Prevalence of neurovascular structures in the anterior mandible and differences based on dentition, age and sex; a retrospective cone-beam computed tomography study

Running title: Prevalence of neurovascular structures in the anterior mandible

Xavier Demers[1]

- demersx@myumanitoba.ca

Research committee:
Chrysi Stavropoulou[1] (advisor)
- chrysi.stavropoulou@umanitoba.ca

Sunil Mutalik[1]
- sunil.mutalik@umanitoba.ca

Anastasia Cholakis[1]
- anastasia.cholakis@umanitoba.ca

Alexa Hryniuk[1]
- alexa.hryniuk@umanitoba.ca

Data gathering:
Galvin Huen[2]: ghuen@cancercare.mb.ca

1: University of Manitoba, Winnipeg, Canada
2: Cancer Care, Winnipeg, Canada

April 2023

Title of study

Prevalence of neurovascular structures in the anterior mandible and differences based on dentition, age and sex; a retrospective cone-beam computed tomography study

Running title

Prevalence of neurovascular structures in the anterior mandible

Abstract

Objective: To assess the prevalence of lingual and incisive vascular structures in the anterior aspect of the mandible and to see the effect sex, age and dentition status may have.
Methods: A total of 191 anonymized cone-beam computed tomography (CBCT) scans were assessed by a single calibrated operator. Incisive canals and lingual canals present between the mental foramina were counted, with location, size, dentition status in the lower anterior mandibular sextant, as well as the distance between the alveolar crest for the most coronal centered lingual canal being noted.
Results: Lingual canals were present in the midline area in 96% and in the lateral areas in about 25% of cases. Incisive canals had a prevalence under 10% for a given area in the mandible. Most canals observed were below 1 mm in diameter. The most coronal lingual canal in the center was 2 mm closer to the alveolar crest in females and in patients showing a degree of edentulism in the anterior mandible, with dentate patients also showing an increased number of lingual canals below 1 mm in size at the midline. Furthermore, aging appeared to impact the presence of lateral lingual canals. Although unclear, the dentition status could also affect the presence of larger incisive canals.
Conclusions: The anterior mandible features several structures visible on CBCT scans. The present findings suggest that sex, age and dentition status could have an effect on their presence. As such, the previous variables should be considered when planning surgical interventions in the area.

Word count:
Abstract: 250
Text: 2870

Mesh terms

Cone-Beam Computed Tomography, Dental Implants, Arteries, Mandible, Sex, Dentition, Aging

Introduction

The placement of dental implants has become a frequent procedure in dental offices. While many anatomical landmarks in the oral cavity are known as possible complicating factors for surgical procedures, the anterior mandible is commonly referred to as a safe zone for implant placement. Nonetheless, excessive bleeding episodes are a potential consequence of implant placement in that area and as such these may have to be managed clinically (Greenstein, 2006). The persistent presence of a midline foramen has been confirmed when assessing dry mandibles, but an inconsistent terminology in the literature over the years along with a much smaller prevalence when observing radiographs (McDonnell, 1994) could explain why practitioners may be unfamiliar with this anatomical feature. Cone beam computed tomography (CBCT) has been reported to be an accurate method to assess lingual vascular channels when confirming findings with cadaveric dissection (Gahleitner, 2001). A recent systematic review noted that the direct clinical implication of lingual mandibular anatomical structures, along with a broad range of characteristics reported for certain parameters (such as the distance between the midline lingual foramen and the alveolar crest), mandates further epidemiologic studies (Barbosa, 2022). The bulk of the literature also stems from Europe and Asia, potentially limiting the extension of the findings to other populations.

Incisive canals are another mandibular structure elusive on standard radiographs but for which cadaveric studies have shown CBCTs to be an accurate tool to help visualization (Mraiwa, 2003). The very existence of incisive canals is a controversial topic in the literature, and they could represent either a bona fide extension of the inferior alveolar nerve canal or a meshwork of neurovascular tissue (Romanos, 2009). Consequences following injury are likely possible but remain theoretical in nature, such as edema caused by injury to the epineurium and soft tissue encapsulation of the neurovascular bundle due to the absence of bone contact in that area (Rosenquist, 1996).

