Assessment of Mental and Lingual Foramen, Mandibular Canal, and Maxillary Sinus by CBCT in Southern Mexico. How Important Is It?

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This study aimed to determine the frequency of anatomical variants of the jaws considered critical and their limitations in implant surgical procedures by analyzing cone beam computed tomography (CBCT) scans. A random sample of 46 CBCT images was retrieved. Computed tomography (CT) scans with correct visualization of the anatomical area to be studied with different fields of view (FOV) were included: 5X5, 8X5, and 8X8. Ex3D-plus software was used to obtain the various measurements of each patient. The statistical program STATA V.15 was used, and $P \leq .05$ was considered significant. In total, 6 anatomical structures corresponding to 46 CBCT images were analyzed. Seventy-eight percent of mentonian foramen (n = 39) were oval, while 16% (n = 8) were circular. In 81% of the CT scans (n = 21), no accessory mentonian foramen were seen. In 100% of patients (n = 25), anterior loops were present. In addition, 96% (n = 24) presented lingual foramen. According to gender, it was found that the average distance between the maxillary sinus floor and the disto-vestibular and palatal apices of the upper second molar was significantly greater in men than in women ($P \leq .05$). In conclusion, dentists should have a comprehensive knowledge of the anatomy of the maxillofacial. Based on the results reported in our study, it should be considered that structures that have been classically determined to be inconstant, such as the lingual foramen and the anterior loop, should now be considered part of normal anatomy.

Key Words: dental Implants, therapy, maxilla, mandible, cone-beam computed tomography

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INTRODUCTION

It is essential to have complete and concise information about the anatomy of the maxillary bones before performing any surgical procedure in this area.[1] Despite the general belief that both anatomical regions are considered safe for dental implant (DI) placement and other surgical procedures for prosthetic purposes, the detailed anatomy remains controversial.[2] In implant dentistry, the critical anatomical structures present in the posterior and anterior segment of the mandible include the mandibular canal (MC) through which the inferior alveolar nerve (IAN) runs, the mentonian foramen (MF), the accessory mentonian foramen (AMF), the anterior loop (AL), the lingual foramen (LF), and the mandibular incisor canal (MIC). The anatomical structures in the posterior and anterior segments of the maxilla include the maxillary sinus (MS), Schneider's membrane (SM), and nasopalatine canal, mainly.[3]

The IAN gives sensory innervation to the mandible. It enters the mandibular foramen and runs postero-anteriorly throughout

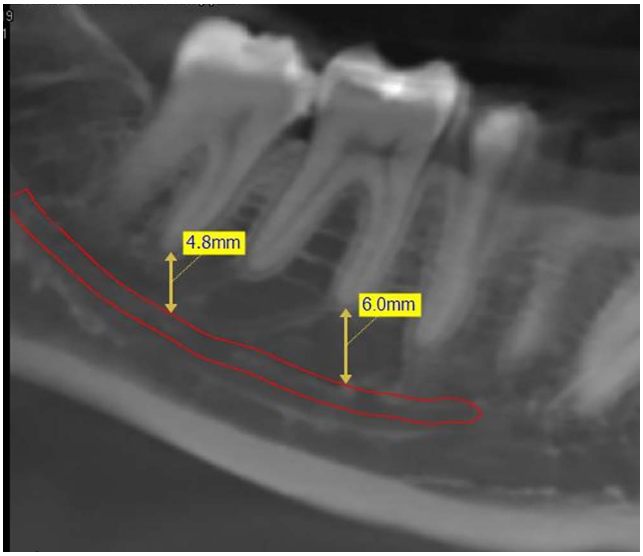

Figure 1. Distance between mandibular canal and dental apex.

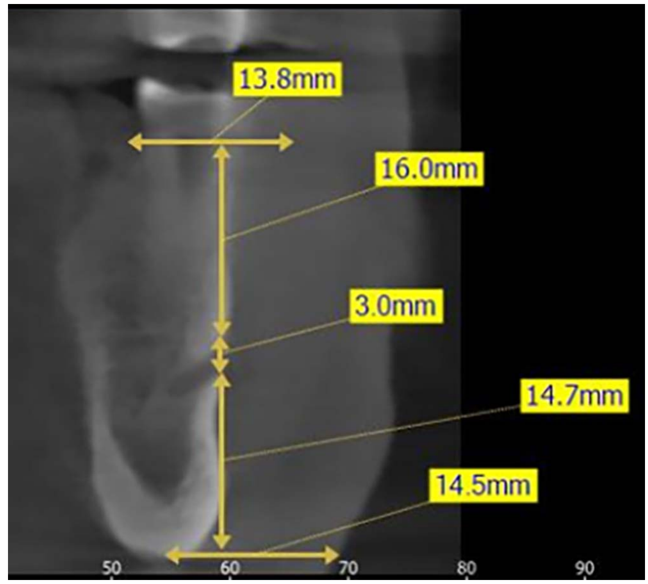

Figure 2. Location of mental foramen.

