Abstract: To facilitate safe placement of orthodontic anchor screws (miniscrews), we investigated the frequency of maxillary sinus perforation after screw placement and the effect of sinus perforation on screw stability. Maxillary sinus perforations involving 82 miniscrews (diameter, 1.6 mm; length, 8 mm) were evaluated using cone-beam computed tomography. All miniscrews were placed in maxillary alveolar bone between the second premolar and first molar for anchorage for anterior retraction in patients undergoing first premolar extraction. The placement torque and screw mobility of each implant were determined using a torque tester and a Periotest device, and variability in these values in relation to sinus perforation was evaluated. Eight of the 82 miniscrews perforated the maxillary sinus. There was no case of sinusitis in patients with miniscrew perforation and no significant difference in screw mobility or placement torque between perforating and non-perforating miniscrews. The sinus floor was significantly thinner in perforated cases than in non-perforated cases. A sinus floor thickness of 6.0 mm or more is recommended in order to avoid miniscrew perforation of the maxillary sinus.


Original

Maxillary sinus perforation by orthodontic anchor screws

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Introduction

Orthodontic anchor screws (miniscrews) are used to strengthen anchorages and ensure predictable tooth movement without reciprocal movement (1-7). Risk factors for miniscrew failure have been investigated in an attempt to improve success rates (8). Loosening of the miniscrew is thought to be related to inflammation around the placement site (9), overloading (8), cortical bone thickness and mineral density (10), screw design (9), and root proximity to the adjacent tooth (11). However, clinical miniscrew failure is frequent and is often caused by unknown factors. Risks associated with screw placement need to be clearly understood by orthodontists and patients. Complications during screw placement and after orthodontic loading can affect stability and patient safety.

The maxillary posterior alveolar region is frequently used as an insertion site, although incidental maxillary sinus perforation may occur in conjunction with descent of the maxillary sinus floor. Ardekian et al. (12) and Brånemark et al. (13) reported that immediately loaded dental implants that perforated nasal or maxillary sinuses exhibited no difference in implant stability. However, few studies have investigated the impact of miniscrew perforation of the maxillary sinus, including the rigid fixation of bone fragments in oral surgery. The effects of sinus perforation on the stability of low-caliber mini-screws have not yet been determined in humans. Sinus perforation may affect miniscrew stability and cause complications such as maxillary sinusitis.

Kravitz and Kusnato (14) stated that if the maxillary sinus has been perforated, the miniscrew may not require immediate removal, due to its small diameter. They
recommend that orthodontic therapy should continue and that the patient should be monitored for potential development of sinusitis and mucocele. To guarantee safe placement, researchers should verify in an in vivo clinical study that there is no development of sinusitis in cases of miniscrew perforation of the sinus. A case report using miniscrews (15) supported the findings of studies on maxillary sinus augmentation (sinus-lift procedure) (16-18). It found that while small, uncomplicated perforations may heal spontaneously, larger perforations in unfavorable areas can cause inflammation and other complications. Small miniscrew perforations without mobility or inflammation may heal spontaneously, but the possibility of complications such as sinusitis cannot be ignored in cases of perforation with mobility and inflammation.

Pazera et al. (19) determined the frequency of incidental maxillary sinus findings using cone-beam computed tomography (CBCT) images and identified incidental maxillary sinus findings in 65 of 134 (46.8%) orthodontic patients. Gracco et al. (20) used CBCT to determine the prevalence of incidental maxillary sinus findings in Italian orthodontic patients and found incidental maxillary sinus findings such as pseudocysts and mucosal thickening in half the patients. It is unclear whether maxillary sinus perforation induces sinusitis development and loosening of miniscrews in patients with incidental maxillary sinus findings, such as mucosal thickening.

We investigated the frequency of miniscrew perforation of the maxillary sinus and the effects of sinus perforation on screw stability. In addition, we discuss the relationships between sinus perforation, mucosal thickening when placing miniscrews, miniscrew stability, and the frequency of onset of maxillary sinusitis after screw placement.

**Materials and Methods**

The study included 45 patients (28 females, 17 males; average age 23.3 ± 8.9 years) who had miniscrews placed in the maxillary buccal alveolar bone between the second premolar and first molar at Nihon University Dental Hospital. In total, CBCT was used to evaluate 82 miniscrews. Cases in which miniscrews contacted adjacent tooth roots were excluded, to avoid the effects of root contact on miniscrew stability or loosening. This study was approved by the Ethics Committee of Nihon University School of Dentistry (2012-2). All patients consented to participate in this study.

Commercial self-drill miniscrews (ISA orthodontic anchor screw; diameter, 1.6 mm; length, 8 mm; Biodent, Tokyo, Japan) were used (Fig. 1). After administering local anesthesia, we placed the miniscrew in the buccal alveolar bone between the second premolar and the first molar of the maxilla. A hand screwdriver was used to place the miniscrew without a pilot hole so that it was inclined at 40° to 60° from vertical to the adjacent tooth axis, to avoid root contact. To prevent infection, an antibiotic (100 mg Flomox tablets, Shionogi, Osaka, Japan) was prescribed to each patient for 3 days after placement. The miniscrews were placed by three skilled clinicians (M.M., Y.U., N.S.) who each had more than 10 years of clinical experience. Using a torque tester (DIS-RL05; nominal accuracy ± 0.5%; Sugisaki Meter Co., Ltd., Tokyo, Japan), we measured maximum placement torque during terminal rotation of the miniscrew. To evaluate stability, a Periotest device (PTV) was used to assess miniscrew mobility (21). For each miniscrew, PTV values were obtained by holding the tip of the instrument’s handpiece as parallel as possible to the bone.
surface, in accordance with the manufacturer’s instructions. Each measurement was repeated three times, and the mean of the three values was calculated. To identify any incidental complications, such as root contact and/or root injury, an orthodontic force of ~2 N was applied to the miniscrew, and each participant underwent CBCT for post-placement examination. The CBCT diagnostic images were used to determine maxillary sinus perforation, vertical inclination of the miniscrew, and thickening of the sinus mucosa.

