Evaluation of Length and Location of the Maxillary Sinus Intraosseous Artery Using Computerized Tomography

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**Summary:** CBCT can identify the maxillary sinus intraosseous artery in 84% of cases. It's mean intraosseous length is 7.4 mm and mean diameter is 0.91 mm.

**Word count:** 3369

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/JPER.20-0560.

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**Tables and figures:** 3 tables and 3 figures

**Running title:** Evaluation of sinus intraosseous artery using CBCT.

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**Conflict of interest and source of funding:**

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The authors deny any conflicts of interest related to this study, we do not have any financial interests, either directly or indirectly from the information listed in the paper. This paper was partially supported by the University of Michigan Periodontal Graduate Student Research Fund.

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## ABSTRACT

**Background:** The intraosseous artery is a branch of the posterior superior alveolar artery that supplies the lateral wall of the maxillary sinus. The present study seeks to analyze the location of the intraosseous artery and its site of termination.

**Materials and Methods:** Cone beam computed tomography (CBCT) was used to evaluate 200 patients making up 400 maxillary sinuses. The following criteria were measured: (1) the distance of the lower border of the intraosseous artery to the floor of the sinus, (2) the average length of the artery, (3) the diameter of the artery, (4) the site at which the artery terminates at, and (5) the distance of the artery from the first premolar, second premolar, first molar, and second molar.

**Results:** The artery was identified in 336 (84.0%) quadrants and its site of termination was most commonly at mesial of the second molar (22%), regardless of dental status and right or left quadrant. Its overall mean diameter was 0.91 ± 0.56 mm, with no difference within dental status. Its overall mean length was 7.40 ± 3.39 mm, with significant difference between dentate and edentulous quadrants ($p<0.001$). Its overall mean distance from the sinus inferior floor was 6.95 ± 6.49 mm, with no difference within dental status. All parameters showed no difference between right or left quadrants.

**Conclusions:** The chances of encountering the intraosseous artery at the premolar area is less than 21% during a lateral window sinus floor elevation. The most common (22%) site of

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termination of the intraosseous artery is at the mesial of the second molar. Understanding of the course, location, and termination of the artery enhances the precision of a clinician when it comes to pre-operative treatment planning.

**Keywords:** [Cone-Beam Computed Tomography; dental implants; Sinus Floor Augmentation; Complications]

## INTRODUCTION

When patients lose dentition, they often experience continuous resorption of the residual ridge in addition to pneumatization of the maxillary sinus.[1] These patients have the option to restore edentulous areas with the use of dental implants, bridges, partial dentures, and/or complete dentures. Dental implants have become a very popular solution due to their overall high success rate, predictability, and ability provide an esthetic result while restoring mastication ability to (partially or fully) edentulous patients.[2] However, with areas that undergo atrophy of the alveolar ridge and maxillary sinus pneumatization, the placement of implants is compromised.[3] In turn, these areas require an augmentation of the maxillary floor prior to or during the placement of the dental implants.[3] Tatum et al. was the first to describe the sinus lift technique.[31] However, Boyne et al. was the first to publish on the sinus lift approach.[32] Several surgical methods have been developed in order to achieve adequate alveolar bone height, but the lateral window technique is still the preferred surgical approach.[3, 4, 13, 33]

During a lateral window sinus lift, an osteotomy is made in the lateral wall of the sinus. Within the lateral wall of the maxillary sinus lies the intraosseous artery, which is a branch of posterior superior alveolar artery.[5]

Prior to performing maxillary floor augmentations, pre-operative assessment of the maxillary sinus is essential for a successful surgery.[6] Evaluation of the maxillary sinus via

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cone beam computed tomography (CBCT) scans is recommended prior to dental implant placement, and allows the clinician to avoid surgical complications.[7, 8] One of the complications that can be avoided for is the traumatization of the intraosseous artery, which may result in intraoperative bleeding that ranges from mild to severe.[5, 8, 11] Several studies have evaluated the exact position of the intraosseous artery in respects to the sinus floor.[9, 10] However, the purpose of this study was to evaluate the position of the artery in relationship to the floor of the sinus, the average length, diameter, site of termination, as well as the distance of the artery from the first premolar, second premolar, first molar, and second molar utilizing preoperative CBCT scans.

## MATERIALS AND METHODS

This study was approved by the Institutional Review Board (IRB) of the Lake Erie College of Osteopathic Medicine (LECOM) School of Dental Medicine as protocol number 24-110 on January 5, 2016.

CBCT images were acquired from patients being treated in a private periodontal practice located in Orlando, FL that is affiliated with LECOM School of Dental Medicine. All images were taken using the same CBCT machine[i]. Imaging parameters for all scans were as follows: area dose 693 mGy x $cm^2$, tube current 6 mA, and tube voltage 85 kVp. The field of view (FOV) was set at 8 cm by 8 cm for each patient. Total radiation received per patient was set to 166 micro Sieverts (Sv). The images were analyzed with an implant planning software program[ii].

A total of 200 CBCT scans (400 sinuses) taken between January 2013 and March 2016, were evaluated for the purpose of this study. Scans were assessed in panoramic, tangential, cross sectional, and axial planes for accurate analysis. All measurements were completed by two

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calibrated examiners (TT, NE) with at least one other calibrated examiner present under standardized conditions [workstation in dimly lit room, 13.3-inch LED-backlit display with IPS technology; 2560-by-1600 native resolution at 227 pixels per inch]. The examiners did not have access to the name, sex, age, or previous findings at the time of examination. All anomalies found were reviewed for integrity by a board-certified periodontist (TY), and a board-certified radiologist (EE).

