Localisation of the mental foramina in dogs using computed tomography and intraoral radiography

Research project

Evelien van der Meer (EvdM)
4097858

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Supervisors:

Dr. H.E. Booij-Vrieling (HBV),

Dr. S. Veraa (SV)

Utrecht University I Faculty of Veterinary Medicine

Department of Clinical Sciences

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Abstract

A fair amount of research covering the mental and accessory mental foramina in humans has been conducted because of their importance in dentistry. Information about the frequency and location of accessory mental foramina is important to prevent damage to the mental nerves and blood vessels during surgery. Little research has been done on this subject in veterinary dentistry, but accessory mental foramina have been reported. The aims of this study were to identify the prevalence of a caudal mental foramen, to determine what the exact location is of the middle and caudal mental foramina and to determine whether intraoral radiography (IOR) is an efficient method of imaging the mental foramina, compared to computed tomography (CT).

Materials and Methods: IOR of 53 dogs were assessed retrospectively. There were seven dogs that underwent both IOR and CT. An additional 140 dogs were included for retrospective assessment of CT examinations. For both CT and IOR the number of the foramina and the ease of identification (difficult, easy, excellent) was scored. Location was determined on CT and on parallel views of IOR. The scores for ease of identification of the CT images were compared with the scores of the IOR.

Results: It was found that the presence of a rostral, middle and caudal mental foramen is the most common, namely in 65.5% for the left side (L) and 68.3% for the right side (R) of the cases on CT. Dogs have also been found with 2, 4, 5 and 6 foramina on one side. The middle mental foramen was mostly located in the area around 305-306 and 405-406. In 37.1 to 39.3% of the cases the foramen was located apical of both -05 and -06, in 22.1 to 27.2% it was located between -05 and -06. The caudal mental foramen was mostly located apical of the -07. Foramina were excellent to identify most often on CT, in 82.9% (L) and 86.4% (R) of the cases, compared to 11.3% (L) and 18.9% (R) of the cases on IOR. Whereas foramina were difficult to identify on IOR in 24.5% (L) and 22.6% (R), compared to 1.4% (only L) on CT. In addition, the results showed that dogs weighing up to 10kg have significantly less foramina on the right than dogs weighing > 10kg.

Conclusion: The vast majority of dogs have three (rostral, middle and caudal) mental foramina on either side. Locations of the mental foramina left and right are comparable but there is some variation. CT appears to be a more efficient method to visualize the mental foramina compared to IOR. In addition, it has been found that the size of the dog affects the number of foramina. This effect has only been found on the right side.

Keywords: Mental foramen, accessory mental foramen, dogs, computed tomography, intraoral radiography

Introduction

Clinical relevance

In dogs, dental disorders such as periodontitis and endodontic disease are a common problem.[1] Dentistry is therefore part of the daily activities of veterinarians. The majority of dental procedures require good anesthesia and analgesia. Next to systemic anesthesia and analgesia, a widely used method for local analgesia is the regional nerve block.[2] Using local analgesia has multiple advantages for the patient. First of all, it reduces the required level of general anesthesia. As a result, the blood pressure of the patient during the operation is improved and the patient recovers faster from the anesthesia. In addition, local analgesia provides pain relief for a few hours after the procedure. It also works synergistically with other analgesics such as alpa-2 agonists, NSAIDs and opioids. [3]

The regional nerve block is a form of local analgesia, used to desensitize certain regions. The infraorbital nerve, the middle mental nerve, and the inferior alveolar nerve are nerves that are often blocked by a regional nerve block to gain local analgesia when performing dental procedures.[2,4] In humans, the bone of the maxilla is known to be thin and porous making it suitable for infiltration anesthesia. The bone of the lower jaw is more dense, making infiltration anesthesia ineffective. Therefore, in the mandible, block anesthesia will have to be used to obtain effective anesthesia.[5,6] The mental block is often used in surgical procedures and dental extractions in the part of the mandible rostral to the mental foramina.[2,3]

The mental nerve block, as shown in Figure 1, should be placed inside the mental foramen and pressure must be applied to the mental foramen in order to let the anaesthetic diffuse through the mental foramen into the mandibular canal. If this is done correctly, the bone, dental structures and soft tissues around the canine teeth and incisors will be anesthetised. If the block is placed outside the foramen, the bone and dental structures will not be anesthetised. [3]

FIGURE 1 REGIONAL NERVE BLOCK OF THE MIDDLE MENTAL FORAMEN [9]

Regional nerve blocks should be performed carefully since there is a possibility of damaging the nerves and vessels.[10] In order to properly implement a regional nerve block, extensive knowledge of the anatomy is essential.

