Association of location and diameter of alveolar antral artery to crest of alveolar bone in dentate and partially edentulous patients – A cone-beam computed tomography study

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Abstract:
Background: One of the most challenging anatomical conditions to manage during sinus augmentation using lateral window approach is the alveolar antral artery (AAA) when it is unusually wide in diameter and passes through the area of the osteotomy with a complete intraosseous course. The purpose of this study was to investigate the association of location and diameter of AAA to the crest of alveolar bone in dentate and partially edentulous patients using cone-beam computed tomography (CBCT). Materials and Methods: Totally 100 CBCT scans of patients (50 dentate and 50 edentulous) were selected and analyzed. The location and diameter of AAA in the lateral wall of the maxillary sinus were evaluated in association with alveolar bone height with respect to three posterior maxillary teeth: first premolar (P1), second premolar (P2), and first molar (M1). Results: The diameter of AAA in dentate patients was higher in M1 region (1.32 ± 0.34 mm) than P1 (0.91 ± 0.20 mm) and P2 (1.07 ± 0.24 mm) regions as compared to edentulous patients. It was found that the location of AAA for P1 in the dentate group (22.35 ± 4.17 mm) was significantly higher than that of the edentulous group (20.37 ± 2.48 mm). A negative relationship has been found between age and the distance between the AAA canal and crest of the alveolar ridge in both dentate (P = 0.001) and edentulous (P = 0.003). Conclusion: A significantly negative relationship existed between age, diameter, and location of AAA in both the dentate and edentulous groups.

Key words:
Alveolar antral artery, cone-beam computed tomography, lateral window, maxillary sinus, sinus augmentation, sinus lift complications

INTRODUCTION

Dental implants have been the emerging treatment modality in the current era of oral rehabilitation. However, the posterior maxilla is the area of concern, especially in cases of inadequate alveolar bone height. The major snag is the pneumatization of the maxillary sinus leading to loss of residual alveolar bone height making implant placement difficult, thereby entailing sinus elevation. The direct maxillary sinus lift technique was first described by Tatum. There are several factors and possible complications that must be taken into consideration while planning the surgical procedure. There are several vascular vessels that supply the maxillary sinus, such as the posterior superior alveolar artery (PSAA), the anterior superior alveolar artery, and the infraorbital artery (IOA). These arteries form an anastomosis in the bony anterolateral wall, which also supplies the Schneiderian membrane. The anatomy of PSAA should be well understood, as the blood supply and vascularization of the sinus cavity, Schneiderian membrane, and lateral maxillary wall are of crucial importance as the graft material gets its blood supply from this source. Accidental severing of this vessel during the antrostomy can lead to intraoperative complications.
PSAA anastomoses intraosseously and extraosseously with IOA. Intraosseous branch of the PSAA also known as alveolar antral artery (AAA) supplies halfway of the lateral wall of the maxillary sinus, maxillary sinus membrane, and posterior teeth.[10] Extraosseous anastomosis was shown by Traxler et al., in a cadaveric study to be present in 44% of dissections.[10] Among all the maxillary posterior teeth, the first premolar area is considered to be the safest one for performing direct sinus augmentation procedure because of the highest distance of AAA from the alveolar crest.[6] The location and diameter of AAA can dramatically complicate the procedure due to the presence of larger canals at dentate sites, as damage to this bony vessel can cause intense bleeding, obscuring the vision, and may lead to perforation of the Schneiderian membrane, which can be an impediment in assessment of the sinus membrane reflection and thereby prolong the surgical procedure.[7]

Numerous studies were performed to evaluate the prevalence, position, and anatomy of PSAA using computed tomography (CT) imaging.[8–10] However, very few of them have evaluated and compared the PSAA anatomy in dentate and edentulous population. This faster rate of bone resorption in edentulous areas would make the anatomic landmarks more prominent and vulnerable to injuries, especially in cases which are indicated for sinus lift procedures. Hence, the present study aimed to study the association of location and diameter of AAA to the crest of alveolar bone in dentate and partially edentulous patients using cone-beam computed tomography (CBCT).