Using the built-in digital caliper on the CBCT software program, the following parameters were measured in all subjects (dentate, or edentulous) via preoperative CBCT scans:

(1) *Distance between the lower border of the intraosseous artery to the floor of the maxillary sinus*. This was measured utilizing a coronal cross-sectional view. The artery was visualized upstream and downstream. The most apical point of the sinus floor with the greatest distance was included. (Fig. 1)

(2) *Length of the intraosseous artery*. This was measured by utilizing both coronal cross-sectional and panoramic views. The intraosseous canal was visualized upstream and downstream in the cross-sectional view. The most mesial and distal points of the artery located within the lateral wall of the maxillary sinus was identified. The total anteroposterior distance between these two markings was then traced and measured via the panoramic view. (Fig. 2)

(3) *Diameter of the artery*. This was measured in the coronal cross-sectional view. The artery was visualized upstream and downstream within the lateral wall of the maxillary sinus. The site with the greatest diameter was considered for measurement. This site was measured from the lower border of the artery to the upper border. (Fig. 1)

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(4) *Site at which the artery terminates at*. This was determined by tracing the canal of the intraosseous artery through the lateral wall of the maxillary sinus from the most posterior to anterior direction via a cross-sectional view. The most anterior point at which the artery could no longer be visualized was considered the site of termination. To determine where the artery terminated at in relation to the maxillary premolars and molars, the panoramic CBCT view of the crowns of the teeth were used as reference points. Sites that were anterior to midline of the crown was considered the mesial aspect of the tooth, and posterior to the midline was considered as the distal aspect. For edentulous patients, the implant planning software was utilized to provide references for PM1, PM2, M1, M2, and M3. Implants were respectively planned to start with M3 at the most posterior end of the maxilla.

(5) *Distance of the artery from the sinus floor in relation to the maxillary first premolar, second premolar, first molar, second molar, and third molar*. This was determined by tracing the canal of the intraosseous artery through the lateral wall of the maxillary sinus from the most posterior to anterior direction via a cross-sectional view. To determine this distance in relation to the maxillary premolars and molars, the panoramic view of the crowns of the teeth were used as reference points. Within the confines of the crowns, the most apical point of the sinus floor with the greatest distance was included. For edentulous patients, the implant planning software was utilized to provide respective references for PM1, PM2, M1, M2, and M3. Implants were respectively planned to start with M3 at the most posterior end of the maxilla.

The following inclusion criteria was applied:

(1) CBCT scans of acceptable quality to identify one or more of the following parameters to be assessed in edentulous or dentate maxillary sinuses.

(2) Premolar and molar sites that were of natural dentition.

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(3) CBCT files free of corrupt DICOM data.

If the CBCT scan failed to meet the inclusion criteria, the scan was excluded. If a CBCT scan presented with a site that included premolar and/or molar implant(s), only the region with the implant(s) was excluded from the study.

Statistical Analysis

The means, standard deviations (SD), ranges and frequencies were obtained for continuous and categorical data appropriately. The differences in frequency of site of termination between genders, ethnicities and dentate versus edentulous quadrants were assessed using two-tailed Fisher's Exact tests, respectively. The difference in frequency of site of termination between right and left quadrants was assessed using the McNemar-Bowker test. The differences in the means of artery diameter, artery length and artery/tooth distance from the sinus between right and left quadrants were assessed using a Paired sample t-test. An independent samples t-test was used to assess the same differences between males and females as well as dentate and edentulous quadrants. Pearson's correlation coefficient was used to identify any correlation between age and artery diameter, length and distance. The impact of ethnicity on artery diameter, length and distance while adjusting for age was evaluated using an analysis of covariance (ANCOVA). Each quadrant (right/left and dentate/edentulous) was considered a statistical unit. Level of significance was set at 0.05 for all analyses. Data analysis was conducted using specialized software[iii].

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## RESULTS

The total study sample included 62 males and 102 females (mean age of 55.34 years a range from 18 to 101). Data obtained from the charts indicated that the scans were from 117 Caucasian, 25 Hispanic, 10 African American, and 12 Asian patients.

The artery site of termination was identified in 336 (84.0%) of the total sample; 174 (87.0%) of the right quadrants and 162 (81.0%) of the left quadrants included (Table 1). Additionally, the site of termination was identified in 261 (99.2%) and 75 (100%) of the edentulous quadrants.

As summarized in Table 1, in the right quadrant, this site was mostly frequently (23.0%) at mesial of the second molar and least frequently at mesial or distal of the first premolar (0.6%). Similarly, in the left quadrant, it was also mostly frequently (21.0%) at mesial of the second molar. The difference in frequency distribution between the right and left quadrants was significantly different ($p<0.001$).

In terms of dental status, the site of termination was also most frequently at mesial of the second molar for both dentate (21.8%) and edentulous (22.7%) quadrants. It was least frequently (1.1%) at mesial of the first premolar in dentate quadrants and (0.0%) at distal of the third molar in edentulous quadrants. The difference in frequency distribution between dentate and edentulous quadrants was also found to be significantly different ($p=0.002$). Figure 3 shows the frequency of artery termination at mesial and distal sides of molars and premolars in both dentate and edentulous patients (Fig. 3).

