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Orthodontic tooth movement through maxillary sinus

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เนื่องด้วยความต้องการการรักษาทางทันตกรรมจัดฟันในผู้ใหญ่ที่เพิ่มมากขึ้น ทำให้ทันตแพทย์จัดฟันต้องพบปัญหาหลายอย่างที่ต่างจากการจัดฟันในเด็กวัยรุ่น การสูญเสียฟันหลังเป็นภาวะหนึ่งที่พบได้บ่อยในผู้ใหญ่ การให้การรักษาทางทันตกรรมจัดฟันเพื่อปิดช่องว่างในฟันหลังบนหรือเพื่อดันฟันหลังบนเข้าในเบ้าฟันก่อนการใส่ฟันปลอมในขากรรไกรล่าง มักพบปัญหาการห้อยย้อยของโพรงอากาศขากรรไกรบน ซึ่งอาจกลายเป็นปัญหาขัดขวางการเคลื่อนฟันได้ แต่อย่างไรก็ตามพบว่าหากเลือกใช้แรงและชีวกลศาสตร์ที่เหมาะสม ก็สามารถเคลื่อนฟันผ่านโพรงอากาศขากรรไกรบนได้ สำหรับบทฟื้นฟูวิชาการนี้จะเน้นประเด็นปัญหาของโพรงอากาศขากรรไกรบนต่อการเคลื่อนฟันทางทันตกรรมจัดฟัน ชีวกลศาสตร์ การตอบสนองทางมิชญวิทยา ปัจจัยเสี่ยงและภาวะแทรกซ้อนที่เกี่ยวข้อง

With the markly increased demand of adult orthodontic, orthodontists often face different problems from teenager patients. One of the most common problems is loss of posterior teeth. Orthodontic tooth movement for space closure in maxillary posterior area or intrusion of maxillary molar prior lower posterior prosthesis construction often faced pneumatization of maxillary sinus. The pneumatization of maxillary sinus may interfere orthodontic tooth movement. However, if proper force and mechanic are applied, tooth movement through maxillary sinus can be achieved. This review focuses on problem of pneumatization of maxillary sinus for orthodontic tooth movement, biomechanics, histological response, risk and complication.

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Introduction

With the markly increased demand of adult orthodontic, orthodontists often face different problems from teenager patients. Several authors had mentioned about the limitation of orthodontic treatment in adult[1,2]. One of the most common problems for adult patient is tooth movement into compromised bone area[3]. The compromised bone area can be result from edentulous alveolar ridge due to previous extraction. This is a challenging situation for orthodontist, especially when maxillary first molar have been extracted and orthodontics treatments is now need to upright maxillary second molar or even close extraction space by mesial movement of maxillary second molar. In this situation, orthodontist must face the difficulty of tooth movement with atrophy of alveolar ridge and pneumatization of maxillary sinus. In case of pneumatization of maxillary sinus is present, it can be considered as anatomical limitation set by cortical bone.

The maxillary sinus is the largest of paranasal sinus within the skull bone. It is developed late in fetal life and ends its growth approximately 20 years of age with the eruption of the third molars[4,5]. The floor of maxillary sinus is similar to

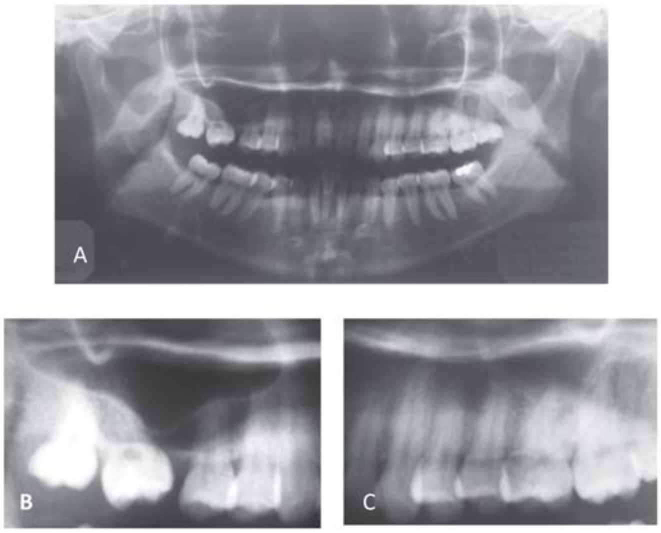

Figure 1 Radiographic image showed pneumatization on the right side after maxillary first molar had been extracted (A). Comparing the level of sinuses floor between right and left sides in the same patient (B-C).

the cortical bone, because it is a layer of compact bone lining with periosteum[6]. Topographic images showed that the root apices of maxillary molars were located closer to the inferior wall of the sinus than the premolars[7]. In addition, the lowest area of the inferior wall of the maxillary sinus is known as the second molar area[8].