Anatomy

The inferior alveolar nerve, which is a divarication of the mandibular branch of the trigeminal nerve, runs through the mandibular canal. At the level of the mental foramina, the inferior alveolar nerve turns into the mental nerve. The mental nerve provides sensory innervation to the rostral part of the mandible, lower lip and chin.[7,8] The inferior alveolar artery runs through the mandibular canal as well, along with a vein. The inferior alveolar artery is a branch of the maxillary artery. At the level of the mental foramina it splits into the caudal, middle and rostral mental arteries. These provide the rostrolateral part of the mandible and chin with blood.[7,8]

The mental foramina are openings in the mandibular bone and form the exit of the mandibular canal that runs on the medial side of the mandibula, from the mandibular foramen, to the mental foramina.[7] Variation in location and position of the mental foramina has been well described in humans.[9-12] In dogs the rostral mental foramen can be distinguished at the level of the first incisor. Apical to the canines or first premolar another foramen can be found. This foramen, called the middle mental foramen, is the largest. It can be palpated below the frenulum of the lower lip or lateral of the canines.[7,8,13] The prevalence of an accessory mental foramen has also been well described in humans. The prevalence of a second mental foramen in humans is between 2.0 and 14.3% [9-12] and the prevalence of a third mental foramen is reported to be 1.2%.[9] In dogs however, information on the variation in number and location of the (accessory) mental foramina is limited, but caudal mental foramen have been reported. They are expected to be located apical of the second premolar.[13] It is not clear whether the presence of a caudal mental foramen can be considered normal or if a caudal mental foramen is accessory.

CT versus IOR

Computed tomography (CT) has increasingly been used in veterinary dentistry. In human dentistry it has been described that CT and Cone Beam CT (CBCT) are preferred in diagnosing dental conditions over intraoral radiography (IOR).[1,10,11] However, in veterinary medicine, IOR is still the most widely used method of diagnosing dental diseases.[1] Advantages of IOR include that it is cheaper and more available than CT. Also, animals require a shorter anesthesia for IOR than for CT, which reduces the burden on the animal. In addition to the advantages of IOR, there are also disadvantages. The angle of the X-ray beam and distance of the X-ray beam to the animal can vary, which can cause inconsistencies.[1] Moreover, making a 2D image of a 3 dimensional structure, such as with IOR, can lead to errors of assessment due to overlapping of structures.[1,14] For example, confusion with a peri-apical abscess can occur when a foramen is projected over a root tip. A CT scan does not have these overlapping problems since a cross-sectional examination of the object is made.[1,13]
Brachycephalic dogs in particular are challenging in assessing IOR because they have more overlapping structures, crowding of the teeth and rotation of the teeth than mesaticephalic and dolichocephalic dogs.[14] CBCT and CT have already been proven to be good methods for identifying various anatomical landmarks in brachycephalic dogs.[13, 14]

Aim of the study

This project was a pilot study and had several goals. The main research question was 'what is the prevalence of a caudal mental foramen in the dog? The sub-questions were 'what is the location of the middle and caudal mental foramina with respect to dental landmarks?' and 'is IOR an efficient method to visualize the mental foramina, compared to CT?'

Hypothesis

What is the prevalence of a caudal mental foramen in the dog?

H0: The prevalence of a caudal mental foramen is around 1%, comparable to a third mental foramen in humans
H1: The prevalence of a caudal mental foramen is not comparable to the prevalence of a third mental foramen in humans

What is the location of the middle and caudal mental foramina with respect to hard tissue landmarks?

H0: The middle mental foramen is located apical of the canine teeth (304 and 404) and the caudal mental foramen apical to the second premolar (306 and 406) in all dogs
H1: The middle mental foramen is not located apical of the canine teeth and the caudal mental foramen in not located apical to the second premolar in all dogs

Is IOR an efficient method to visualize the caudal mental foramina, compared to CT?

