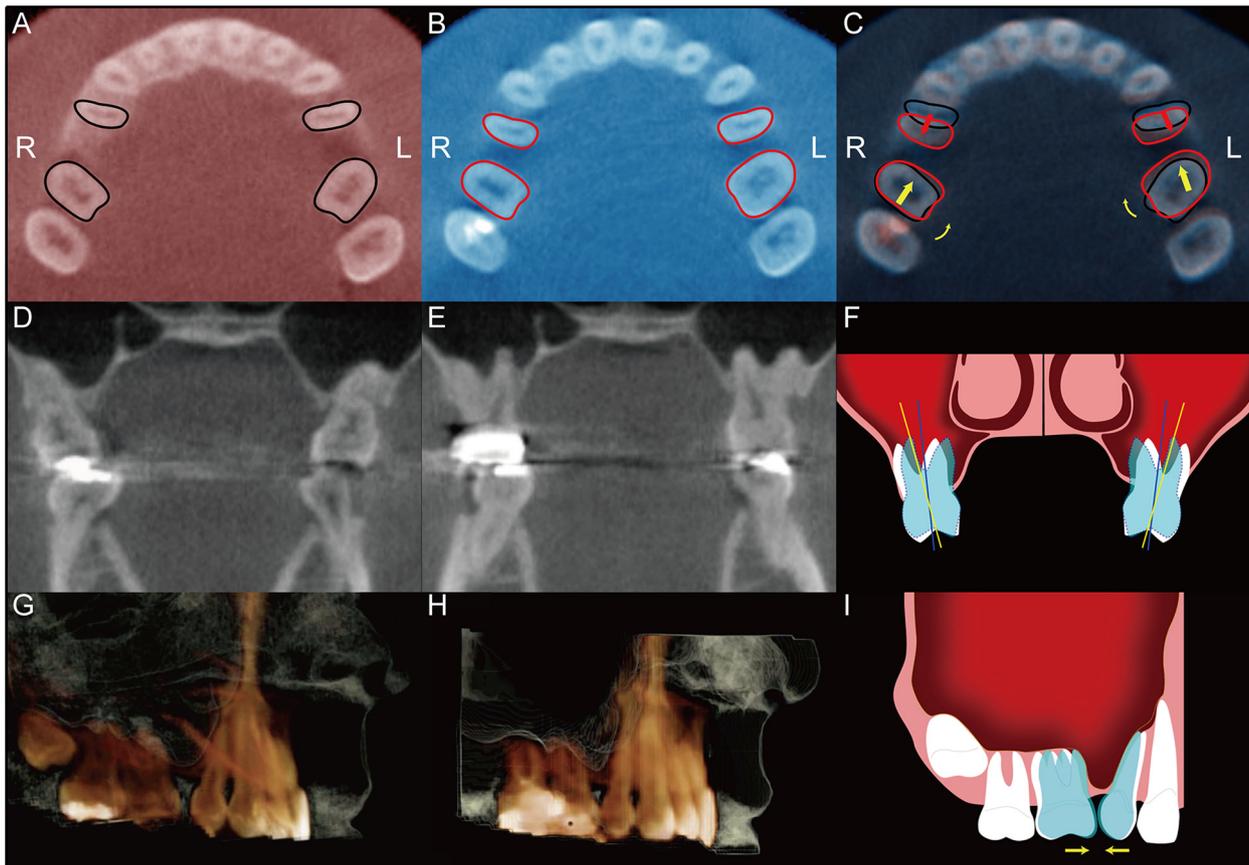


Fig 11. Representative CBCT images and illustrations showing maxillary posterior tooth movement through the maxillary sinus: **A-C**, CBCT axial sections at pretreatment and posttreatment, and their superimposition, respectively, at the cemento-enamel level of the maxillary first molars; **D-F**, coronal sections of the pretreatment and posttreatment images, and their superimposition, respectively; **G-I**, sagittal volume-rendering scans of the pretreatment and posttreatment images, and their superimposition, respectively.

alveolar socket remodels to the extent that the teeth have moved in the bone: ie, a 1:1 ratio of bone remodeling to tooth movement. On the other hand, Vardimon et al³⁶ recommended using a 1:2 bone remodeling to tooth movement ratio as a guideline to determine the optimal range of orthodontic tooth movement during maxillary incisor retraction.

To move the target tooth bodily, light and continuous force passing near the center of resistance is required. Re et al²⁷ reported that segmented archwire mechanics with a 0.017 × 0.025-in beta-titanium alloy T-loop can move a tooth through the maxillary sinus at a rate of approximately 1 mm per month by using a 50-g per millimeter load-deflection rate. Melsen³⁷ stated that the limitation of tooth movement through the maxillary sinus is hindered by improper selection of a force system for tooth movement and stressed correct force distribution.

When maxillary posterior teeth have been extracted, orthodontists want to accomplish bodily movement of adjacent teeth to close the extraction spaces. Wehrbein et al¹⁰ stated that bodily or tipping movement through the maxillary sinus depends on the morphology of the sinus. They demonstrated that if there is a more vertical extension of the basal maxillary sinus in front of the tooth to be moved, greater tipping was accomplished than with teeth moved through a more horizontal maxillary sinus base. This should be considered when planning orthodontic space closure in the maxillary posterior region.

With orthodontic movement through the sinus, we must also consider root resorption. When maxillary molars were moved through the sinus, the 2-dimensional radiographic images showed minimal root resorption.^{19,22,38} However, histologic tissue changes were substantially more pronounced than with radiographic

observation.³⁹ Wehrbein et al⁴⁰ also reported that periapical root resorption in maxillary molars that were moved through the sinus could be verified histologically, but it could not be detected radiologically. Root blunting is a common type of root resorption and is usually corrected by formation of cementum.⁴¹ Currently, however, there are no reliable markers to predict which patients might develop apical root resorption or the severity of the apical root resorption after orthodontic tooth movement.^{42,43} Excessively frequent activation of orthodontic appliances interferes with the normal process of breakdown and repair during root remodeling,⁴⁴ so a longer interval between adjustments is suggested.⁴⁵ Because roots do not respond the same way in all patients, a light and continuous force is recommended to reduce iatrogenic root resorption during orthodontic treatment through the maxillary sinus.

CONCLUSIONS

Spaces from tooth extractions can be closed by bodily movement through anatomic barriers such as the maxillary sinus, but in view of the proximity of the maxillary sinus floor and maxillary root tips, orthodontists must be particularly cautious when doing this. Before attempting orthodontic tooth movement, various anatomic characteristics and relationships between the inferior wall of the maxillary sinus and its surrounding structures must be carefully evaluated.

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