The site of termination did not differ significantly between genders ($p=0.468$) or ethnicities ($p=0.742$). The least frequent site of termination was distal of the third molar (n=1; 1%) in females and both distal of the first premolar and third molar (3.3%) in males. The most frequent sites of termination in females were distal of the first molar and mesial of the

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second molar (19.8), while the most frequent in males was mesial of the second molar (23%). With regard to ethnicity, mesial of the second molar was the most frequent site in Hispanic (28%), Asian (25%) and Caucasian (20.5) subjects. Similarly, there was no association detected between the site of termination and age in this sample (p=0.857).

The mean artery diameter in the total sample was 0.91 ± 0.56 mm (range: 0.08 to 9.01 mm). There were no significant differences identified between right (0.94 ± 0.71 mm) and left (0.88 ± 0.32 mm) or between dentate (0.91 ± 0.60 mm) and edentulous (0.90 ± 0.34 mm) quadrants (Table 2). Similarly, no significant difference was identified between mean artery diameter in females (0.86 ± 0.32 mm) and males (0.92 ± 0.32 mm) (p=0.306). Similarly, among different ethnicities, mean artery diameter demonstrated no significant difference (p=0.686).

The mean artery length in the total sample was 7.40 ± 3.39 mm (range: 0.69 to 20.47 mm). While there was no significant difference between right (6.87 ± 6.15 mm) and left (7.05 ± 6.85 mm) quadrants, a statistically significant difference was demonstrated between dentate (7.31 ± 6.70 mm) and edentulous (5.68 ± 5.54 mm) quadrants (p=0.001; Table 2). The mean artery length in females (7.91 ± 7.90 mm) versus that in males (5.61 ± 4.31 mm) displayed significant difference between the two genders (p=0.001), however, no significant difference was demonstrated between different ethnicities (p=0.987).

The mean artery distance from the floor of maxillary sinus in the total sample was 6.95 ± 6.49 mm (range: 0.68 to 34.85 mm). There were no significant differences between right (7.53 ± 3.27 mm) and left (7.27 ± 3.52 mm) or between dentate (7.06 ± 3.26 mm) and edentulous (8.95 ± 4.47 mm) quadrants, however, the latter was only barely below the predetermined statistical level of significance (p=0.054; Table 2). The mean artery distance from the sinus did not differ significantly between females (7.24 ± 3.57 mm) and males (7.33 ± 3.47 mm) or between different ethnicities (p=0.696). In the overall sample, age did not

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demonstrate any association with site of termination (p=0.857) and did not correlate with artery distance from the floor of the maxillary sinus, diameter or length.

As for the distance of specific teeth from the sinus floor (Table 3), the first premolar demonstrated a mean distance of 6.27 ± 2.04 mm, albeit with a small sample size (n=4). The second premolar, first molar and second molar demonstrated a mean distance of 6.46 ± 2.89, 7.03 ± 3.37 and 6.88 ± 3.25 mm from the sinus, respectively.

## DISCUSSION

Pre-operative planning is essential prior to a sinus floor elevation procedure.[6] Part of this pre-operative planning includes identifying the precise location of the intraosseous artery.[6] The artery was detected 84.0% of the time in our study. Based on the following cadaveric studies[18, 25, 35, 36], the artery was present 100% of the time. Furthermore, the mean detection rate reported in literature is 61.36% (range 10.5% to 93.9%) when using CBCT analysis.[29] Although CBCT is known to be a reliable method when performing an assessment of the artery, detection of the artery itself is not always possible.[29, 36] Multiple studies[5, 23, 29, 34, 36] have reported on reasons as to why such a board range in the detection rate exists in the literature. The wide degree of variation may be attributed to (1) the experience of the operator for detecting such anatomical structures[29], (2) the anatomical dimensions or location of the artery[5, 34, 36], and (3) studies that reported results using different methods of assessment, such as printed, film-based images versus imaging software[23]. Utilizing CBCT software allowed us to elevate the diameter of arteries as small as 0.08 mm via zooming capabilities, and a built-in digital caliper.

When the diameter of the intraosseous canal is larger than 2 mm, there is higher probability for the risk of hemorrhage.[16, 17, 34] The mean artery diameter of the intraosseous

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artery in the total sample was 0.91 mm with a wide range of 0.08 to 9.01 mm. The reported diameter for our study is similar to what a few studies[9, 10, 18, 19] have found (means ranging from 0.9 mm to 1.04 mm), but slightly less than what most literature[16, 20-25] shows (means ranging from 1.17 mm to 1.61 mm). The use of different CBCT machines among the studies could account for the differences in data.[26] When comparing different CBCT machines, differences in overestimation bone quality and aberrant structural patterns are known.[26] This affects standardization and interpretation of results when compared to other studies.