While other CBCT studies have been conducted in the past, recurrent limitations include small sample size and the lack of age-based stratification when analyzing the data. To the best of our knowledge, only one other study has been conducted examining an association between age and vasculature in the anterior mandible (Jacobs, 2002). Aging has been shown to affect angiogenesis through a reduction of growth factors and endothelial senescence (Hodges, 2018), and as such it would be interesting to further test for an interaction between the presence of vascular vessels in the anterior mandibular region and age.

The primary objective of the present study was to assess the distribution and frequency of lingual vascular channels and incisive canals in the anterior mandible as seen on CBCT scans. Secondary objectives included assessing the effect of location (center, left and right), size (up to 1 mm, more than 1 mm), sex, age, and dentition status on their distribution and frequency.

Material and methods

A retrospective study was designed, and approval was obtained from the Bannatyne Campus Research Ethics Board at the University of Manitoba (registration number HS25155). A total of 202 CBCT scans covering the entire portion of the mandible located between the mental foramina were anonymized and retrieved from a private dental practice in Winnipeg, Canada (Southwest Specialty Group) with the age and sex for each scan being registered. The scans were taken using a CS 9300 machine (Carestream, New York), between 2013 and 2022 inclusively. Scans from patients classified as ASA class III or higher, with a history of head or neck cancer or taking either angiogenesis inhibitors or antiresorptive agents were excluded. CBCTs were then imported on Anatomage Invivo6 (Wright, 2020) as DICOM files in the X, Y, and Z planes for further analysis. The scans were re-oriented as necessary so that the mandible would be placed parallel to the floor, directly facing the observer. The path of the inferior alveolar nerve canal was identified bilaterally, with the presence of anterior loops also being marked. Coronal, sagittal, and axial cross-sections were then observed individually with slices at an interval of 1 mm for the presence of canals completely perforating the lingual cortex in the area denoted by the mental foramina. The presence of incisive canals was also assessed, with anterior loops extending past the mesial aspect of canines being considered as incisive canals. In edentulous patients, the interforaminal distance was assessed and an anterior loop extending past 1/3 of the interforaminal distance was identified as an incisive canal. Canals and channels with a presumed diameter over 1 mm were confirmed by measurement using a digital caliper and reported as such. For each structure, location was also assessed, with the center corresponding to the position of the central incisors, while the left and right included the area from the lateral incisors to the mental foramen (see Figure 1). Additionally, a measurement was taken from the cortical border of the alveolar crest to the superior cortical outline at the opening of the most coronal lingual canal located at the midline (see Figure 2). Lastly, the dentition status of each patient was assessed. Patients not missing any teeth in the lower anterior mandibular sextant were deemed as dentate, while patients missing one or more teeth in the sextant of interest were recorded as partially or completely edentulous.

A calibration exercise was completed on 10 CBCTs between a board-certified oral radiologist and a periodontics resident. Differences in observations were discussed until an agreement was obtained. An inter-examiner reliability assessment was then completed on a new set of 5 CBCTs, with an intraclass correlation of 0.69 for the measurement from the crest at the midline and an agreement percentage of 88.6% for the rest of the data points. Four weeks after the completion of data extraction, an intra-examiner reliability assessment was performed on 10 randomly selected CBCTs, with an intraclass correlation of 0.74 for the measurement from the crest at the midline and an agreement percentage of 90.7% for the rest of the data points. The entirety of the data was assessed by one operator.

Descriptive statistics were used to present the distribution of the data, including the size and location of the canals. Secondary variables of interest (dentition, age, and sex) were assessed with a combination of parametric and non-parametric tests, with the statistical significance set at the 0.05 level. When evaluating the dentition status, partially edentulous and edentulous scans were combined. For the age, two groups were formed, with the first one ranging from 20-59 (n=90) and the second one from 60-70 (n=101). While 5 groups were planned initially (20-29, 30-39, 40-49, 50-59, 60-70), the highly skewed age distribution did not allow for this. Three categories that featured a zero count could not be included in the canal count analysis (lingual canals greater than 1 mm on the right, lingual canals greater than 1 mm on the left; incisive canals greater than 1 mm on the centre). Counts were calculated and chi-squares tests were used to compare the canal variables. Mann-Whitney tests were used to test for an interaction between the secondary variables and the number of lingual canals below 1 mm at the center. Additionally, independent t-tests were set up to assess the effect of the secondary variables on the distance between the most coronal centered lingual canal and the alveolar crest.