the mandibular body.[4] Before emerging through the MF, it ascends and curves a few millimeters, where it is called the AL.[5] Subsequently, it divides into its terminal branches, the mentonian and incisive nerves, which follow their paths through the MIC.[6] Another structure of special interest present in the anterior segment of the mandible is the LF located in the mandibular midline, immediately superior and inferior to the mentonian spines.[7] An important consideration when placing DI in the anterior and posterior segment of the mandible is to avoid injury to the IAN and terminal branches, as iatrogenic injury could result in postoperative pain and reversible or permanent paresthesia, depending on the severity of the injury.[8]

The MS is a pyramid-shaped cavity located in the upper part of the maxilla. It has been shown that the shape, size, and thickness vary between the sides of the same skull.[9] The mucous membrane lining the internal part of the maxillary sinuses corresponds to the SM, consisting of a pseudostratified ciliated columnar epithelium, with an average thickness of 1 mm.[10] Respecting these anatomical structures during DI placement or other types of surgeries in the area will help avoid certain complications such as oroantral communications, lesion of the SM, displacement of foreign bodies, and infections, among others.[11] Thus, the anatomical landmarks in both jaws have been the subject of study and have regained their special attention to optimize preoperative planning in the placement of DI, or other types of surgeries in the area, and to avoid serious complications.[12]

Accurate radiographic evaluation of the mandible and maxilla anatomical structures by preoperative surgical planning is a prerequisite for successful DI therapy.[13] The selection of the appropriate diagnostic image and the clinical expertise of the implantologist helps in treatment planning.[14] Both orthopantomography and CBCT are the most commonly used imaging modalities in surgical and prosthetic oral implantology. In conventional radiographs such as orthopantomography, the anatomical structures can only be observed in two planes, that is, the dimension in the buccolingual direction cannot be appreciated; this offers a significant disadvantage for the clinician concerning DI placement. However, they are more economical compared with CBCT.[15] On the other hand, CBCT allows 3-dimensional (3D) evaluation of anatomical structures, with the facility to show bone in axial, coronal and sagittal sections, which enables the clinician to obtain more precise and detailed information about the quality and quantity of bone tissue (bone density), as well as the location and characteristics of anatomical structures that could be considered limiting at the time of DI placement.[16]

This study analyzed CBCT scans to determine the frequency of anatomical variants of the jaws considered critical and their limitations in implant surgical procedures.

Materials and Methods

Study population and selection criteria

A cross-sectional study was carried out in an implantology and oral rehabilitation clinic. The Ethics Committee of the Faculty of Dentistry of the Autonomous University of Guerrero (authorization EIRB-001/2021) approved the research protocol; the study adheres to the Declaration of Helsinki of the World Medical Society. A convenient, non-random sample of 46 CBCT was retrieved from April 16, 2021, to February 29, 2022. CT scans with correct visualization of the anatomical area to be studied (MC, MF, AMF, AL, LF, and MS) with different FOV were included: 5X5, 8X5, and 8X8. CT scans of total dentate patients of both genders and aged 10 to 79 years were included. The anatomical areas to be studied were: MC (Figure 1), MF (Figure 2), AMF, AL (Figure 3), LF (Figure 4), and MS (Figures 5 and 6). CT scans that did not visualize the anatomical area to be studied and patients with intraosseous pathologies of the jaws and/or any syndrome with intraoral manifestations that would affect the shape of the anatomical structures to be studied were excluded.

