Evaluation of the Anastomosis Canal in Lateral Maxillary Sinus Wall With Cone Beam Computerized Tomography: A Clinical Study

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This clinical study used cone beam computerized tomography (CBCT) to locate the position of the anastomosis canal in lateral wall of maxillary sinuses, and to evaluate the thickness of lateral sinus wall and the distance from the lower border of the canal to the sinus floor, which could provide surgeon with information about this anastomosis. Two hundred and forty-two (242) volumes of CBCT scans were included in this study. The distances from the lower border of the anastomosis canal to the sinus floor and from the maxillary alveolar crest to the sinus floor were evaluated in transversal plane, and the thickness of the lateral sinus wall was measured at the distance of 3, 6, 9 mm from the sinus floor and at the level of the lower border of the canal at the same plane. The canal was identified in 87.6% (424/484) of the sinus. Most canals were intraosseous, or beneath the sinus membrane. The mean distance was $9.2 \pm 3.5$ mm from the lower border of the canal to the sinus floor, and $10.8 \pm 4.0$ mm from the alveolar crest to the sinus floor. The thickness of the lateral sinus wall was $2.4 \pm 0.9$ mm, $1.8 \pm 0.8$ mm, $1.7 \pm 0.7$ mm, $1.8 \pm 0.8$ mm at the distance of 3, 6, 9 mm from the sinus floor and at the level of the lower border of the canal. The location of the anastomosis canals varied from each patient, but the distance from the sinus floor was similar in different teeth sites. The sinus floor could be an anatomic landmark of sinus floor augmentation. In order not to interrupt this canal, great care must be taken by the implant surgeon to identify this canal.

Key Words: cone-beam computed tomography, maxillary sinus, anastomosis canal, sinus floor augmentation

INTRODUCTION

The prognosis of an implant is determined by its sufficient osseointegration with bone tissue. However, limited alveolar crest volume caused by long-term tooth loss and a pathogen of endodontic or periodontal disease cannot meet the needs of an implant. Moreover, the maxillary posterior region of edentulous or partially edentulous patients is particularly difficult to restore because of the presence of the maxillary sinus. It has been well described in the literature that the sinus floor augmentation (SFA) procedure could increase the remained bone height (RBH) of the sinus floor and allow a good long-term prognosis of the implants.

SFA was explored by Tatum in 1976, and Boyne and James first described this procedure in the literature in 1980. The classic SFA procedure consists of bone window preparation on the lateral sinus wall, Schneiderian membrane separation, and filling of grafted material. This technique could be applied in the maxillary posterior region with serious deficiency of RBH and has a reliable prognosis, but the implant surgeon must be aware of the potential complications, such as bleeding and hemorrhage.

Profuse bleeding while performing an antrostomy at the lateral wall is a significant intraoperative complication, second only to perforation of the Schneiderian membrane. Bleeding is due to the interruption of arteries in the lateral wall of maxillary sinus. The blood supply of the maxillary posterior teeth, the lateral maxillary sinus wall, and its mucoperiosteum comes from the posterior superior alveolar artery (PSAA) and the infraorbital artery (IOA), both of which are ultimate branches of the maxillary artery, connected by a horizontal anastomosis. Experimental studies in edentulous cadavers reported 83% involvement of this anastomosis at first and second molar region in SFA procedure. Bleeding could obscure the surgical field and increase the risk of Schneiderian membrane perforation, and severe bleeding could lead to postoperative hemorrhage.

There have been many studies describing the location of this anastomosis. Hur et al classified the anastomosis into 2 categories: straight and U-shaped. Günsütal divided the anastomosis into 3 areas: the external cortex of the lateral sinus wall, intraosseous, and beneath the membrane. Most studies have focused on the diameter of the anastomosis canal.
and the distance from its lower border to the alveolar crest. Others evaluated the distance from the lower border of the canal to the sinus floor and the thickness of lateral sinus wall. But the atrophy of alveolar crest differs in each patient, making the distance from the canal to the alveolar crest less conclusive. Therefore, authors of this study decided to analyze the distance from the lower border of the canal to the sinus floor.

Cone beam computerized tomography (CBCT) has been commonly applied in clinical oral radiology. CBCT units are more cost effective and emit a lower dose of radiation to cover an equal area than does traditional computerized tomography (CT) and might be easier to access in clinical department. There have been plenty of studies evaluating the lateral maxillary sinus wall with CBCT, with a sensitivity much higher than traditional CT. In addition, CBCT volumetric reconstructions provide precise information about the location of important anatomical landmarks. Researchers agree that the anastomosis canal can be located precisely with CBCT.