Results

Upon further examination, 11 CBCTs had to be screened out due to the region of interest not being fully included or poor legibility. The final sample size consisted of 191 scans, from 106 females and 85 males. The age range was 20 to 70, with a mean age of 56.7 years. 147 patients were dentate in the lower anterior mandibular sextant, whereas 44 exhibited a degree of edentulism in said sextant. Anterior loops were present in 82.7% of scans on the right, and in 83.8% of scans on the left. Small lingual canals at the midline were a near universal finding, being identified in 96.1% of the CBCTs. The highest amount being observed on a single scan was 4 (see figure 5). Lingual canals in the center of 1 mm or more in size were only identified in 4.7 % of cases. Lingual canals below 1 mm on the right or left side were also noted in close to 25% of the scans.

Incisive canals with a diameter over 1 mm were only identified in less than 3% of the mandibles when assessing the middle and lateral portions separately. Smaller incisive canals below 1 mm were somewhat more common, with a frequency in the anterior and lateral portion of the mandibles of about 5 and 9% respectively. The distance from the osseous crest to the most superior portion of the lingual canal varied from 3 to 29.6 mm, with a mean of 16.4 mm.

The frequency of incisive canals greater than 1 mm on the right appeared to be affected by the presence of edentulism in the anterior mandibular sextant. There was a significantly higher count for lingual canals less than 1 mm in the center in dentate patients. Additionally, the dentate patients had a significantly higher distance between the alveolar crest and the superior border of the lingual canal (by about 2 mm).

Count analysis did not reveal significant differences based on sex. While there was no difference noted on the frequency of lingual canals less than 1 mm at the center, the distance from the alveolar crest to the lingual canals below 1 mm was significantly higher in males compared to females. The difference was just over 2 mm. While there was no difference noted on the frequency of lingual canals less than 1 mm at the center, the distance from the alveolar crest to the lingual canal was significantly higher in males compared to females (17.6 mm and 15.4 mm).

Count analysis revealed an interaction between the presence of lingual canals smaller than 1 mm on the right and left and the age group the patient was part of. No significant differences were found when assessing the presence of lingual channels less than 1 mm in the center, as well as the distance from the alveolar crest.

Discussion

The existence of lingual foramina in the anterior mandible is historically well documented. Consistent with the results from our retrospective CBCT scan study, a recent meta-analysis reported the presence of a single lingual foramen at the midline to be the most common pattern (Barbosa, 2022). Additional lingual foramina in the premolar and canine regions observed here have also been previously discussed in the literature (Katakami, 2009). Furthermore, the distribution and size characteristics presented for lingual canals are in line with a previous publication that reported a minimum of one lingual foramen in the anterior portion of the mandible to be a universal feature, with the average size oscillating around 0.7 mm, while the canals extending to the premolar regions were closer to 0.6 mm (Gahleitner, 2001). Lingual canals at the center appeared to be closer to the alveolar crest in females by around 2 mm. Their presence in the lateral areas also seem to be affected by age.

The prevalence of incisive canals is less agreed on. A previous study noted a prevalence of the incisive canal of 86% in the middle portion of the mandibles. This number increased to 96% when the preserved mandibles were assessed, with an average canal size of 1.8 mm (Mraiwa, 2003). The authors did however define the anterior region differently, which could partly explain the disagreement. A more recent study found a slightly lower prevalence, with incisive canals noted on 61% and 59% of edentulous and dentate scans respectively (Wright, 2020). When present, the incisive canal has been said to slope towards the apical and diminish in size as we get closer to the midline (Mraiwa, 2003). Alternatively, a previous study with cadaveric dissection found little to substantiate the existence of an incisive canal, preferring the term incisive bundle when looking at cross-sections (Polland, 2001). The present data suggests that incisive canals could be present in less than 10% of scans.