CBCT (3D Accuitomo, J. Morita, Kyoto, Japan; voxel size, 0.125 mm³; X-ray tube voltage, 80 kV; current, 5.5 mA) was used for diagnostic imaging of the area around the site, immediately after placement. Using three-dimensional viewing software (One Volume Viewer, ver. 1.6.1.13; J. Morita), an examiner (R.S.) evaluated miniscrew perforation of the maxillary sinus, vertical inclination of the miniscrew, and thickening of the sinus mucosa. CBCT (3D Accuitomo, J. Morita, Kyoto, Japan; voxel size, 0.125 mm³; X-ray tube voltage, 80 kV; current, 5.5 mA) was used for diagnostic imaging of the area around the site, immediately after placement. Using three-dimensional viewing software (One Volume Viewer, ver. 1.6.1.13; J. Morita), an examiner (R.S.) evaluated miniscrew perforation of the maxillary sinus, vertical inclination of the miniscrew, and thickening of the sinus mucosa.

To evaluate intra-examiner error, we re-evaluated sinus perforation and screw inclination on randomly selected CBCT images from 10 subjects 2 weeks after the initial evaluation. Measurement error was assessed using Pearson’s correlation coefficient. The chi-square test or Fisher’s exact probability test was used to compare failure rate in relation to sinus perforation. The Mann-Whitney U-test was used to examine differences in sinus floor thickness, placement torque, vertical inclination of miniscrews, and PTV between perforated and non-perforated cases. The Breslow-Day test was used to estimate the common odds ratio. The Mantel-Haenszel test was then used to calculate the odds ratio (risk ratio) for risk of sinus perforation in relation to sinus floor thickness. These analyses were carried out using SPSS software (ver. 16.0; SPSS Japan, Tokyo, Japan). A P value <0.05 was considered to indicate statistical significance.

### Results

Ten participants were randomly selected to undergo re-measurement 2 weeks after initial measurements. This reliability test showed a significant correlation (r = 0.83-0.90; P < 0.01) and confirmed the accuracy of the measurements. Of the 82 miniscrews, eight perforated the maxillary sinus between the second premolar and first molar (Table 1). Of the eight, one failed. This miniscrew had been inserted into a sinus with mucosal thickening >3 mm at the time of placement. Four of the 74 unperforated miniscrews also failed (Tables 1, 2). There was no significant difference in PTV, placement torque, or vertical inclination between perforating and non-perforating miniscrews (Table 3). The sinus floor was significantly thinner in the perforated cases compared to the non-perforated cases (Table 3).
thinner for perforated cases than for unperforated cases (5.62 ± 2.19 mm vs 10.54 ± 3.59 mm, respectively; Table 3). The mean depth of miniscrew penetration of the sinus was 0.79 ± 0.39 mm (range, 0.25-1.50 mm). There was no evidence of sinusitis development in post-diagnostic radiographic images of the perforated cases.

The common odds ratio was estimated using the Breslow-Day test ($P = 0.388$) (Tables 4, 5). The odds ratio (risk ratio) for maxillary sinus perforation was 21.63 ($P < 0.001$) when sinus floor thickness was <6.0 mm, as compared with a thickness of ≥6.0 mm.
perforation; the odds ratio was therefore estimated using this value as a cut-off. The Mantel-Haenszel test showed a high odds ratio, 21.63 (P < 0.001). Thus, a sinus floor thickness of ≥6.0 mm is recommended in order to avoid maxillary sinus perforation with 8-mm miniscrews. However, as Baumgaertel and Hans (24) and Kravitz and Kusnoto (14) also reported, if perforation occurs, interruption of orthodontic treatment and miniscrew removal are not warranted because neither sinusitis development nor a decline in screw stability was seen in the present perforated cases.

In a study of dry adult human skulls, Baumgaertel and Hans (24) concluded that maxillary sinus perforation is likely when inserting 6 mm or longer miniscrews into the infrazygomatic crest. As mentioned above, the maximum depth of screw penetration of the sinus was 1.5 mm for 8-mm miniscrews. Thus, a 6 mm or shorter miniscrew is recommended if maxillary sinus perforation must be avoided when inserting miniscrews at the interradicular space between the second premolar and first molar.

To ensure safe miniscrew placement, we investigated the frequency of maxillary sinus perforation after screw placement and the effects of sinus perforation on screw stability. Approximately 10% of miniscrews perforated the maxillary sinus, but maxillary sinus perforations ≤1.5 mm in depth are unlikely to affect screw stability. Small, uncomplicated perforations of the maxillary sinus by miniscrews may heal spontaneously. To avoid maxillary sinus perforation, the thickness of the sinus floor should be >6.0 mm or the screw length should be <6 mm.

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