Our findings in regard to the mean artery distance from the maxillary sinus floor in the total sample was 6.95 mm (range: 0.68 to 34.85 mm) was similar to what Apostolakis et al. found (mean of 7.04 mm). However, when compared to most studies[18, 19, 22, 23, 27, 28] with reported means ranging from 7.75 mm to 9.70 mm, our data seems to be much lower. Differences seen could be due to the degree of anatomical variation between subjects, which can be seen by the wide ranges found in our study, and other studies[16, 22, 23, 29]. Moreover, it is worth noting that our study included 75 edentulous subjects (22.3%). Although alveolar ridges were not measured in our study, smaller edentulous ridges are associated with lower values for this distance compared to dentate ridges.[20, 38] In addition, a wide range (1.0 mm to 20.0 mm) for differences in the residual bony alveolar ridges have been reported, which further supports the level of variation one can expect.[34, 37] In contrast, some studies[23] have suggested that no statistically significant difference exists between edentulous or dentate subjects, including our study. Although a statistically significant difference was not found between dentate and edentulous subjects, the authors believe a clinically significant difference of 1.89 mm should be taken into consideration.

The mean intraosseous artery length in the total sample was 7.40 mm (range: 0.69 to 20.47 mm). To the best of our knowledge, only one other study[21] has evaluated the length of the intraosseous artery. The study done by Bernardi et al. found that the length of the artery ranged from 4–27 mm with a left side mean 12.55 mm and right side 12.43 mm.[21] This

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difference could be attributed to the much smaller sample size (71 sites) used by Bernardi et al. compared to our study (336 sites).[21] Bernardi et al. also completed the study in a specific patient population in Central Italy whereas our study included Asians, African-American, and Hispanics, but mainly Caucasian patients.[21] Although there were differences between our study, the data reported in our study improves our current understanding of the anatomy of the artery.

In the present study, the mean distance of the intraosseous artery from the floor of sinus at PM1, PM2, M1, and M2 was 6.27, 6.46, 7.03 and 6.88 mm, respectively. The results from our study are similar to findings reported by Yang et al. and Apostolakis et al. who reported ranges for PM1, PM2, M1, and M2 from 5.90 to 6.67 mm, 5.80 to 8.19 mm, 7.58 to 7.59 mm, and 7.80 to 8.00 mm, respectively.[16, 27] However, the results differed from the data reported by Hur et al., Kim et al., Watanabe et al., and Danesh-Sani et al.[18, 22, 28] Aside from the cadaveric study[18], the ability to detect the artery via CBCT could have been why our results deviated from other CBCT studies[22, 27, 28] that identified the artery in 29% to 60.58% of subjects. The study that reported similar findings, also reported a similar level of identification, 82% compared to 84% from our study.[16] This could account for our similar findings.

When comparing our results to cadaveric studies, our group found a significantly lower value for the distance of the sinus floor to the intraosseous artery in regard to maxillary posterior teeth. However, our group did report similar findings in regard to the diameter of the artery when compared with Hur et al. (0.8 mm), but not with Solar et al. (1.59 mm).[18, 25] Hur et al. looked at 42 hemifaces from a Korean population.[18] The mean measurements from the sinus floor to the intraosseous artery were reported as follows: 9.4 mm at PM1, 9.7 mm at PM2, 10.3 mm at M1, 9.6 mm at M2, and 9.5 mm at the maxillary tuberosity (M3) region.[18] Kqiku et al. looked at 40 hemifaces and found that the mean distances of the intraosseous artery to the alveolar ridge were: 14 mm for PM2, 13 mm for

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M1, and 17 mm for M2.[35] Both studies[18, 35] reported significantly different results from each other in this regard, which further supports that anatomical variation that exists between subjects. In addition, the reported means did not correlate to the minimum and maximum distances (18.90-19.60 mm) found by Solar et al.[25] Also, a trend was reported regarding how the artery tends to be lowest at the level of the first premolar region, which was seen in our study.[18]

There are a limited number of studies that have reported on the prevalence of the intraosseous artery in regards to the posterior teeth.[9, 22, 30] To the best of our knowledge there is currently no literature that has precisely distinguished where the intraosseous artery could be found with regards to the mesiodistal relationship of the maxillary posterior teeth. To further aid clinicians, we have pinpointed exactly where one could expect the artery the most, which was at the mesial of M2 (22% of the time). Prevalence of the artery was the least found at the mesial of PM1 (1.5%). However, there was a small sample size (n=5) for this category. When evaluating the prevalence both mesial and distal aspects of the posterior teeth together, the second molar had the highest prevalence (36.3%), and the first premolar had the lowest (3.3%). When compared to Watanabe et al., Lee et al., and Duruel et al., the most frequent posterior site was reported to be PM2, M2, and PM2, respectively.[9, 22, 30]

Few studies have reported on the exact dimensions of a bone window. One study suggested that the window be a minimum of 10-15 mm in length, and 8-10 mm in height.[39] Whereas another group mentioned that 20 mm in length and 15 mm in height was the correct dimensions.[40] If these dimensions were hypothetically applied when treating patients from this study, the artery would be encountered 100% of the time. However, it is estimated that the artery is seen clinically about 20% of the time during sinus lift surgery.[5] A cadaveric study looked at how often the artery was seen when a bone window was made between the first and second maxillary molars and found the artery 66% of the time.[41] This value is similar to the average detection percentage via CBCT. Based on the clinical experiences of

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the authors with lateral window sinus floor elevations, the authors were in agreement that the artery is detected clinically less frequently than what is suggested by the present study or the mentioned cadaveric study.