Reports of surgical complications in the anterior portion of the mandible exist but they are for the most part scarce. The size of the canal may represent a determining feature. While lingual canals below a 1 mm diameter are hypothesized to be unlikely to cause complications if damaged (Gahleitner, 2001), a case report featuring an incisive canal with a 3 mm diameter detailed significant intra-operative swelling and pain following an attempted implant placement, but no serious sequelae (Romanos, 2009). A case report featuring cadaveric dissection noted that a lingual foramen in the premolar and canine area represented an anastomosis between the incisive branch of the mental artery and the submental artery (Kawai, 2006). With over 25% of the mandibles examined in this study presenting with a canal smaller than 1 mm in size on the right or left side, these smaller lingual foramina may represent areas of vascular anastomosis and as such still pose a risk for intra-operative hemorrhage.

Particular attention should be paid to the dentition of the patient when weighting the potential for complications. As noted in the current study, the position of the most coronal lingual canal appears to be closer to the alveolar crest in patients with a degree of edentulism in the mandibular anterior portion. The combination of an initially reduced bone height with surgical procedures such as alveoloplasty prior to or after implant placement may consequently increase the risk of exposing neurovascular structures (Wright, 2020). Age should also be kept in mind; not only is it often linked with the degree of edentulism (Roberto, 2019), but age also appears to affect the presence of lateral lingual canals as brought forward by the current data. Additionally, previous works have mentioned the importance of the ridge morphology, as the presence of undercuts on the lingual aspect may increase the risk of injury (Tepper, 2001). Furthermore, sex is a supplemental factor that should be considered as evidenced by the data presented. Sexual dimorphism of the mandible (Schmittbuhl, 2001), as well as the increase in bone remodeling and the decrease in mineral density starting with menopause (Karlamangla, 2018) may help explain why lingual canals at the midline are closer to the alveolar crest in women compared to men.

Limitations of the current study include a highly skewed sample size towards older patients, which can be explained by the fact that CBCT scans are often taken to help plan extensive dental work. The absence of confirmation of the current findings through cadaveric dissection also limits the clinical applicability, as a common thread in the literature is that radiographic approaches seem to underestimate the prevalence of neurovascular structures in the mandible compared to cadaveric studies (Romanos, 2009). It remains unclear whether a smaller voxel size necessarily increases diagnostic power, and there appears to be no clear consensus recommending CBCT settings for specific purposes (Spin-Neto, 2013). While differences were found depending on age and sex in this study, a previous publication reported these variables as having no effect on the radiographic visibility of lingual foramina and incisive canals (Jacobs, 2002). Contrasting the data presented is also complicated by the fact that the anterior segment of the mandible can be hard to define, with different existing reference points. With all patients being partially or completely edentulous prior to implant placement (given the goal of treatment), the mental foramen represents an anatomical reference point that has been employed previously (Di Bari et al. 2012) and that can be identified regardless of the dental status of a patient. The mental foramen however is not a constant reference point either; differences in the exact positioning of the mental foramen in the vertical and horizontal position have also been found across individuals and potentially ethnicities (Greenstein, 2006). The mental foramen may even present at the level of the canine (Romanos, 2009) in certain instances. The lingual canal and the lingual foramina have been reported to be intimately linked anatomical structures, with the lingual canal originally extending from the mandibular canal and eventually passing through lingual foramina (Kawai, 2006). Due to the design of the current study this could not be closely verified, but the assessment of such a relationship could help understand their true anatomical nature.