**MATERIALS AND METHODS**

This prospective radiographic study was performed at the outpatient department of periodontology and implantology of our institute from March 2019 to August 2019 and was performed in accordance with the Helsinki Declaration of 1975, as revised in 2013. This clinical trial was registered at Clinical Trials Registry-India (CTRI/2019/03/017961) being primary register of the WHO International Clinical Trials Registry Platform. Based on the study by Aung et al.,[10] where the authors compared the distance of AAA and alveolar crest between the dentate and edentulous groups, the effect size ranged between 0.1 and 0.35. Hence, a total of 100 CBCT scans of patients who were indicated for implant surgery were selected and assessed. Patients were divided into two groups as follows:

1. Group 1 – 50 dentate patients
2. Group 2 – 50 partially edentulous patients.

Inclusion criteria for study population were dentate and partially edentulous patients including both males and females with the age ranging from 20 to 50 years and those advised CBCT for sinus augmentation procedures, intrabony defects, and implant therapy. While patients with the presence of radiographic signs of sinusitis (acute or chronic), upper jaw fractures, pathologic lesions that involve the maxillary sinus, first premolar anterior to the maxillary sinus, CBCT with distorted images of bone crest and artifacts, history of prosthesis, and/or root canal treatment of teeth at the site of interest were excluded from the study.

**Clinical examination**

A complete case history was recorded for the selected patients. The patients were subjected to clinical and radiographic examination which constituted of CBCT scanning.

**Radiographic image analysis**

All CBCT images were acquired using Orthophos® XG 3D/Ceph, Sirona Dental Systems GmbH, Germany, at kVp = 84 and mA = 16. The location of AAA in the lateral wall of the maxillary sinus was evaluated in association with alveolar bone height with respect to three posterior maxillary teeth: first premolar (P1), second premolar (P2), and first molar (M1). In a coronal view [Figures 1 and 2], a horizontal line was traced along the lower border of the artery canal (A).[9,10] The second horizontal line was traced to the lowest point of the alveolar bone crest (B).[10] The alveolar bone height in respective scans was measured by a perpendicular line drawn from the lower border of the artery canal to the lowest point of the alveolar bone crest (C) at three locations on examined teeth P1, P2, and M1.[10] The diameter was measured in mediolateral direction of the canal. Two examiners (RK and PR) performed radiographic measurements and interpretations. The inter- and intraexaminer reliability of measurements was determined using intraclass correlation coefficient which ranged between 0.93 and 0.97 for different study parameters.

**Statistical analysis**

The statistical significance of difference of mean parametric values between the groups was determined using f-test for independent samples, while within-group comparison across tooth types was done using ANOVA. The relationship between demographic and different parameters was established using multiple linear regressions. Further, Pearson’s correlation coefficient was used to determine the relationship between different parameters according to tooth type. All the analyses were performed using SPSS version 20.0 (IBM Corp, Armonk, NY, USA), and p value <0.05 was considered to be statistically significant.

**RESULTS**

Table 1 gives the descriptive statistics for demographic characteristics of individuals according to the groups. The mean age of patients and the gender distribution in the two groups differed insignificantly, as indicated by P > 0.05. Table 2 depicts the comparison of diameter, location, and prevalence of canal between the two groups for each tooth type. The mean diameter for P1, P2, and M1 was 0.91 ± 0.20 mm, 1.07 ± 0.24 mm, and 1.32 ± 0.34 mm, respectively, in the dentate group, whereas in the edentulous group, it was 0.82 ± 0.24 mm, 1.00 ± 0.20 mm, and 1.15 ± 0.25 mm, respectively. For P1 and P2, the difference in

| Parameter          | Group, mean±SD         | P     |
|--------------------|------------------------|-------|
|                    | Dentate (n=50)         |       |
|                    | Edentulous (n=50)      |       |
| Age (years)        | 40.44±5.05             | 40.02±5.18 | 0.681 |
| Sex                | Female: 26 (52)        | 26 (52) | 0.999 |
|                    | Male: 24 (48)          | 24 (48) |       |