H0: IOR is an efficient method to visualize the caudal mental foramina
H1: IOR is not an efficient method to visualize the caudal mental foramina

Materials and Methods

Patient selection

This retrospective study was performed at the Department of Clinical Sciences of the Faculty of Veterinary Medicine in Utrecht, The Netherlands. CT examinations were collected from the PACS (picture archiving and communication system) [a] of the Diagnostic Imaging section. Dogs referred for head CT examination during the period 2018-2019 were selected. The database of intraoral radiography examinations was searched for dogs referred for dental treatment during the period 2014-2019. All dogs that had radiographs of the rostral aspect of the mandibula were included. Data on the breed, size (small (up to 10kg), medium (10 < - > 25kg), large (25 < - > 45kg), and very large (> 45kg)) and skull shape of the animal (brachycephalic, mesaticephalic and dolichocephalic) was collected. For purebred dogs the reference weight of the breed was used to classify the dog as small, medium, large or very large. To classify a crossbreed dog, their file-registered weight was used.

The mental foramen were divided into rostral, middle and caudal. Additional foramina surrounding the rostral or middle foramen, but smaller or in an abnormal location were defined as accessory mental foramina (AMF). Also foramina positioned caudally to the caudal mental foramen were defined as AMF (Figure 2).

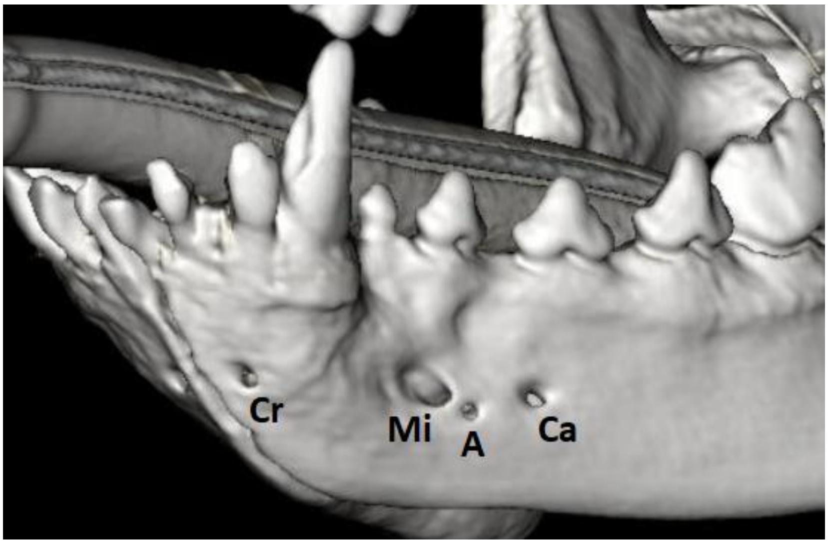

Figure 2 Rostral (Cr), Middle (Mi), Caudal (Ca) and an Accessory (A) mental foramen

IOR

A list of patients referred for a dental treatment to the University Clinic for Companion Animals between 2014 and 2019 was assessed. Patients that had intraoral radiography of the area of the 304-308 and the 404-408 were selected. Dogs with all teeth removed, as part of the treatment, were also included. Data on which teeth were included in the radiograph, view (parallel or lateral), and score for ease of identification was collected. Of all of the patients selected for IOR, the PACS [a] was checked to see if there was a CT examination available of this patient. Dogs were excluded if the rostral part of the mandible was not included in the CT examination. During the reviewing of the IOR, not all selected dogs were found eligible. The area of 304-308 or 404-408 had to have been radiographed. Dogs were excluded if this condition was not met, or if there was extensive periodontal disease with bone lysis up to the foramina, which meant that the foramina could not be assessed. Animals that were referred for a dental condition associated with deciduous teeth were also excluded.