Conclusion

Lingual canals at the center of the mandible appear almost universal, with a distance from the crest that is higher when all mandibular anterior teeth are present and in males compared to females. A complete dentition in the lower anterior sextant is also associated with a higher number of lingual canals at the center. Lateral lingual canals are a common anatomical structure, featuring in about 25% of scans, on which age appears to have an effect. On the contrary, incisive canals are a lot less frequently observed on CBCT, even if cadaveric studies suggest a high prevalence. The dentition status in the anterior mandible may influence their presence. Both lingual and incisive canals appear to be less than 1 mm in most cases. Future studies should ideally confirm CBCT findings with cadaveric dissection and further explore the relationship between the presence of lingual foramina and incisive canals. Any surgical intervention in the anterior mandible should be meticulously planned. We recommend including age, sex, and the dentition status in pre-surgical assessment to help avoid iatrogenic damage in the anterior mandibular area.

Funding and conflict of interest disclosure

The authors report no conflict of interest.

Acknowledgments

The present study was funded with internal funds from the University of Manitoba.
The authors would like to acknowledge the statistical analysis provided by Loring Chuchmach at the George & Fay Yee Centre for Healthcare Innovation, as well as the guidance from John Tsourounakis, Vasilis Papadopoulos and the rest of the team at the Southwest Specialty Group.

References

Barbosa, D. A. (2022). Systematic review and meta-analysis of lingual foramina anatomy and surgical-related aspects on cone-beam computed: a PROSPERO-registered study. *Oral radiology*, 38(1), 1–16.

Gahleitner, A. H. (2001). Lingual vascular canals of the mandible: evaluation with dental CT. *Radiology* , 220(1), 186–189.

Greenstein. (2006). The mental foramen and nerve: clinical and anatomical factors related to dental implant placement: a literature review. *Journal of periodontology*, 77(12), 1933–1943.

Hodges, N. A.-M. (2018). Understanding angiogenesis during aging: opportunities for discoveries and new models. *Journal of applied physiology (Bethesda, Md. : 1985)*, 125(6), 1843–1850.

Jacobs, R. M. (2002). Appearance, location, course, and morphology of the mandibular incisive canal: an assessment on spiral CT scan. *Dento maxillo facial radiology*, 31(5), 322–327.

Karlamangla, A. S.-B. (2018). Bone Health During the Menopause Transition and Beyond. *Obstetrics and gynecology clinics of North America*, 45(4), 695–708.

Katakami, K. M. (2009). Anatomical characteristics of the mandibular lingual foramina observed on limited cone-beam CT images. *Clinical oral implants research*, 20(4), 386–390.

Kawai, T. S. (2006). Anastomosis between the inferior alveolar artery branches and submental artery in human mandible. *Surgical and radiologic anatomy : SRA*, 28(3), 308–310.

McDonnell. (1994). The mandibular lingual foramen: a consistent arterial foramen in the middle of the mandible. *Journal of Anatomy*, 184, p. 363-369.

Mraiwa, N. J. (2003). Presence and course of the incisive canal in the human mandibular interforaminal region: two-dimensional imaging versus anatomical observations. *Surgical and radiologic anatomy : SRA*, 25(5-6), 416–423.

Polland, K. E. (2001). The mandibular canal of the edentulous jaw. *Clinical anatomy (New York, N.Y.)*, 14(6), 445–452.

Roberto, L. L.-J. (2019). Sociodemographic determinants of edentulism in the elderly population: A systematic review and meta-analysis. *Gerontology*, 36(4), 325–337.

Romanos, G. E. (2009). The incisive canal. Considerations during implant placement: case report and literature review. *The International journal of oral & maxillofacial implants*, 24(4), 740–745.

Rosenquist, B. (1996). Is there an anterior loop of the inferior alveolar nerve? *The International journal of periodontics & restorative dentistry*, 16(1), 40–45.

Schmittbuhl, M. L. (2001). Sexual dimorphism of the human mandible: demonstration by elliptical Fourier analysis. *International journal of legal medicine*, 115(2), 100–101.

Spin-Neto, R. G. (2013). Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review. *Journal of digital imaging*, 26(4), 813–820.

Tepper, G. H. (2001). Computed tomographic diagnosis and localization of bone canals in the mandibular interforaminal region for prevention of bleeding complications during implant surgery. *The International journal of oral & maxillofacial implants*, 16(1), 68–72.