The authors believe that by further clarifying the length, termination, and location of the artery, clinicians will be better equipped when performing procedures involving the maxillary sinus. It can also be inferred that the level of experience of a clinician can affect the size of the bone window that a clinician will choose to make.[40] The following data reported should decrease intra- and post-operative complications associated with injury to the intraosseous artery.[23]

## CONCLUSION

The chances of encountering the intraosseous artery at the premolar area is less than 21% during a lateral window sinus floor elevation. The most common (22%) site of termination of the intraosseous artery is at the mesial of the second molar. Understanding of the course, location, and termination of the artery enhances the precision of a clinician when it comes to pre-operative treatment planning. This may help limit intra- and post-operative surgical complications during lateral window sinus floor elevation procedures.

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References


1. Hinshaw JR, Pearse H. *Histological techniques for the differential staining of burned and normal tissues*: Office of Technical Services, Department of Commerce; 1956.
2. Shemtov-Yona K, Rittel D. An overview of the mechanical integrity of dental implants. *BioMed research international* 2015;2015.
3. Starch-Jensen T, Jensen JD. Maxillary sinus floor augmentation: a review of selected treatment modalities. *Journal of oral & maxillofacial research* 2017;8.
4. Zaniol T, Zaniol A. A rational approach to sinus augmentation: The low window sinus lift. *Case Reports in Dentistry* 2017;2017.
5. Elian N, Wallace S, Cho S-C, Jalbout ZN, Froum S. Distribution of the Maxillary artery as it relates to sinus floor augmentation. *International Journal of Oral & Maxillofacial Implants* 2005;20.
6. Rahpeyma A, Khajehahmadi S. Open sinus lift surgery and the importance of preoperative cone-beam computed tomography scan: a review. *Journal of international oral health: JIOH* 2015;7:127.
7. Dobele I, Kise L, Apse P, Kragis G, Bigestans A. Radiographic assessment of findings in the maxillary sinus using cone-beam computed tomography. *Stomatologija* 2013;15:119-122.
8. de Souza Nunes LS, Bornstein MM, Sendi P, Buser D. Anatomical characteristics and dimensions of edentulous sites in the posterior maxillae of patients referred for implant therapy. *International journal of periodontics & restorative dentistry* 2013;33.
9. Duruel O, Ataman-Duruel ET, Tözüm MD, Karabulut E, Tözüm TF. The radiological evaluation of posterior superior alveolar artery topography by using computed tomography. *Clinical implant dentistry and related research* 2019;21:644-648.
10. Ilguy D, Ilguy M, Dolekoglu S, Fisekcioglu E. Evaluation of the posterior superior alveolar artery and the maxillary sinus with CBCT. *Brazilian oral research* 2013;27:431-437.
13. Maridati P, Stoffella E, Speroni S, Cicciu M, Maiorana C. Alveolar antral artery isolation during sinus lift procedure with the double window technique. *The open dentistry journal* 2014;8:95.
14. Testori T, Rosano G, Taschieri S, Del Fabbro M. Ligation of an unusually large vessel during maxillary sinus floor augmentation. A case report. *European journal of oral implantology* 2010;3.


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15. Chen L, Cha J. An 8-year retrospective study: 1,100 patients receiving 1,557 implants using the minimally invasive hydraulic sinus condensing technique. *Journal of Periodontology* 2005;76:482-491.

16. Apostolakis D, Bissoon AK. Radiographic evaluation of the superior alveolar canal: measurements of its diameter and of its position in relation to the maxillary sinus floor: a cone beam computerized tomography study. *Clinical oral implants research* 2014;25:553-559.

17. Ella B, Sédarat C, Da Costa Noble R, et al. Vascular connections of the lateral wall of the sinus: surgical effect in sinus augmentation. *International Journal of Oral & Maxillofacial Implants* 2008;23.

18. Hur M-S, Kim J-K, Hu K-S, Bae HEK, Park H-S, Kim H-J. Clinical implications of the topography and distribution of the posterior superior alveolar artery. *Journal of Craniofacial Surgery* 2009;20:551-554.

19. Şimşek Kaya G, Daltaban Ö, Kaya M, Kocabalkan B, Sindel A, Akdağ M. The potential clinical relevance of anatomical structures and variations of the maxillary sinus for planned sinus floor elevation procedures: A retrospective cone beam computed tomography study. *Clinical implant dentistry and related research* 2019;21:114-121.

20. Tehranchi M, Taleghani F, Shahab S, Nouri A. Prevalence and location of the posterior superior alveolar artery using cone-beam computed tomography. *Imaging science in dentistry* 2017;47:39-44.

21. Bernardi S, Mummolo S, Ciavarelli LM, Vigni ML, Continenza MA, Marzo G. Cone beam computed tomography investigation of the antral artery anastomosis in a population of Central Italy. *Folia Morphologica* 2016;75:149-153.

22. Watanabe T, Shiota M, Gao S, Imakita C, Tachikawa N, Kasugai S. Verification of posterior superior alveolar artery distribution in lateral wall of maxillary sinus by location and defect pattern. *Quintessence International* 2014;45.

23. Danesh-Sani SA, Movahed A, ElChaar ES, Chong Chan K, Amintavakoli N. Radiographic evaluation of maxillary sinus lateral wall and posterior superior alveolar artery anatomy: A cone-beam computed tomographic study. *Clinical implant dentistry and related research* 2017;19:151-160.

24. Güncü GN, Yildirim YD, Wang HL, Tözüm TF. Location of posterior superior alveolar artery and evaluation of maxillary sinus anatomy with computerized tomography: a clinical study. *Clinical oral implants research* 2011;22:1164-1167.