CBCT

All samples were captured using the same equipment (PaX-i3D Green, Vatech) of CB type and the same settings (120 KVp,

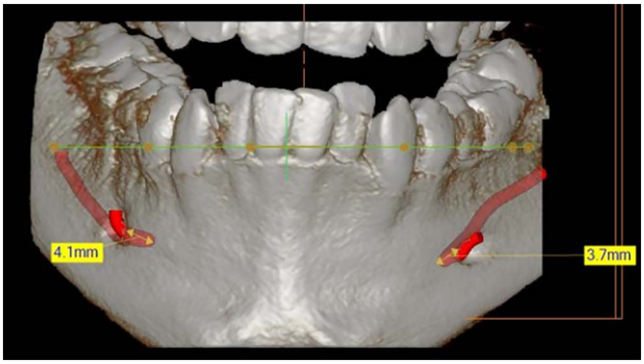

Figure 3. Mental loop.

5mA in full rotational mode, a 5X5, 8X5, and 8X8 FOV of innovative technology with specialized sensors to obtain fast scan images of 5.9 seconds and 0.3 mm as voxel size).

Radiographic measurements

Ex3D-plus software was used to obtain the different measurements on each patient on both sides (L = left, R = right). To minimize measurement bias, all measurements were repeated twice at an interval of at least 1 week.

The following measurements were performed:

1. In the coronal plane:
   - The distance between the MC and the mesial apex of the first, second, and third lower molars in the right and left hemiarch was measured.
   - The distance between the MC and the cortices, one superior alveolar and the other inferior or basal border in both hemiarchs, was measured. Its size was measured, and the evaluation of its oval or circular shape was considered. The AL was measured by previously drawing the MC and following its course until it emerged in the MF. The presence of AMF was visualized.
   - Distance between the floor of the MS to the apices of the first and second premolar, first and second upper molar in both hemiarchs. Positive values were placed for apices below the floor of the MS, and negative values were placed for apices immediately above the floor of the MS.
2. In the axial plane:
   - MS: Once located, the area of the right and left MS was delimited with the CBCT software's polygon tool, and the anteroposterior distance, mid-lateral area, and perimeter were measured.
3. In the sagittal plane:
   - LF: The sagittal plane was placed on the mandibular midline, the mental spines were located, and with it, the location of the lingual foramen.

Statistical analysis

The STATA V.15 (Stata Corp, College Station, TX) statistical program was used, considering a value of $P \leq .05$ as significant. The normality of the data was examined using the Shapiro-Wilk test. The data had a normal distribution, so a parametric analysis was performed using the Student *t* test. The χ^2 test and Fisher exact test were used to compare qualitative variables. All statistical analyses have been carried out by an independent statistician.

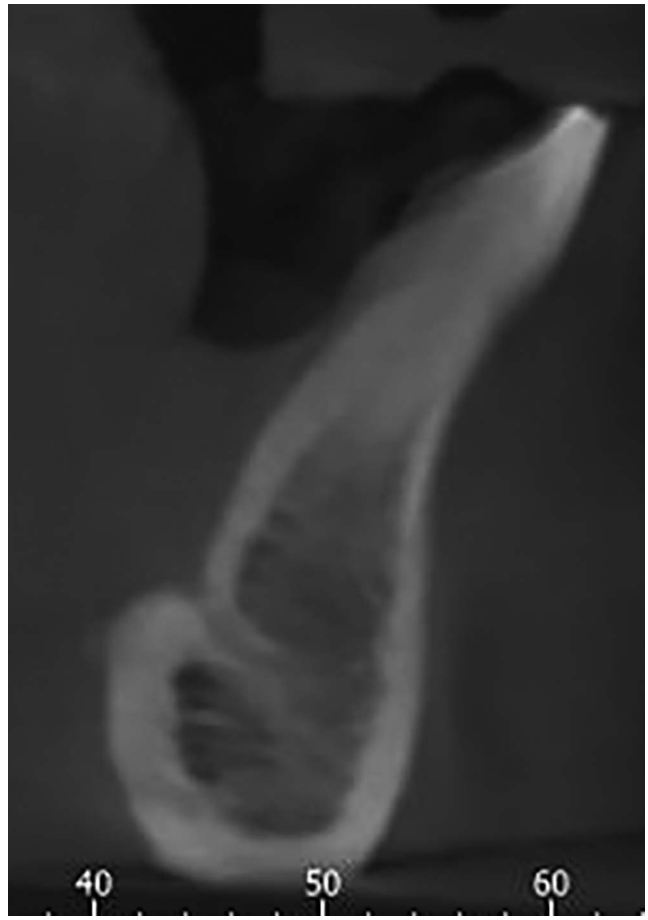

Figure 4. Lingual foramen.