CT

Dogs that had a CT examination of the head, made between January 2018 and December 2019 at the Diagnostic Imaging section of the department of Clinical Sciences, were searched for in the PACS [a]. Inclusion criteria were: CT skull, 1 January to 31 December 2018 or 2019. Data on number of the mental foramina, location, height and width and score for ease of identification were collected. Of 2018, only the first 50 patients on the list were assessed. Animals were excluded if the rostral part of the mandibula was not on the examination, or if there was extensive periodontal disease with bone lysis up to the foramina, which meant that the foramina could not be assessed.

Image acquisition

All images were acquired under general anesthesia. A 64-slice sliding gantry Somatom Definition AS CT-scanner [b] was used to obtain images. Field of view was dependent on size of the dogs head. mA Was dependent on the size of the head and was scanned with 'care for dose'. kVp Varied per patient but was usually between 100 and 120. Rotation time was 0.7 s/rotation and images were reconstructed with slice thickness 1mm in bone algorithm with a standard bone filter of H60.

Dental radiographs were obtained by the use of a intraoral X-ray tube [c] at 7.5 mA and 65 kVp. Exposure time was around 200 msec (0.16-0.20). Focal spot was 0.7 mm. View was dependent on the patient.

All radiographs belong to the Dentistry section of the Department of Clinical Sciences of the Faculty of Veterinary Medicine in Utrecht. All CT images belong to the Diagnostic Imaging Section of the Department of Clinical Sciences of the Faculty of Veterinary Medicine in Utrecht.

Assessment of IOR

IOR were viewed in VisiQuick [d]. All radiographs were analysed by the first author (EvdM). She was instructed in the use of the program by the second author (HBV, a diplomate of the European Veterinary Dental College (EVDC)). First, all available IOR of the patient was roughly scanned on the area that was on the radiograph and in which view (lateral or parallel) the pictures were taken. Parallel images were preferred to assess over lateral images. Radiographs were scored on number of foramina. If the caudal mental foramen was visible it was assumed that the animal had at least 3 foramina on that side because on parallel images of that region, the rostral and middle mental foramen are not visible. The ease with which the foramina could be identified was scored. If there were parallel images, the location was also noted. The location could not be determined on lateral images. The ease with which they could be identified was scored (0 = unable to identify, 1 = difficult to identify, 2 = easy to identify, 3 = excellent to identify) (Figure 3 and 4).[14]

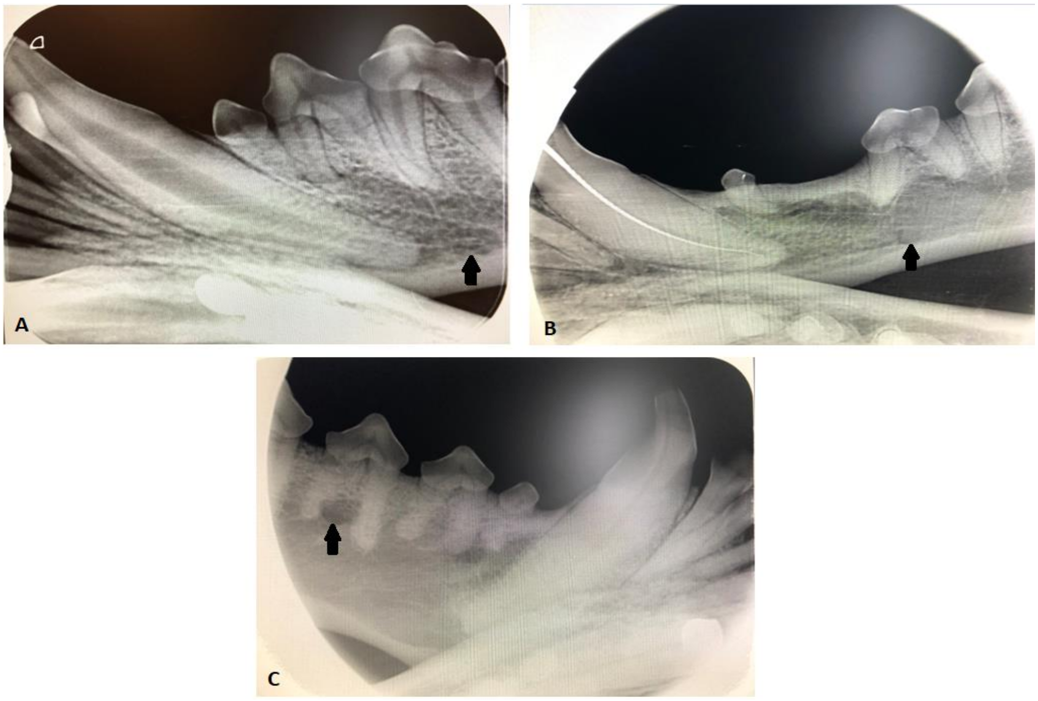

Figure 3 Scoring System caudal foramen IOR, lateral images, A =1 difficult, B = 2 easy, C = 3 excellent