25. Solar P, Geyerhofer U, Traxler H, Windisch A, Ulm C, Watzek G. Blood supply to the maxillary sinus relevant to sinus floor elevation procedures. *Clinical Oral Implants Research* 1999;10:34-44.

26. Van Dessel J, Nicolielo L, Huang Y, et al. Accuracy and reliability of different cone beam computed tomography (CBCT) devices for structural analysis of alveolar bone

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in comparison with multislice CT and micro-CT. *Eur J Oral Implantol* 2017;10:95-105.

27. Yang S-M, Kye S-B. Location of maxillary intraosseous vascular anastomosis based on the tooth position and height of the residual alveolar bone: computed tomographic analysis. *Journal of periodontal & implant science* 2014;44:50-56.

28. Kim G-T, Choi B-J, Lee D-W. A radiographic study of the position and prevalence of the maxillary arterial endosseous anastomosis using cone beam computed tomography. 2011.

29. Valente NA. Anatomical considerations on the alveolar antral artery as related to the sinus augmentation surgical procedure. *Clinical implant dentistry and related research* 2016;18:1042-1050.

30. Lee J, Kang N, Moon Y-M, Pang E-K. Radiographic study of the distribution of maxillary intraosseous vascular canal in Koreans. *Maxillofacial plastic and reconstructive surgery* 2016;38:1-4.

31. Tatum OH. Lecture presented to the Alabama Implant Congress. 1976.

32. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. Journal of Oral Surgery. 1980;38(8):613–616.

33. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. Compendium. 1994;15(2):152–162.

34. Mardinger O, Abba M, Hirshberg A, Schwartz-Arad D. Prevalence, diameter and course of the maxillary intraosseous vascular canal with relation to sinus augmentation procedure: a radiographic study. Int J Oral Maxillofac Surg. 2007;36:735-738.

35. Kqiku L, Biblekaj R, Weiglein AH, Kqiku X, Städtler P. Arte- rial blood architecture of the maxillary sinus in dentate specimens. Croat Med J 2013; 54:180–184.

36. Rosano G, Taschieri S, Gaudy JF, Weinstein T, Del Fabbro M. Maxillary sinus vascular anatomy and its relation to sinus lift surgery. Clin Oral Implants Res 2011; 22:711–715.

37. Lekholm U, Zarb GA. Patient selection and preparation. In:

Brånemark PI, George AZ, Albrektsson T. Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago, IL: Quintessence; 1985. p. 199-209.

38. Pramstraller M, Schincaglia GP, Vecchiatini R, Farina R, Trombelli L. Alveolar ridge dimensions in mandibular posterior regions: a retrospective comparative study of dentate and edentulous sites using computerized tomography data. Surg Radiol Anat. 2018;40(12):1419-1428. doi:10.1007/s00276-018-2095-0

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39. Vercellotti, T., De Paoli, S. & Nevins, M. (2001) The piezoelectric bony window osteotomy and sinus membrane elevation: introduction of a new technique for simplification of the sinus augmen- tation procedure. The International Journal of Periodontics & Restorative Dentistry 21: 561– 567.

40. Testori, T. & Wallace, S.S. (2009) Surgical proce- dures: lateral window approach. In: Testori, T., Del Fabbro, M., Weinstein, R. & Wallace, S., eds. Maxillary Sinus Surgery and Alternatives in Treatment, Chapter 12, p.21. Chicago, IL: Quin- tessence Publishing.

41. Rodella LF, Labanca M, Boninsegna R, Favero G, Tschabitscher M, Rezzani R. Intraosseous anastomosis in the maxillary sinus. *Minerva Stomatol.* 2010;59(6):349-354.