SD – Standard deviation; n – Number of patients; P – Probability of occurrence. P < 0.05 indicates statistical significance.
the mean canal diameter was statistically insignificant, whereas that of M1 was significant \( (P < 0.015) \). The location of the AAA was compared between the two groups for each tooth type. It was evident that for P1, the mean distance in the dentate group (22.35 ± 4.17 mm) was significantly higher than that of the edentulous group (20.37 ± 2.48 mm), as indicated by \( P = 0.012 \). The comparison was also performed within the groups across tooth type using one-way ANOVA. In both the groups, the mean differences across tooth type were statistically significant across tooth types, with \( P < 0.0001 \). The comparison of prevalence of AAA in the two groups as per the tooth type was done. The prevalence was insignificantly different between the two groups for all the three tooth types, as indicated by \( P > 0.05 \).

Table 3 displays that the relationship of demographic parameters with AAA diameter and location was established for each tooth type using multiple linear regression. For P1, age showed a significantly negative relationship with AAA diameter in both the dentate and edentulous groups, with \( P = 0.001 \) and 0.003, respectively. Similarly, for P2 and M1 tooth types, the effect of age was statistically significant. This means that as age increases, the diameter of AAA decreases.

The relationship of demographic parameters with AAA location for each tooth type was established. For P1, in both the groups, the negative coefficients revealed that as age increases, the distance decreases significantly. Similarly, for P2, age was negatively related with distance; however, the relationship was significant only in the dentate group \( (P < 0.0001) \). For M1, the effect of increasing age on distance was negatively related and was significant in both the groups, with \( P = 0.001 \) and 0.003, respectively. Figure 3a and b shows the prevalence of AAA according to age categories for each tooth type. The prevalence was higher with the increasing age category, and the observation was consistent with all the three tooth types.

The prevalence of AAA was also determined according to gender. It was found that the prevalence was higher for females as compared to males for each tooth type. Figure 4 gives the correlation of location and diameter of AAA according to tooth type using Pearson’s correlation coefficient. It is evident that the location and diameter were significantly positively related for all the three tooth types \( (P < 0.0001) \).

**DISCUSSION**

Anatomically, AAA is a vital structure within the walls of the maxillary sinus, and severing this artery can lead to excessive...
hemorrhage. Sato et al. in a study found that the sensory nerve fibers of calcitonin-related peptides accompany this artery,\(^{11}\) indicating that damage to this vessel may increase postoperative pain. Preoperative evaluations of the lateral wall thickness and this artery can reduce intraoperative complications. The alveolar bone height is an essential factor to ponder upon before sinus augmentation. It determines if implant can be simultaneously placed or not, as it may influence the possibility of achieving implant primary stability. The greater the residual alveolar bone height, the better is the chance of achieving primary implant stability.\(^{12}\)

Considering the abovementioned facts, the present investigation was performed to assess the location and diameter of AAA in dentate and partially edentulous patients in the P1, P2, and M1 areas. The presence or absence of teeth affects the course and location of these vessels.\(^{11}\)

In the present investigation, the diameter of the AAA canal was found to be more in dentate population as compared to partially edentulous ones. This can be attributed to the fact that tooth loss leads to more bone resorption in that area.\(^{13}\) Less blood supply leads to atrophy of the artery, thereby decreasing its diameter. Moreover, it was found that the M1 region exhibited the largest diameter in both the dentate and edentulous groups as compared to both premolar regions and the differences were statistically significant. These findings are in accordance with a study by Rahpeyma et al.\(^{14}\) where they found that the diameter of AAA was more in the first molar region as compared to the premolar region and also the mean diameter of this artery in premolar and molar regions was 1.024 mm and 1.124 mm, respectively, which is similar to our findings.