Wright, R. A. (2020). An analysis of anterior mandibular anatomy by using cone beam computed tomography: A study of 225 mandibular images. *Journal of prosthetic dentistry*, 123(4), 595–601.

Tables

Table 1. Distribution of the lingual and incisive canals

	% of scans with at least 1 count (exact number)	Maximum count	Most common count
Lingual Canals Less 1 mm Right	26% (50)	2	0
Lingual Canals Greater 1 mm Right	0% (0)	0	0
Lingual Canals Less 1 mm Left	24.1% (46)	2	0
Lingual Canals Greater 1 mm Left	0% (0)	0	0
Lingual Canals Less 1 mm Centre	96.1% (185)	4	1
Lingual Canals Greater 1 mm Centre	4.7% (9)	1	0
Incisive Canals Less 1 mm Right	8.9% (17)	1	0
Incisive Canals Greater 1 mm Right	2.6% (5)	1	0
Incisive Canals Less 1 mm Left	8.9% (17)	2	0
Incisive Canals Greater 1mm Left	2.1% (4)	1	0
Incisive Canals Less 1mm Centre	5.2% (10)	2	0
Incisive Canals Greater 1mm Centre	0% (0)	0	0

Table 2. Presence of canals according to dentition, sex, and age

Anatomical structure and location	**Dentition status (p-value shown)**	**Sex (p-value shown)**	**Age group (p-value shown)**
Lingual Canals Less 1 mm Right	0.101	0.454	0.028*
Lingual Canals Greater 1 mm Right	n/a	n/a	n/a
Lingual Canals Less 1 mm Left	0.691	0.372	0.012*
Lingual Canals Greater 1 mm Left	n/a	n/a	n/a
Lingual Canals Greater 1 mm Centre	0.433	1	0.176
Incisive Canals Less 1 mm Right	1	0.61	0.072
Incisive Canals Greater 1 mm Right	0.010*	0.657	1
Incisive Canals Less 1 mm Left	0.095	0.886	0.694
Incisive Canals Greater 1mm Left	1	0.325	0.624
Incisive Canals Less 1 mm Centre	0.053	0.729	0.238
Incisive Canals Greater 1 mm Centre	n/a	n/a	n/a
Anterior loop Right	0.824	0.849	0.186
Anterior loop Left	0.816	0.844	0.079

Chi-square used for comparisons. Exact sig shown.
Note. n/a=the canal counts are constant and as such stats could not be computed.

Table 3. Comparison of lingual canals/foramina less than 1 mm at the centre according to dentition, sex, and age

Dentition status	**Dentate**	**Partially edentulous and edentulous**	**U-Stat**	**p-value**
Lingual Canals Less 1 mm Centre	(n=147)	(n=44)	2474	0.009*
Median (mean)	2.0 (1.63)	1.0 (1.32)		
Mean rank	101.17	78.73		
Sex	**Female**	**Male**	**U-Stat**	**p-value**
Lingual Canals Less 1 mm Centre	(n=106)	(n=85)	4561.5	0.87
Median (mean)	2.0 (1.55)	1.0 (1.58)		
Mean rank	95.47	96.66		
Variable	**Ages 20-59**	**Ages 60 and older**	**U-Stat**	**p-value**
Lingual Canals Less 1 mm Centre	(n=90)	(n=101)	4518	0.938
Median (mean)	2.0 (1.56)	1.0 (1.56)		
Mean rank	96.3	95.73		

Mann-Whitney test used for comparisons

Table 4. Comparison of distance from crest according to dentition, sex and age

Dentate	**Partially edentulous and edentulous**	**t**	**p -value**
(n=146)	(n=42)	2.18	(0.034)*
16.85 (4.09)	14.80 (5.69)		
Female	**Male**	**t**	**p -value**
(n=105)	(n=83)	-3.22	(0.002)*
15.44 (4.12)	17.59 (4.83)		
Ages 20-59	**Ages 60 and older**	**t**	**p -value**
(n=87)	(n=101)	0.414	0.68
16.54 (4.88)	16.26 (4.28)		

Independent t test used
Mean (standard deviation)

Figures

Figure 1. An anterior loop extending into the yellow or green zones was considered an incisive canal. Location was recorded as center in the green area, and as right or left when in the yellow or red areas.