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**Legends:**

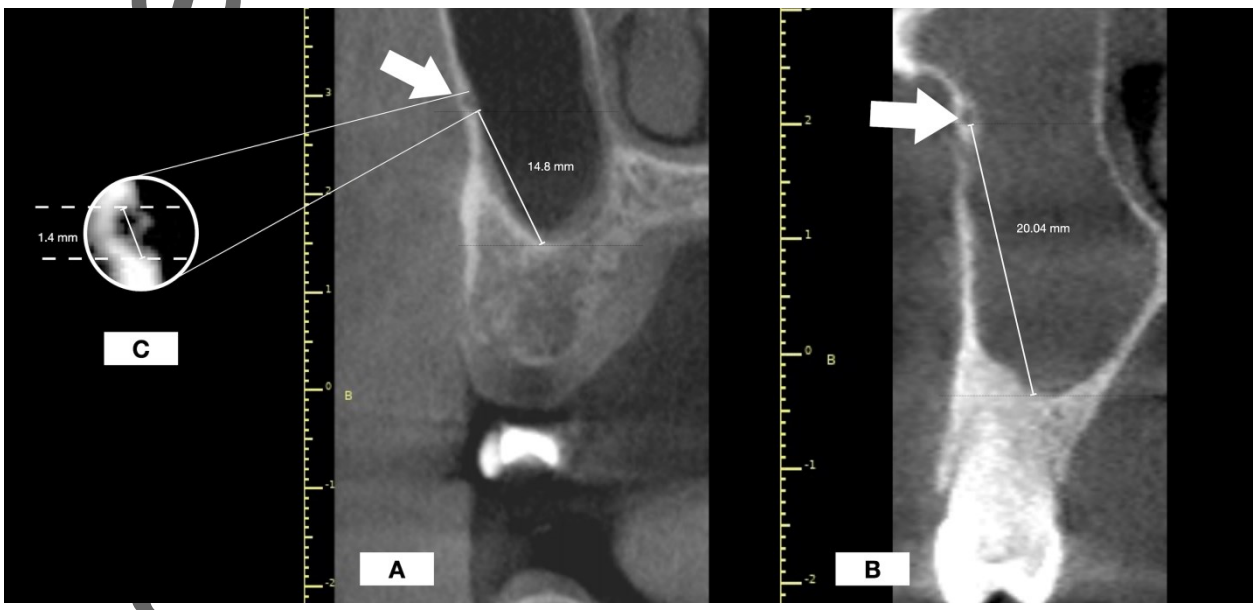
**Figures:**

**Figure 1.**

**A.** A coronal CBCT view showing the location of artery in an edentulous ridge with a radiographic stent in place.

**B.** A coronal CBCT view showing the location of artery in a dentate ridge.

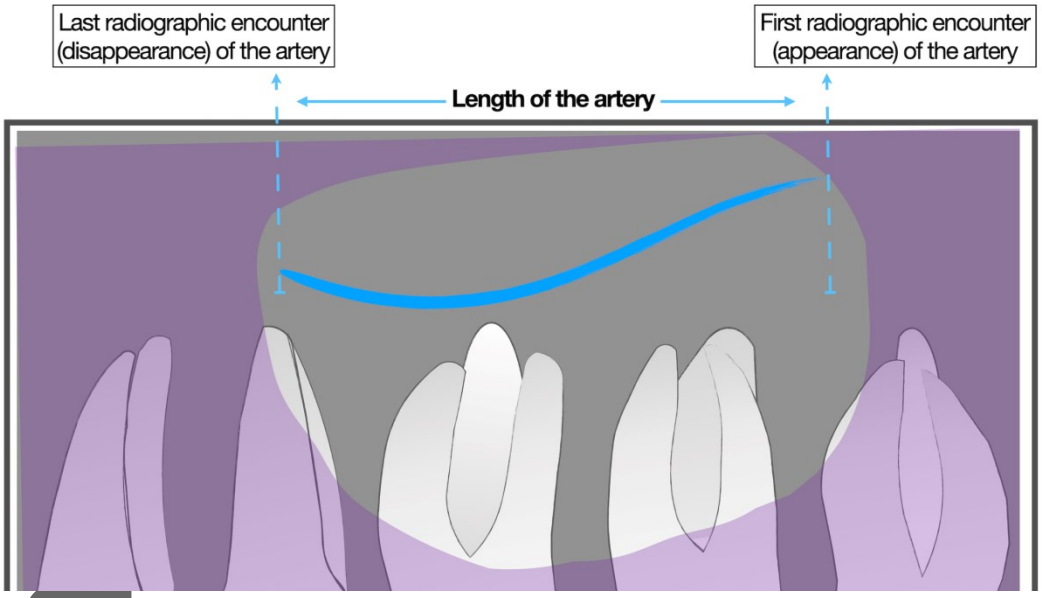
**C.** A magnification of the artery in coronal cross-sectional view showing the sites at which the measurements were performed.




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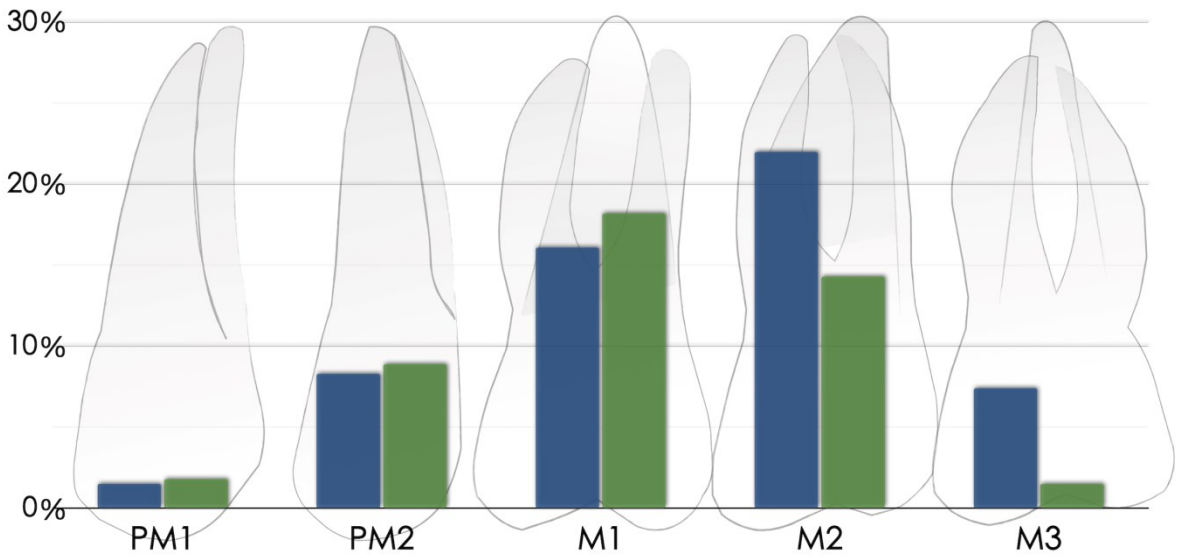
**Figure 2.** An illustration demonstrating the approach by which the length of the artery was determined.