The size and shape of maxillary sinuses can change due to many factors[9]. One of the most common causes is maxillary posterior teeth are extracted. This leads to 'pneumatization' of sinus (Figure 1A-C). This phenomenon can be described as postextraction expansion of the sinus in an inferior direction. Moreover, it was found that extraction of second molars led to larger expansion than extraction of first molars[10]. In severe cases, the sinus can extend into the alveolar process between the roots of the teeth. Then, the periapical tissue of a root is direct contact with the lining membrane of the sinus.

The cause of pneumatization of maxillary sinuses can be explained that they develop as 'replacement' of functionless bone. By the loss of a tooth, has loss some of its mechanical function.

Pneumatization of maxillary sinus and orthodontics tooth movement

There are various opinions of an anatomical limitation of sinus especially dense cortical bone of maxillary sinus. Some indicated that displacement of teeth through the maxillary sinus was considered as limitation[11]. This situation is similar to orthodontic tooth movement through substantial atrophy of alveolar ridge because tooth needs to be moved through dense cortical plate.

However, this idea must be revised because several clinical experiences have shown that it is possible to move teeth through the initial anatomic limitations such as sinusal, sutural or cortical barriers[12]. There are many reports stated the possibility of bodily tooth movement through the maxillary sinus[11-13].

With basic axiom in orthodontics, 'bone trace tooth movement' which suggests that whenever orthodontic tooth movement occurs, bone around the alveolar socket will remodel to the same extent[14,15]. According to pressure tension theory, application of adequate force to tooth allows bone resorption at the pressure side while newly formed bone is deposited on the tension side. This way tooth can be moved with bone. In this scenario, a simultaneous compensatory apposition occurs in medullary space anterior to the tooth. A bone layer of constant thickness is preserved by this mechanic and the dental displacement occurs without any bone loss[16]. A tooth can be said to move 'with the surrounding periodontium' if the bone surrounding the tooth is modeled by building up of the alveolar process in the direction of tooth movement[17]. As a result, it is clinically possible to displace a tooth and the whole of its periodontium with it by the generation of orthodontic movement consistent with physiological displacement[18]. With all of these processes, it is possible to reshape the anatomy of the maxillary sinus with tooth movement[19]. Yao et al[20]. reported that the maxillary sinus remodeling followed the maxillary molar intrusion.

Biomechanics of tooth movement through maxillary sinus

Tooth movement through maxillary sinus is 'tooth movement with bone'. This process required light and constant strain that is distributed along the entered length of the periodontal ligament[16]. It can be achieved by applying a constant force passing through or closing to the center of resistance of the tooth to be displaced. According to pressure tension theory, a low and constant force produces 'frontal bone resorption'. However, it is not possible to exactly quantify the term 'light force'. Traditionally, forces in the range below 200 gm were referred to as light forces, and force in the rage above 600 gm were referred to as heavy forces[21]. Cacciafesta and Melsen[16] suggested segmented archwire mechanics to provide constant force in a situation that tooth movement through maxillary sinus was planned. They demonstrated that force only 50 gm exerted from Ni-Ti sentalloy spring could be achieved tooth movement through maxillary sinus. Re et al[12]. showed that segmented archwire mechanic with T-loop could obtain good result of tooth movement through sinus. They used 0.017x0.025 TMA T- loop which was characterized by approximately 50 g/mm load/ deflection rate. About 6 months after the beginning of orthodontic treatment, a distal translation of second premolar through maxillary sinus was observed. Second premolar was displaced approximately in rate 1 mm/month.