The aim of the present study is to evaluate the location of the anastomosis canal in the lateral maxillary sinus wall, the distance from the maxillary alveolar crest to the sinus floor, and the thickness of the lateral sinus wall. The results of this study could provide help with the implant planning and prevent complications caused by the interruption of this anastomosis.

**Materials and Methods**

The methodology was designed and reviewed by Yufeng Xie, corresponding author of this work. In the current study, we evaluated 242 volumes of CBCT scans from patients (111 males and 131 females, 484 sinus, mean age of 41.4 years [22–86]) who visited the Department of Periodontology at the Ninth People’s Hospital, Shanghai Jiao Tong University School of Medicine, between March 2016 and March 2017. These CBCT scans were taken for various reasons (eg, trauma, implant planning, endodontic diseases). The inclusion criteria were as follows: (1) the maxillary alveolar crest and the maxillary sinus floor; (2) the images of the volume should be of adequate clarity, and (3) the maxillary sinus had no pathology that could affect the position of PSAA, IOA, and their anastomosis canal. We obtained patient information including age, gender, and remaining teeth.

Scanning for each patient was accomplished using a KODAK9500 device (Carestream Health, Concord, Ontario, Canada) using the following imaging protocol: a reconstructed volume of 9 (height) × 15 cm and a voxel size of 0.3 mm. The device operated at 120Kv, 10mA, with an exposure time of 10.8 s.

**Measurements**

All measurements were accomplished with 3D Imaging Software (Carestream Health). The transversal plane for the measurement should be orthogonal to the occlusal plane. When the tooth or root was identified on the slice, the plane for measurement was located at the middle site of the tooth or root. If the tooth was missing, the plane should pass through the middle site of the edentulous space. For two or more consecutive teeth missing, the position of the plane should refer to the teeth at the other side and lower mandible. The anastomosis canal was identified at each tooth site (from second premolar to second molar) and classified into 3 types: (1) on the external cortex of the lateral sinus wall (type I); (2) intraosseous (type II); and (3) beneath the sinus membrane (type III), shown in Figure 1.

The distance from the lower border of the canal to the sinus floor (D₁) (Figure 2a), and the distance from the alveolar crest to the sinus floor (D₂) were measured at the same transversal plane (Figure 2b). The bone thickness (BT) of the lateral sinus wall was measured at distances of 3, 6, 9 mm from the sinus floor (BT3, BT6, BT9) and at the level of the lower border of the canal (BTD) (Figure 3).

**Statistics**

The results were collected by authors Sun and Liu. The statistics were presented as mean ± SD and analyzed by Sun in SPSS (Version 22.0, IBM Corp, Armonk, NY) under the guidance of author Xie. Unpaired t-test and Spearman’s rho correlation coefficient were used to determine the correlation between age, gender, and D₁, D₂, BT. The Wilcoxon rank-sum test was used to compare the distribution of each type of canal. The statistical significance on D₁, D₂, and BT between the left and right sides were analyzed with an unpaired t-test.

The differences on D₁, D₂, and BT between each tooth site were analyzed with ANOVA. Pearson’s correlation test was applied to evaluate the relation of D₁ and D₂, D₂, and BTD.

Values of P < .05 were considered statistically significant.

**Results**

The anastomosis canal was identified in 87.6% maxillary sinus (424 of 484 sinuses). Three planes were evaluated in each sinus, and 9.7% sites (123 of 1272 planes) were edentulous. The mean value of D₁ was 9.2 ± 3.5 mm. The mean value of D₂ was 10.8 ± 4.0 mm. The mean bone thickness of the lateral sinus wall was 1.8 ± 0.8 mm at the level of the lower border of the canal, and 2.4 ± 0.9 mm, 1.8 ± 0.8 mm, and 1.7 ± 0.7 mm at 3, 6, and 9 mm from the sinus floor (Table 1).

No statistically significant differences on D₁, D₂, and BT between left and right side were revealed (P > .05) (Table 2). Further, there was no correlation between age, gender, and D₁, D₂, and BT (P > .05) (Table 2).

The distribution of each type of canal significantly varied from the first molar and the other region (P < .0001) (Figure 4); the prevalence of type III was relatively higher at the first molar than the others, and type II occurred more frequently at the second premolar and second molar.