Results

In total, 6 anatomical structures (MC, MF, AMF, AL, LF, and MS) corresponding to 46 CBCT images were analyzed; 30.4% (n = 14) were complete volumetric tomography (maxilla and mandible), 24% (n = 11) were volumetric tomography of the mandible and 46% (n = 21) were volumetric tomography of the maxilla.

The patients presented an age range of 10–79 years, with a mean age of 46.2 years, and 67% (n = 31) of the subjects were female and 33% (n = 15) were male. Participants of the female gender, generally aged 61–70 years, represented the majority of patients.

According to the ordered description of the anatomical structures previously described, it was found that, on mean, the distance between the MC and the mesial apices of the mandibular molars was more significant at the level of the lower first molar (2.35 ± 3.01 mm) (Table 1). Regarding the MF, it was found that the mean distance between the MF and the superior alveolar cortex was 5.92 ± 6.37 mm. While the MF to the basal margin was 4.10 ± 6.17 mm (Table 2). On mean, its vertical size was 1.52 mm, it was also found to be larger on the left side than on the right,

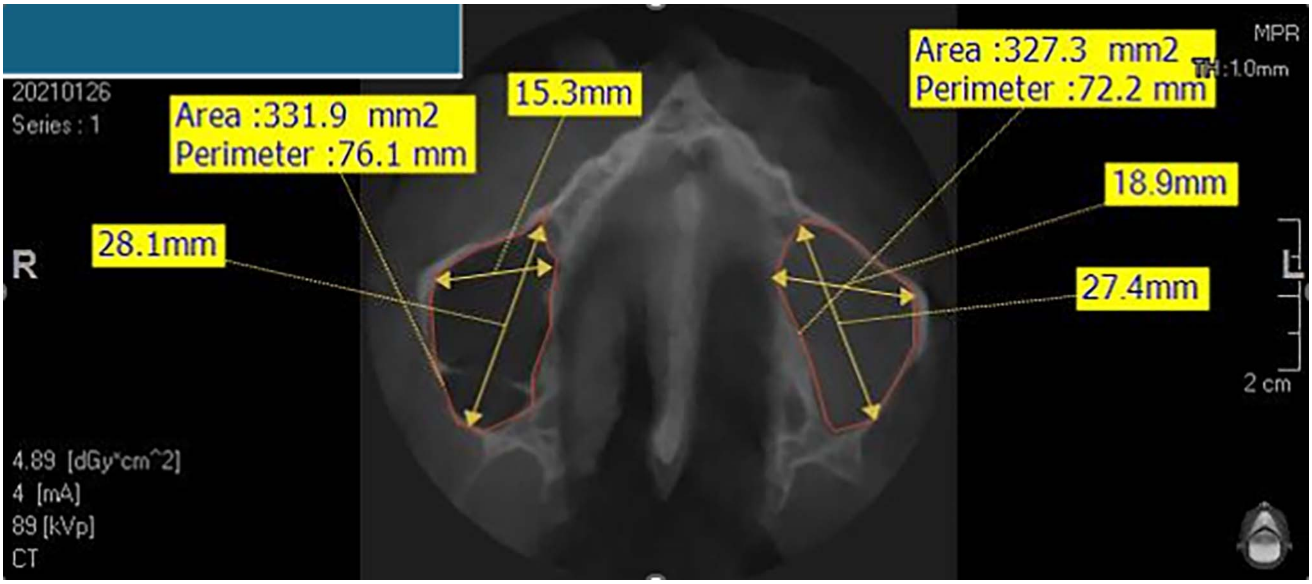

Figure 5. Dimensions of maxillary sinus.

and concerning gender, it was larger in women than in men, but without statistical significance ($P > .05$). In addition, it was found that 78% (n = 39) of the MF were oval, while 16% (n = 8) were circular.

On the other hand, it was also observed that 81% (n = 21) of CT scans did not appreciate the AMF. Meanwhile, 100% (n = 25) of the patients presented AL, which, on mean, was 2.42-mm long. The extension of the AL was greater on the left side than on the right ($P > .05$), and it was greater in women than in men but without statistical significance ($P > .05$).

Figure 6. Distance between dental apex and floor of maxillary sinus.