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**Figure 3.** An illustration demonstrating mean frequency of artery termination at mesial and distal surfaces of molars and premolars in both dentate and edentulous patients. PM1 = first premolar; PM2 = second premolar; M1 = first molar; M2 = second molar; M3 = third molar.




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**Tables:**

**Table 1.** Frequency of artery site of termination corresponding to tooth site in total, in right versus left and in dentate versus edentulous quadrants. PM1 = first premolar; PM2 = second premolar; M1 = first molar; M2 = second molar;

| | Total | | Right | | Left | | | Dentate | | Edentulous | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Frequency (%) | n | Frequency (%) | n | Frequency (%) | *p* value | n | Frequency (%) | n | Frequency (%) | *p* value |
| Mesial of PM1 | 5 | 1.5 | 1 | 0.6 | 4 | 2.5 | <0.001 | 3 | 1.1 | 2 | 2.7 | |
| Distal of PM1 | 6 | 1.8 | 1 | 0.6 | 5 | 3.1 | | 5 | 1.9 | 1 | 1.3 | |
| Mesial of PM2 | 28 | 8.3 | 14 | 8.0 | 14 | 8.6 | | 23 | 8.8 | 5 | 6.7 | |
| Distal of PM2 | 30 | 8.9 | 15 | 8.6 | 15 | 9.3 | | 26 | 10.0 | 4 | 5.3 | |
| Mesial of M1 | 54 | 16.1 | 28 | 16.1 | 26 | 16.0 | | 42 | 16.1 | 12 | 16.0 | 0.002 |
| Distal of M1 | 61 | 18.2 | 35 | 20.1 | 26 | 16.0 | | 51 | 19.5 | 10 | 13.3 | |
| Mesial of M2 | 74 | 22.0 | 40 | 23.0 | 34 | 21.0 | | 57 | 21.8 | 17 | 22.7 | |
| Distal of M2 | 48 | 14.3 | 23 | 13.2 | 25 | 15.4 | | 40 | 15.3 | 8 | 10.7 | |
| Mesial of M3 | 25 | 7.4 | 15 | 8.6 | 10 | 6.2 | | 9 | 3.4 | 16 | 21.3 | |
| Distal of M3 | 5 | 1.5 | 2 | 1.1 | 3 | 1.9 | | 5 | 1.9 | 0 | 0 | |
| Total | 336 | 100.0 | 174 | 100.0 | 162 | 100.0 | | 261 | 100.0 | 75 | 100.0 | |
| Undetected | 64 | | 26 | | 38 | | | 2 | | 0 | | |

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**Table 2.** Artery diameter, length and distance from the maxillary sinus in total, in right versus left and in dentate versus edentulous quadrants.

| | | n | Mean (mm) | Range (Min. - Max.) | *p* value |
|---|---|---|---|---|---|
| Diameter | Total | 336 | 0.91 ± 0.56 | 0.08 — 9.01 | |
| | Dentate | 261 | 0.91 ± 0.60 | 0.08 — 9.01 | 0.850 |
| | Edentulous | 75 | 0.90 ± 0.34 | 0.28 — 1.97 | |
| | Right | 174 | 0.94 ± 0.71 | 0.08 — 9.01 | 0.611 |
| | Left | 162 | 0.88 ± 0.32 | 0.28 — 2.57 | |
| Length | Total | 336 | 7.40 ± 3.39 | 0.69 — 20.47 | |
| | Dentate | 261 | 7.31 ± 6.70 | 0.91 — 34.85 | 0.001 |
| | Edentulous | 75 | 5.68 ± 5.54 | 0.68 — 30.20 | |
| | Right | 174 | 6.87 ± 6.15 | 1.08 — 28.92 | 0.845 |
| | Left | 162 | 7.05 ± 6.85 | 0.68 — 34.85 | |
| Distance from the maxillary sinus | Total | 336 | 6.95 ± 6.49 | 0.68 — 34.85 | |
| | Dentate | 260 | 7.06 ± 3.26 | 0.69 — 20.47 | 0.054 |
| | Edentulous | 75 | 8.95 ± 4.47 | 1.94 — 32.00 | |
| | Right | 174 | 7.53 ± 3.27 | 1.11 — 20.47 | 0.272 |
| | Left | 162 | 7.27 ± 3.52 | 0.69 — 19.48 | |

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**Table 3.** Distance of individual tooth types from the maxillary sinus. PM1 = first premolar; PM2 = second premolar; M1 = first molar; M2 = second molar.

| | | n | Mean (mm) | Range (Min. - Max.) |
|---|---|---|---|---|
| Distance from the maxillary sinus | PM1 | 7 | 6.27 ± 2.04 | 3.35 — 9.59 |
| | PM2 | 57 | 6.46 ± 2.89 | 0.69 — 12.08 |
| | M1 | 144 | 7.03 ± 3.37 | 1.11 — 19.48 |
| | M2 | 214 | 6.88 ± 3.25 | 1.14 — 19.06 |

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[i] Sirona XG3 CBCT (Dentsply Sirona, York, PA).
[ii] Galaxis/Galileo Implant Viewer (Dentsply Sirona, York, PA).
[iii] IBM SPSS Statistics for Windows, Version 25.0, IBM Corp., Armonk, NY, USA.

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