D₁ showed no significant difference between regions (P > .05) (Table 2), the canal located most frequently more than 9 mm from the sinus floor (Figure 5). In addition, in 98.4% of teeth sites, D₁ were larger than 3 mm; only 20 teeth sites (out of 1272) were evaluated under 3 mm. D₂ of second premolar was significantly larger than first and second molar (P < .0001) (Table 2). D₂ in dentulous regions were significantly larger than edentulous regions (P < .01) (Table 2).
FIGURES 1–3. **FIGURE 1.** Canal of anastomosis of sinus lateral wall in the cone beam computerized tomography scan. (a) Type I: on the external cortex of the lateral sinus wall. (b) Type II: intraosseous. (c) Type III: beneath the sinus membrane. **FIGURE 2.** Measurements of the distance from the lower border of the canal to the sinus floor (D₁) and the distance from the alveolar crest to the sinus floor (D₂). (a) D₁, tooth site #4. (b) D₂, tooth site #4. **FIGURE 3.** Measurements of bone thickness of the lateral sinus wall. BTD indicates bone thickness of the lower border of the canal.
The BT of the first molar was significantly larger than the second premolar and second molar (P < .01) (Table 2). The lateral sinus wall was cone-shaped in the transversal plane of most CBCT scans, its thickness relatively larger at the level of sinus floor.

The statistics of D1, D2, and BT are shown in Table 3. Pearson's correlation test showed negative correlation between D1 and D2 (the absolute value of r = -0.5, P < .0001), and positive correlation between D2 and BTD (the absolute value of r = 0.5, P < .0001) (Figure 6).

### DISCUSSION

The blood supply of the maxillary posterior teeth, the lateral maxillary sinus wall, and its mucoperiosteum comes mainly from the maxillary artery and its branches. The maxillary artery, as well as its branches, anastomose with the infraorbital artery, the posterior superior alveolar artery, the middle superior alveolar artery, and the anterior superior alveolar artery. This anastomosis provides a rich blood supply to the maxillary posterior teeth, the lateral maxillary sinus wall, and its mucoperiosteum. This rich blood supply is crucial for maintaining the vitality of these structures and ensuring their proper function.
from PSAA and IOA. The anastomosis between PSAA and IOA has a relapse rate of 100%, with a diameter varying from <1 mm to >2 mm. This anastomosis could locate on the external cortex of the lateral sinus wall, intraosseous, or beneath the sinus membrane.

Any surgical procedures applied to the lateral sinus wall might involve this anastomosis, including SFA, Caldwell-Luc surgery, Le Fort I osteotomy, and osteosynthesis for maxillary fractures. In 2% of patients, the visualization of surgical field could be obscured because of bleeding, which could be severe if the diameter of the canal is large (diameter >3 mm). Eighty-three percent of anastomoses were involved at first and second molar regions in experimental SFA in the edentulous cadavers. While intraoperative bleeding is not life threatening, it could obscure visualization of the surgical field and increase the risk of Schneiderian membrane perforation. In addition, these arteries are important because the vascularization of the sinus wall is necessary for wound healing and the integration of grafted bone. Further, the involvement of this anastomosis could increase the failure of SFA and the implant procedure.

The perforation of the Schneiderian membrane and bleeding are the two most frequent intraoperative complications of SFA. Wallace et al. reported that bleeding occurs from interruption of the anastomosis of PSAA and IOA, most commonly by vertical osteotomy cutting. The location and diameter of PSAA, IOA, and their anastomoses in the sinus wall vary by patient. Kang et al. reported that 31% of anastomoses are located less than 15 mm from the alveolar crest. If the inferior horizontal bone cut is made 3 mm above the alveolar crest and the vertical osteotomies are long enough (10–15 mm) for the surgeons to contact the medial sinus wall when the window is collapsed inward, an anastomosis could occur during the vertical osteotomy.

Former studies about this anastomosis have usually focused on its distance from the alveolar crest, which varied from 2.8 mm to 31.7 mm. Others evaluated the distance from the anastomosis to the sinus floor, presenting results from 5.8 mm to 9.6 mm, which correlated with teeth sites. The distance from the anastomosis to the alveolar crest depends on the alveolar crestal atrophy, the location in

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*BT indicates bone thickness of the lower border of the canal.