In addition, 96% (n = 24) of the patients presented LF. Sixty-eight percent (n = 17) presented a single LF, while 28% (n = 7) presented 2 LF. Regarding gender, 71% (n = 12) of women had a single LF compared with 62% (n = 5) of men ($P > .05$) (Table 3).

Regarding the main characteristics of the MS, it was found that the anteroposterior distance, on mean was 17.5 mm, with a mean mediolateral distance of 9.43 mm, a mean area of 252.55 cm^2, and a perimeter of 47.7 cm^3 (Table 4). The mean distance between the MS floor and the vestibular (Ve) and palatal (Pa) apices of the premolars was greater at the level of the Ve apex of the upper first premolar. It was lower at the level of the palatal apex of the second upper premolar. On the other hand, the mean distance between the floor of the SM and the mesio-vestibular (M-V), disto-vestibular (D-V), and Pa apices of molars was greater at the level of the M-V apex of the upper first molar. It was lower at the level of the M-V apex of the upper second molar (Table 5).

According to gender, it was found that the mean distance between the MS floor and the D-V and Pa apices of the upper second molar was significantly greater in males than in females ($P \leq .05$) (Table 6).

Discussion

Careful clinical and imaging evaluation of the anatomical structures of the jaws is critical when planning any surgical procedure,

Table 1

Mean distance between the mandibular canal, and the mesial apices of the first, second and third lower molars*

Distance (mm)	Mean ± SD
Mandibular canal – 1st molar	2.35 ± 3.01
Mandibular canal – 2nd molar	2.07 ± 2.70
Mandibular canal – 3rd molar	0.77 ± 1.12

*Data were reported with mean ± SD.

Table 2

Mean distance between the mentonian foramen and the superior alveolar cortex and basal border*

Distance (mm)	Mean ± SD
Mentonian foramen – Superior alveolar cortex	5.92 ± 6.37
Mentonian foramen – Basal border	4.10 ± 6.17

*Data were reported with mean ± SD.

Table 4

Maxillary sinus characteristics*

Variables	Mean ± SD
Antero-posterior dimension (mm)	17.5 ± 16.17
Antero-medial dimension (mm)	9.43 ± 10.94
Area (cm^2)	252.55 ± 271.21
Perimeter (cm^3)	47.76 ± 48.99

*Data are reported with mean ± SD.

such as DI placement, surgery of retained teeth, and/or periodontal surgery.[17] In daily clinical practice, orthopantomography is the most commonly used imaging method for MC localization, given its low cost and ease of access. However, it is not highly recommended to visualize other structures such as the MF and AMF, AL, and/or LF due to imaging in 2 planes, overlapping of anatomic structures, and increased radiographic distortions.[18] In comparison, CBCT allows 3D visualization of the anatomical structures in both jaws, allowing the clinician to obtain more accurate information, which can minimize the risk of complications and predict treatment outcomes based on the clinical scenario.[19] A complication that frequently occurs during surgery is injury to the neurovascular bundle corresponding to the inferior alveolar, mentonian, and incisor nerves, resulting in intraoperative bleeding and postoperative pain accompanied by reversible or permanent paresthesia, as the case may be.[8] Therefore, it is essential to perform a thorough preoperative assessment of anatomical variants (MC, MF, AMF, AL, LF, and MS), and their different characteristics such as distance from one structure to another, size, shape, incidence, extent, area, and perimeter, which are considered critical, and to highlight their limitations in implant surgical procedures by analyzing CBCT images.

Our findings showed a closer proximity of the mesial apex of the mandibular second and third molar and a closer proximity of the first molar apices to the MC. Our results are also consistent with those reported by other authors in different parts of the world. A study in Europe (Moscow) showed that the mean distance from the mesial root apices of the first, second, and third mandibular molars to the MC was 4.92 mm, 2.85 mm, and 2.24 mm, respectively.[20] Concerning hemiarches, another study showed that the average distance between the right mesial root apex of the mandibular second molars to the MC was shorter (2.11 ± 2.09 mm) compared with the left side (2.43 ± 2.01 mm).[21] It has been observed that, in female patients, the MC is located more apically and laterally.[22]

On the other hand, our results showed greater discrepancies with Asian populations (Israel, South Korea, and India) who reported a greater average distance of 4.60 mm, 5.45 mm, and 4.35 mm, respectively.[23] In the present study, and given that the sample size was small, no significant differences by age and sex were found (data not shown). Therefore, it is important to thoroughly understand the characteristics of the MC to prevent damage to the IAN or, in the worst case, displacement of the ID through the soft tissue spaces adjacent and/or below the MC to the mandibular body.[24]