Another situation that orthodontic tooth movement must associate with pneumatization of maxillary sinus is when the mandibular first molar had been extracted for long period of time. Consequently, tipping of adjacent teeth and overeruption of the opposing maxillary first molar resulting in occlusal interference and complexity of restoring the edentulous space[20,22]. Prior the application of orthodontic treatment for molar intrusion, leveling of the maxillary posterior occlusal plane often conduced to invasive prosthodontic reduction with root canal treatment, orthognathic surgery with posterior segmental osteotomy to impact the elongated segment or demanding orthodontic therapy requiring extraoral headgear[20,22-25]. Nowadays, microscrew technique provides a minimally invasive treatment alternative. From the study of Kravitz et al[26,27]. showed that maxillary first molar could be intruded with in maxillary sinus. They used two orthodontic microscrews, 1.4 mm in diameter and 8 mm in length each, placed in the maxillary buccal dentoalveolar and palatal slope. The buccal microscrew was inserted between the first and second molar at the level of the mucogingival junction. The palatal microscrew was inserted between the second premolar and first molar, just medial to the greater palatine nerve. The microscrews were loaded with 150 g of intrusive force using NiTi closed coil (7 mm long). Clinical intrusion was observed at the second month of NiTi spring used. At the end of their treatment, cephalometric superimposition revealed that the frist molar was intruded 4.4 mm through maxillary sinus cortical floor. In an animal study, Daimaruya et al[28]. intruded maxillary second premolars into the nasal floor of six beagles to histologically clarify the effect of molar intrusion against the maxillary sinus floor. The beagle's nasal sinus and bony floor are histologically similar to the human maxillary sinus. An intrusive force 80-100 g from NiTi coil spring was applied to each maxillary premolar. The result showed that they were able to effectively intrude maxillary premolar through nasal floor. The average extent of intrusion was 1.8 mm after four months and 4.2 mm after seven month.

Histological finding

The histological study of tooth movement through maxillary sinus was minimal. Almost of studies were reported only radiographic change. However, one of the interesting studies was from Wehrbein et al[29]. Their study was based on a deceased of 19 year-old young woman who had undergone orthodontic therapy. The specimen was the maxilla which was sectioned and stained with toluidine blue. The radiographic of the left second maxillary molar area showed a pneumatization of maxillary sinus mesial to this tooth. It was found that the apex of the mesiobuccal root projected into the maxillary sinus region, with a through-running periodontal fissure and continuous lamina dura. Tooth movement pattern of this tooth was translation. The histological finding showed that the resorptive process was more clearly on the mesiobuccal root than in the others root. In addition, it was found the mesiobuccal root had penetrated the cortical tissue of the maxillary sinus and such this osseous perforation of sinus wall was not recorded in the radiographic. The mucous membrane in the perforation region was thinner than other region. The thin osseous lamella located in front of the mesiobuccal root had resorption lacunae toward the maxillary sinus. Bone surface on the maxillary sinus side also showed multiple osteoclasts in Howship's lacunae in the subperiapical region. No inflammatory cells could be found in the mucosa of the maxillary sinus. These processes were similar to tissue response to tooth movement in cortical tissue. However, one different was the large number of osteoclast to be found below the periosteum of sinus in movement direction. This result reveals that tooth movement through maxillary sinus is achieved by resorptive process from periodontal ligament side and from sinus side.

Another study was animal model system. Daimaruya et al[28] intruded maxillary premolars of six beagles with microscrews into the nasal floor, which was histologically similar to the human maxillary sinus. They showed that there was remodeling bone around the root of intruded premolar. The bone on labial side might be rich in woven bone, whereas bone deposition on palatal side might be rich in lamellar bone. When the root apex of the premolars penetrated the bony floor of nasal cavity, it was found that the nasal floor membrane was lifted into the nasal cavity and covered the root apex of the intruding premolars. The bone formation occurred abundantly around premolar root in the direction at the root apices. Epithelium was degenerated from a pseudostratified ciliated epithelium with serous glands in lamina propria to a striated epithelium without serous gland cells. In contrast of other tissue response, the pulp of intruding teeth showed no remarkable change.