**TABLE 3**

The statistics of the distance from the lower border of the canal to the sinus floor (D1), the distance from the alveolar crest to the sinus floor (D2), and bone thickness (BT)*

**FIGURES 4 AND 5.** Figure 4. The distribution of each type of canal in different teeth sites. Second premolar: 24 canals of type I, 207 of type II, and 193 of type III. First molar: 3 canals of type I, 94 of type II, 327 of type III. Second molar: 22 canals of type I, 222 of type II, 180 of type III. There was significant difference between first molar and other sites (P < .0001) and type in second premolar had no difference with second molar (P = .521).

**Figure 5.** The distance from the lower border of the canal to the sinus floor in each tooth site. There was no significant difference among sites (P > .05). 20 canals located ≤3 mm from the sinus floor, 215 canals were >3 mm and ≤6 mm from the sinus floor, 453 canals were >6 mm and ≤9 mm from the sinus floor, 584 canals were >9 mm from the sinus floor.
the maxillae, and the presence or absence of teeth; this varies in each patient.\textsuperscript{16,34–36} The height of the alveolar crest could decrease 1.7–2.0 mm clinically and 1.5 mm radiographically after tooth extraction.\textsuperscript{37} In studies that focused on the distance from anastomosis to the alveolar crest, researchers may forget to separate the edentulous regions from the dentulous ones, resulting in inaccurate conclusions due to atrophy of the alveolar crest. In this study, the distance from the anastomosis to the sinus floor was evaluated instead of the distance from the anastomosis to the alveolar crest, thereby preventing the influence of crestal bone atrophy.

In the present study, the prevalence of the anastomosis canal was 87.6% according to CBCT scans; this result was similar to other CBCT studies (71%–97%) and higher than studies using traditional CT (47%–64.5%).\textsuperscript{17,18,22,32,33,36,38} Tehranchi et al\textsuperscript{18} reported that the location of this anastomosis was correlated with gender. Other studies reported a larger volume of maxillary sinus in men than in women, but it was not correlated with age.\textsuperscript{39–41} The lateral sinus wall is thicker in men than in women.\textsuperscript{11,21} In the current study, gender and age had no correlation with the location of the anastomosis, the thickness of lateral sinus wall, or the distance from the alveolar crest to the sinus floor.

The anastomosis could be classified into 3 types: (1) on the

FIGURE 6. The correlation of the distance from the lower border of the canal to the sinus floor ($D_1$) and the distance from the alveolar crest to the sinus floor ($D_2$), $D_2$ and the bone thickness of the lower border of the canal (BTD). There was negative correlation between $D_1$ and $D_2$ ($P < .0001$), and positive correlation between $D_2$ and BTD ($P < .0001$) in each tooth site.
external cortex of the lateral sinus wall (type I), (2) intraosseous (type II), and (3) beneath the sinus membrane (type III). In this study, the prevalence of each type in the first molar region significantly differed from the second premolar and second molar ($P < .0001$). The prevalence of type II was 48.8%, 22.2%, and 52.4% in the region of second premolar, first molar, and second molar. The prevalence of type III was 45.5%, 77.1%, and 42.5% in each region. Type I was rarely identified in CBCT scans (Table 1). These results were similar with studies by Tehranchi and Danesh-Sani. It seems that this anastomosis most likely travels intraosseously at the first molar region. The risk of anastomosis interruption during vertical osteotomy cutting is higher at this region.

The mean distance from the lower border of the anastomosis canal to the alveolar crest was 15–31 mm in different studies. Elian et al. found 80% of the anastomosis canals were more than 15 mm to the alveolar crest. Mardinger and Traxlar found first molar to be the lowest position of the anastomosis. Hur et al. described a U-shaped course in most anastomoses (78.1%). Danesh-Sani et al. described the distance from the anastomosis to the sinus floor: 8.57 mm, 8.45 mm, 8.09 mm, and 9.27 mm at each tooth site from first premolar to second molar. The mean distance from the anastomosis to the sinus floor was 9.2 ± 3.5 mm in this current study and showed no difference between tooth sites ($P > .05$), which indicates that the course of this anastomosis was parallel to the sinus floor (Table 1). Therefore, it might be simpler and more reasonable using the sinus floor as a landmark during window preparation in SFA as opposed to the alveolar crest. The relatively large SD indicates that the course of this canal varies enormously: 45.9% canals were more than 9 mm from the sinus floor, and the smallest distance was 1.5 mm in the present study. The inferior bone cutting of window preparation commonly occurs at 3–5 mm from the sinus floor, and vertical osteotomies can possibly interrupt the anastomosis canal.