Regarding the location, morphological and morphometric characteristics of the MF, it has been demonstrated that their most frequent position is between the first and second mandibular premolars[22] and/or below the second premolar,[25] with an average distance of 2–3 mm between the apices and their upper edge.[26] They have a circular or oval shape, with a very similar distribution in symmetry and asymmetry. Moreover, it has been observed that most MFs have only 1 opening and very rarely present 2 or 3 AMF.[22] A cross-sectional study analyzing 4000 CBCT images demonstrated a low prevalence of AMF (6.4%).[27] These findings described in the literature also agree with part of our results and other previous studies.[28–30] Therefore, a thorough knowledge of the characteristics of the MF and its anatomical variants may

Table 3

Characteristics of the mentonian foramen (diameter and shape), accessory foramen, anterior loop, and lingual foramen*

Mental Foramen			Accessory Mental Foramen				Anterior Loop		Lingual Foramen	
			R	L	Bilateral	NA	Present	Absent	Present	Absent
R	L		*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
1.51 mm ± 1.85	1.53 mm ± 1.75		1 (4)	2 (8)	1 (4)	21 (81)	25 (100)	0 (0)	24 (96)	1 (4)
P = .94							Length = 2.42 mm ± 2.56			
M	F						R	L	1 foramen *n* (%)	2 foramens *n* (%)
1.40 mm ± 1.56	1.66 mm ± 1.96						2.31 mm ± 2.50	2.53 mm ± 2.64	17 (68)	7 (28)
P = .794							*P* = .686			
							M	F		
Shape *n* (%)							2.11 mm ± 2.52	2.41 mm ± 2.52		
							P = .708			
Oval	Circular	NA								
39 (78)	8 (16)	3 (6)								

*Data were reported as mean ± SD. The *P* value was reported using Student *t* test. Considering a value of $P \leq .05$ as significant.

Table 5

Mean distance between the maxillary sinus floor, and the vestibular, and palatal apexes of the first, second premolar, and mesio-vestibular, disto-vestibular, and palatal apexes of the first and second upper molar*

Distance	Mean ± SD
Premolars	
Vestibular apex of 1st premolar – maxillary sinus floor	1.41 mm ± 4.58
Palatal apex of 1st premolar – maxillary sinus floor	1.38 mm ± 4.49
Vestibular apex of 2nd premolar – maxillary sinus floor	0.17 mm ± 0.78
Palatal apex of 2nd premolar – maxillary sinus floor	0.07 mm ± 0.41
Molars	
Mesio-vestibular apex of 1st molar – maxillary sinus floor	1.42 mm ± 2.87
Disto-vestibular apex of 1st molar – maxillary sinus floor	0.76 mm ± 1.90
Palatal apex of 1st molar – maxillary sinus floor	0.76 mm ± 2.01
Mesio-vestibular apex of 2nd molar – maxillary sinus floor	0.55 mm ± 1.67
Disto-vestibular apex of 2nd molar – maxillary sinus floor	0.69 mm ± 2.30
Palatal apex of 2nd molar – maxillary sinus floor	1.01 mm ± 2.45

*Data are reported with mean ± SD.

facilitate the clinician in planning implant surgery in that region, preventing nerve damage and, in turn, allowing adequate and deep mental nerve block anesthesia.

The highest reported incidence of AL among different age groups is 20–35 years,[31] with a prevalence of 57.1%, according to recent studies.[32] Subsequently, scientific evidence has shown that, as the age of the subject increases, the frequency of AL decreases, and its extent is shorter.[22] The average length of the AL varies between 1.8 to 2.4 mm,[33] slightly more extensive in men than in women. Concerning the pattern of the loop, and taking as a reference the classification of Solar et al,[34] a study showed that most men (68%) presented a type III pattern, where the AL is evident. The anatomy is Y-shaped, while women more frequently presented a type I pattern, where the AL is not perceptible.[22] In addition, it has been reported that AL is associated with a reduced distance between the neurovascular bundle and the alveolar ridge, which hinders the installation of standard length DI.[35] Therefore, it is important to consider the presence, extent, and location of the AL when placing a DI in the interforaminal region.