In the present investigation, it was evident that the mean distance from the alveolar crest was significantly higher for P1 as compared to P2 and M1 in both the dentate and edentulous groups. Similar results were found by Aung et al.\(^{10}\) in Thai population. The course of the AAA canal was curved in the most superior site of P1 and most inferior site of M1, so the least distance was found in the M1 region, suggesting that the AAA canal being very close to the crest in this region and the safest area being the P1 region for lateral sinus augmentation procedure. Further, it should be noticed that significant differences were found in P1 region in dentate and edentulous group (\(P = 0.012\)) suggesting that the blood vessel distribution in this area changes when the alveolar bone is severely atrophied because of loss of dentition. Similar results were found in the previous studies.\(^{10,14-18}\) Watanabe et al.\(^{19}\) compared the defect patterns of alveolar bone at P1, P2, M1, and M2 with the distances from the alveolar crest and sinus floor to the PSAA and reported that the distance between the PSAA and the alveolar crest in the molar region was significantly shorter than in the premolar region.

![Figure 4: Scatter plots showing the relationship between diameter and distance for all the three tooth types](image.png)

### Table 2: Comparison of diameter and location of canal between two groups for each tooth type and prevalence of (alveolar antral artery) in two groups and its comparison according to tooth type

|          | Dentate | Edentulous | \(P\)   | Dentate | Edentulous | \(P\)   | Dentulous (%) | Edentulous (%) | \(P\) |
|----------|---------|------------|--------|---------|------------|--------|---------------|---------------|------|
| Location | Mean±SD |            | P      | Mean±SD |            | P      | Dentulous     | Edentulous     |      |
| P1       | 0.91±0.20 | 0.82±0.24 | 0.065  | 22.35±4.17 | 20.37±2.48 | 0.012* (S) | 74         | 28            | 82   | 18  | 0.469 |
| P2       | 1.07±0.24 | 1.00±0.20 | 0.102  | 19.87±3.37 | 19.09±2.39 | 0.225  | 78         | 22            | 90   | 10  | 0.173 |
| M1       | 1.32±0.34 | 1.15±0.25 | 0.015* (S) | 15.87±2.65 | 15.37±1.71 | 0.317  | 76         | 24            | 86   | 14  | 0.308 |
| \(P\)    | <0.0001* (HS) | <0.0001* (HS) |        | <0.0001* (HS) | <0.0001* (HS) |        |              |                |      |      |

\(P\) value with * indicates Statistical significance. \(P<0.0001\) (HS), \(P<0.001\) (S). \(P\) – Present; A – Absent; SD – Standard deviation; P1 – First premolar; P2 – Second premolar; M1 – First molar. †Obtained using one way ANOVA; ‡Obtained using t test for independent samples; §Calculated using Z test for proportions. AAA – Alveolar antral artery; S – Significant; HS – Highly significant; \(P\) – Probability of occurrence
The prevalence of AAA was more in the edentulous group as compared to the dentate group in cases of all three tooth types. However, the differences were not statistically significant. These findings are in contrast to those of previous studies\[^{15}\] where the authors found a higher prevalence in the dentate group. In a study by Hayek et al.\[^{10}\], the prevalence of 58.6% was found in edentulous patients whereas that of 48.3% in dentate patients. These prevalence rates were found to be similar to the present study. In our study, a negative relationship has been found between age and the distance between the AAA canal and crest of the alveolar ridge. This implies that with the increase in age, the distance decreases significantly. According to Traxler et al.\[^{19}\] with the increased age and loss of dentition, the number and diameter of the blood vessels decrease. Gender effect was statistically insignificant in the present study. The distance from the artery to the alveolar crest seemed to differ more because of anatomical variations between individuals than with sex.\[^{17}\]