The diameter of the anastomosis canal is correlated with the lateral wall thickness, and a thicker lateral wall was related to a higher risk of bleeding. In the present study, the lateral wall thickness receded into the distance from the sinus floor, and its transversal plane was cone-shaped. In addition, the thickness of the first molar region was significantly thicker than the other sites, but there was no statistical difference between second molar and second premolar (Table 2). These results are related to adjacent structures, such as the maxillary tuberosity and the buttress of the zygoma. Further, the lateral wall seems thicker in dentulous maxillae than in an edentulous one, but the difference has no statistical significance.

In addition, the lateral wall thickness at the level of lower border of the anastomosis canal was thicker at the first molar region (2.0 ± 0.9 mm) than at the other sites. There was no statistical difference between second molar and second premolar (Tables 1 and 2). It indicates that the canal diameter at the first molar region was larger at other sites, and interruption could cause more bleeding in this region. A thicker sinus wall could lead to an increased risk of other complications, such as Schneiderian membrane perforation and hemorrhage. If we take the anastomosis position in the sinus wall into consideration, the risk of anastomosis interruption was higher in first molar region than at the second premolar or second molar. The diameter of the canal was not evaluated in the present study because the bone might not surround the anastomoses of type I and III completely; therefore, the diameter could not be evaluated precisely in CBCT scans.

The distance from the alveolar crest to the sinus floor was larger at the second premolar region (12.8 ± 4.4 mm) than at the other sites. There was no statistical difference between the first and second molar (Table 2). This result was similar to the Pandharbale study, which might be due to the existence of the canine eminence. The present study found that, in most patients, the maxillary sinus floor lifts in the premolar region. According to our result that the anastomosis was parallel to the sinus floor, we could presume that the course of most anastomoses would be U-shaped, which was coincident with Hur’s results. In addition, the anastomosis might be closer to the alveolar crest in the molar region. Rosano et al. reported a high risk of canal interruption in patients with severe alveolar bone loss. The surgeon must take great care to operate the vertical osteotomies when there is little RBH left at molar region.

Moreover, the present study evaluated the correlation between the distance from the lower border of the anastomosis to the sinus floor and the distance from the alveolar crest to the sinus floor; we found negative correlation between these statistics (Table 2). The distance from the alveolar crest to the sinus floor was positively correlated with lateral wall thickness (Table 2), but the correlation was relatively low. The lower RBH and the thinner lateral wall could be the results of pneumatization of the maxillary sinus. According to these results, the pneumatization might increase the distance from the canal to the sinus floor, but it has no influence on its position in maxillae. The surgeons should adjust the inferior border during window preparation according to the position of patient’s sinus floor.

**Conclusions**

We analyzed 242 patient CBCT scans. The results were as follows:

1. The anastomosis of PSAA and IOA could be identified in 87.6% of the sinuses by CBCT.
2. The location of anastomosis canal in relation with the lateral sinus wall differed in different teeth sites, with most canals located intraosseously, or beneath the sinus membrane.
3. The location of the anastomosis canals varied from each patient, but its distances from the sinus floor were similar in different teeth sites. The sinus floor could be an anatomic landmark of SFA.
4. The lateral sinus wall thickness in first molar region was thicker than the other regions, and the anastomosis more likely traveled intraosseously at this region. Surgeons must take great care during SFA to avoid severe bleeding.
5. The position of the anastomosis canal in maxillae had no correlation with sinus pneumatization.

In summary, the anastomosis of PSAA and IOA could be involved in SFA procedure, and the damage of this anastomosis...
could lead to many complications, such as bleeding and Schneiderian membrane perforation. The surgeon must reliably identify and locate the canal during surgery to ensure the safety and prognosis of the implant.

**ABBREVIATIONS**

- BT: bone thickness
- BTD: bone thickness of the lower border of the canal
- CBCT: cone beam computerized tomography
- CT: computerized tomography
- D1: distance from the lower border of the canal to the sinus floor
- D2: distance from the alveolar crest to the sinus floor
- IOA: infraorbital artery
- PSAA: posterior superior alveolar artery
- RBH: remaining bone height
- SFA: sinus floor augmentation

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**NOTE**

There is no conflict of interest in this work.

**REFERENCES**