The LF is another important anatomic landmark for optimizing surgical planning of DI in the anterior mandibular segment.[3] One study reported that the LF is visible in 65.4% of CBCT images, where half of the subjects present 2 foramina, while 27.9% presented only one.[36] Regarding its morphometric characteristics, another study reported that the mean vertical diameter of the LF was 0.9 mm, with a mean distance from the LF to the basal edge of 7.1 mm[37] and the alveolar ridge of 10.84 mm.[36] Therefore, it is essential to consider these anatomical aspects to avoid some complications, such as intraoperative bleeding and incisor nerve injury.

The placement of DI in the anterior and posterior segment of the maxilla is also a frequent procedure.[4–6] However, after tooth loss, factors such as extensive alveolar resorption, poor remaining bone quality, and pneumatization of the MS can complicate therapy.[13,15] It has been determined that as a function of facial index, MS tends to be wider in subjects with the mesoprosopic type and higher in subjects with the hyperleptoprosopic type, so it is suggested that dentists and clinicians focus on the shape of the face during clinical treatments.[38] In addition, the bony volume of MS varies according to gender, whereas the obliterative volume of MS varies according to the pathology present.[39] In this regard, a significant association between DI placement near or within the MS and sinus abnormalities such as mucosal thickening and nonspecific opacification[40,41] has been demonstrated. Therefore, it is important to have a good understanding of the anatomy of the MS and the clinical significance of anatomic variants to avoid complications that may compromise the oral health of patients.[17,19]

A limitation of the present work was its cross-sectional and retrospective design with a small sample size. In addition, an

Table 6

Mean distance between the maxillary sinus floor, and the vestibular, and palatal apexes of the first, second premolar, and mesio-vestibular, disto-vestibular, and palatal apexes of the first, and second upper molar in males, and females*

	Gender		
Variable Distance	Male	Female	*P* Value
Premolars			
Vestibular apex of 1st premolar – maxillary sinus floor	2.57 mm ± 6.45	1.40 mm ± 4.83	.495
Palatal apex of 1st premolar – maxillary sinus floor	2.9 mm ± 6.67	1.35 mm ± 4.66	.367
Vestibular apex of 2nd premolar – maxillary sinus floor	0.06 mm ± 0.25	0.34 mm ± 1.08	.329
Palatal apex of 2nd premolar – maxillary sinus floor	0.08 mm ± 0.30	0.10 mm ± 0.56	.866
Molars			
Mesio-vestibular apex of 1st molar – maxillary sinus floor	0.88 mm ± 1.25	1.35 mm ± 3.41	0.613
Disto-vestibular apex of 1st molar – maxillary sinus floor	0.56 mm ± 0.74	1 mm ± 2.41	0.498
Palatal apex of 1st molar – maxillary sinus floor	0.93 mm ± 1.79	0.85 mm ±2.35	0.910
Mesio-vestibular apex of 2nd molar – maxillary sinus floor	0.70 mm ± 2.18	0.39 mm ± 1.63	0.592
Disto-vestibular apex of 2nd molar – maxillary sinus floor	1.70 mm ± 3.51	0.20 mm ± 1.23	0.03†
Palatal apex of 2nd molar – maxillary sinus floor	2.53 mm ± 4.90	0.69 mm ± 1.13	0.05†

*Data were reported as mean ± SD. The *P* value was reported using Student *t* test.
†Considering a value of $P = \leq .05$ as significant.

evaluation of bone thicknesses (cortication) and bone density values of the posterior and anterior segments of the jaws before implant surgery, with the primary objective of reducing the risk of injury to neurovascular structures, is a topic of interest that deserves further investigation.

Clinical application

General practice dentists and specialists in the area should have a comprehensive knowledge of the anatomy of the maxillofacial region and its variations to ensure the efficacy of surgical procedures and prevent iatrogenic complications.

It is recommended that these structures be evaluated in detail and considered for study mainly through systems such as CBCT, taking into consideration that this type of study provides us with high-quality 3D images. In addition, the use of this technology can help the clinician in the planning of dental treatments that may represent a surgical risk for patients and in the insertion of dental implants.

Conclusions

Given the limitations of the present study, a well-designed clinical trial with a larger sample size, preferably with a prior sample size calculation, could provide an idea of the proposed result, considering that structures that have classically been considered inconstant, such as the lingual foramen and mental loop, should now be considered part of normal anatomy.

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