Males, however, showed more values for the distance between AAA canal and alveolar crest implying more bone thickness as compared to females. Similarly, it revealed that with the increase in age, the diameter of AAA decreased. Although the maxilla is very densely vascularized in young and dentate population, the blood supply to the bone is permanently reduced with age and progressing atrophy, and the number of vessels and their diameter decrease, while tortuosity increases.\[^{14,20}\] Although the gender differences were nonsignificant, the values indicate that the males have a stronger correlation with diameter and location for all tooth types. The findings of the present study are consistent with those of Beretta et al.\[^{21}\] and Mardinger et al.\[^{18}\] where they did not report a relationship between canal diameter and gender. With the increase in age, the prevalence of the AAA increased. The results of the present study are in accordance with the previous study by Chitsazi et al.\[^{18}\] where they evaluated the diameter, relationship, and position of the PSAA on CBCT in dentate and edentulous males and females. They found that the distance between the alveolar crest and AAA was decreased in cases of edentulous males and females as compared to dentate males and females. However, with respect to gender, our study revealed that females showed an increased prevalence of AAA for all tooth types. This finding is in contrast to those of previous studies\[^{17}\] where more prevalence was found in Korean male population. This discrepancy may be due to diversity of the population.

Yang and Kye in 2014 performed a study where they measured the distance of the intraosseous vascular anastomosis in the anterolateral wall of the maxillary sinus from different reference points using CT, and correlated the location of the intraosseous vascular anastomosis with the tooth position and the residual bone height of the maxilla. They found a moderate negative correlation between the residual bone height and the distance from the maxillary sinus floor to the intraosseous anastomosis at the molar sites.\[^{14}\] Therefore, the differences in prevalence and diameter of the artery on CBCT images may indicate that the likelihood of hemorrhages and other complications are higher in females, thus should be considered when excising bone for maxillary bone grafts or lateral sinus window osteotomy. Nevertheless, the present study failed to demonstrate a definite gender-wise distribution

| Tooth type | Diameter | Location | Group | β (SE) [P] | P value with * indicates Statistical significance |
|------------|----------|----------|-------|------------|---------------------------------------------------|
| First premolar | Age (male) | −0.038 (0.01) | <0.0001 (HS) | 0.015 (S) | 0.618 |
| Second premolar | Age (male) | −0.047 (0.01) | <0.0001 (HS) | 0.012 (S) | 0.618 |
| First molar | Age (male) | −0.048 (0.01) | <0.0001 (HS) | 0.001 (S) | 0.618 |
| Second molar | Age (male) | −0.010 (0.03) | 0.001 (S) | 0.557 | 0.618 |

### Table 3: Relationship of demographic parameters with alveolar antral artery diameter and location for each tooth type

The relationship of demographic parameters with AAA location was established for each tooth type using multiple linear regression analysis. β – Standard error for standardized beta. P value with * indicates Statistical significance. AAA – Alveolar antral artery; HS – Highly significant; S – Significant; P – Probability of occurrence.
of the location and diameter of AAA. This can be due to the variation of the study population that may prejudice the results. Further studies are required to confirm these associations in different populations, gender, age groups, and different stages and grades of periodontitis and alveolar bone loss. Another limitation of this present study is its cross-sectional design which may swathe the sequence of events.

Adequate knowledge regarding the anatomy of AAA in dentate and edentulous patients is extremely crucial for periodontal contemplation. The severing of the AAA could dramatically complicate the procedure, damage this bony vessel, can cause intense bleeding, obscuring the vision, and may lead to perforation of the Schneiderian membrane, which prolongs the operation and assessment of the sinus membrane reflection. Furthermore, the presence and integrity of the AAA might be crucial during surgery in order to prevent local bone necrosis and optimize the healing of the graft material, which could be impaired if the vessel is transacted. Hence, evaluation of the location and anatomy of AAA preoperatively may be of remarkable benefit in periodontal and implant surgeries.

**CONCLUSION**

Within the constraints of the study, it can be concluded that the presurgical evaluation using CBCT is very prudent for appropriate assessment and treatment planning for severely atrophic ridges in the posterior maxilla in view of circumventing the intra- and postsurgical occurrence of fatal complications. The first premolar region is the safest area for lateral window osteotomy owing to the smaller diameter of AAA and larger distance of the AAA canal from the crest of alveolar bone as compared to P2 and M1 regions. Moreover, it should be carefully performed in elderly patients, as with increasing age, the distance of AAA from the alveolar crest decreases and the presence of AAA increases in all the likelihood.

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**Conflicts of interest**

There are no conflicts of interest.

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