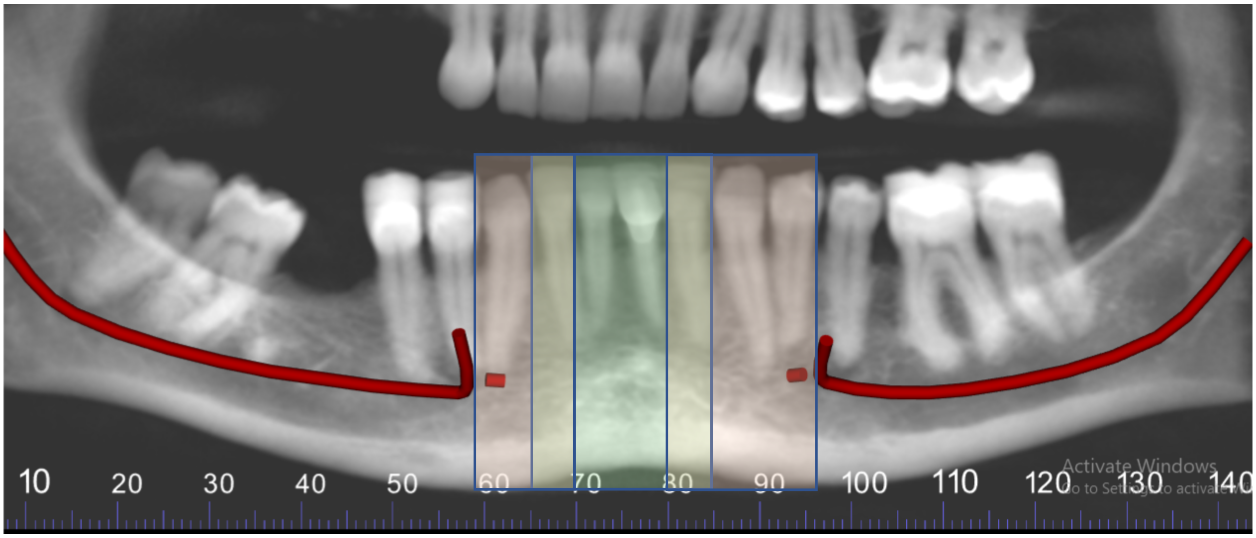

Figure 2. A measurement was taken from the superior sclerotic border of most coronal lingual canal to the highest possibly visible extent of the alveolar crest.

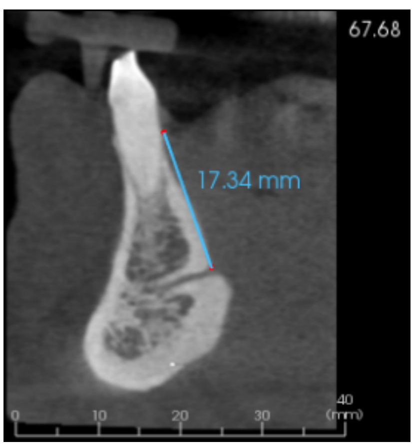

Figure 3. An incisive canal is visible and indicated by a red arrow.

Figure 4. A lingual canal not in the center region is visible and indicated by a red arrow.

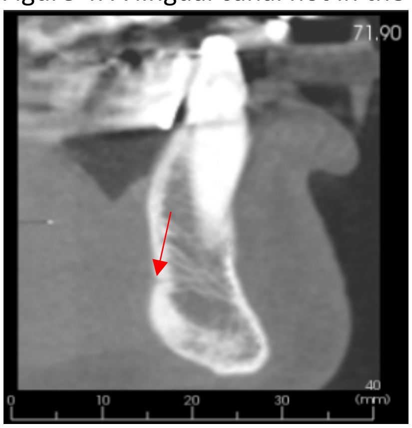

Figure 5. A particular scan revealing 4 lingual canals in the midline area.