In addition, there was some studies investigated bone formations after insertion of titanium implants in the maxillary sinus. The results demonstrated that hard and soft tissue around the penetrating implants were covered with connective tissue and coated with respiratory mucosa[30-32]. There were no sign of pathologic finding at the resolution level of radiograph[33].

These studies suggested that even orthodontic tooth movement penetrated the sinus floor, tissue regeneration including alveolar bone could occurre to reestablish normal periodontal conditions.

Risk and complication

Tipping tooth movement

When maxillary first molar had been extracted and orthodontic treatment was planned to close extracted space, orthodontists would expect mesial bodily tooth movement of maxillary second molar more than tipping movement. Mesial bodily movement results in good root paralleling at the end of treatment. However, The study from Wehrbein et al[11]. suggested that bodily or tipping movement through maxillary sinus depends on morphological structure of sinus itself. It has been shown that with more vertical extension of basal maxillary sinus in front of the tooth to be moved, one can expect obviously the higher degree of tipping as compared to teeth moved through a more horizontal maxillary sinus base (Figure 2 A, B). This factor should be taken into consideration when orthodontic space closure in upper posterior region was planned.

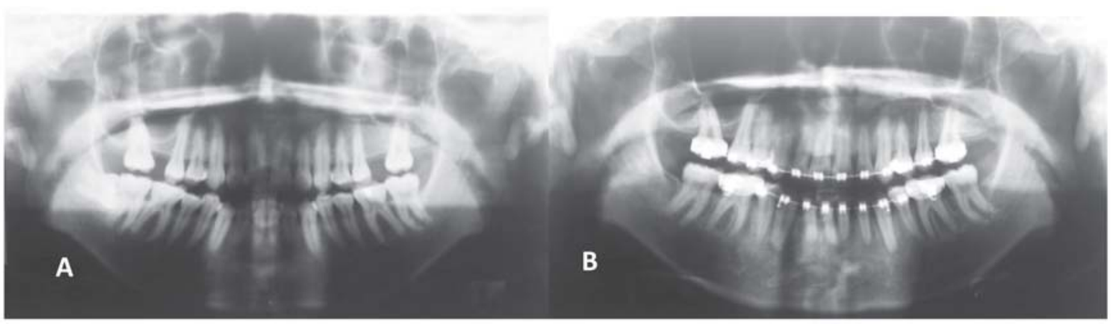

Figure 2 Initial radiographic image, showing the more vertical extension of maxillary sinus in right molar area (A). Radiographic image after space closure by orthodontic tooth movement, note the higher degree of tipping on the right compare to the left (B).

Root resorption

Nowadays, most investigators have confirmed that root resorption is common after orthodontic treatment and it seems that safe tooth movement does not exist[34]. The etiology of root resorption during orthodontic treatment is complicated. Some factors alone or in combination can contribute to the development of root resorption. Root blunting is a common type of root resorption and is usually corrected by formation of cementum[35].

Almost of studies that maxillary molars had been moved through maxillary sinus, radiographic images showed that periodontal health and root length were maintained or minimal root blunting[16,20,26,27]. However, histologically verifiable tissue changes are substantially more pronounced than radiographic and macroscopic evaluation suggested. Radiographic technique also limits evaluation to more extensive apical and lateral root resorption[36]. Dimaruya et al[28]. revealed that intruded beagle's premolars on nasal floor were resorped at their apices. Resorptions were extended into half of the dentine without the formation of reparative dentine in some subjects. Conversely, there were no statistically significant differences in root length measured on radiographic film between before and after intrusion. This finding was concordant with Wehrbein et al[29]. They stated that, root resorption in apical root region of maxillary molar which was moved through maxillary sinus was histologically verified but was not detected radiologically.

Conclusion

Orthodontic tooth movement through anatomical limitation such as sinus can be possible. Direction of tooth movement through sinuses could be achieved both postero-anterior and vertical direction. Light and constant force is necessary to accomplish these types of tooth movement. From histological studies showed resorptive process at periodontal ligament side and sinus side. Remodeling of bone around the root was observed. These processes result in tooth displacement with the whole of its periodontium. On radiographic, reshaping of the sinus can be observed. However, tipping movement and root resorption must take into account when orthodontic tooth movement through maxillary sinus was planned.

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