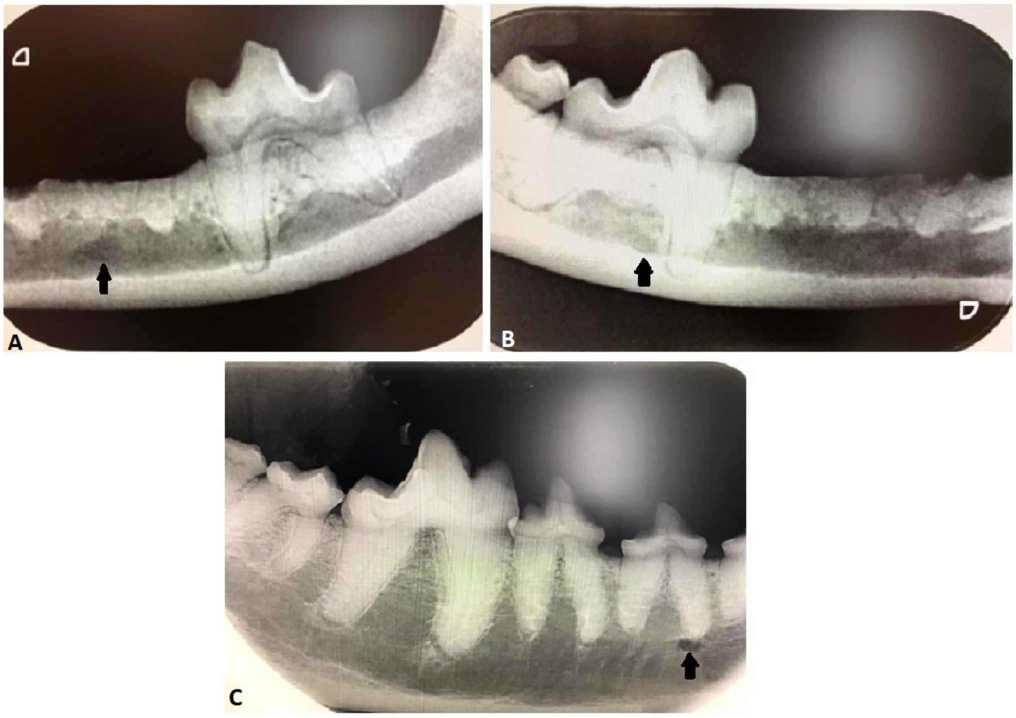

Figure 4 Scoring System caudal foramen IOR, parallel images, A =1 difficult, B = 2 easy, C = 3 excellent

Assessment of CT examinations

CT examinations were viewed using XERO® viewer of the PACS [a]. All CT examinations were analysed by the same observer who reviewed the IOR. This observer practiced with the program for a week, prior to collecting the data and was instructed in the use of the program by the third author (SV, diplomate of the European Collage of Veterinary Diagnostic Imaging (ECVDI)). First the 3D-mode was used to determine how many mental foramina were present and the exact location of the foramina compared to the teeth. Using the 3D-mode (zoomed in to 2 cm = 15 mm), the skull was first fully rotated to the right. The number of foramina and locations were noted, and the ease with which the caudal mental foramina could be identified was scored (0 = unable to identify, 1 = difficult to identify, 2 = easy to identify, 3 = excellent to identify) (Figure 5).[14] Thereafter, the skull was fully rotated to the left and the same was noted. Location was noted as the tooth around which the foramen was located apical to. If the foramen was located between the apices of two teeth, this was noted with a -, e.g. 305-306. If the foramen extended from the apex of one tooth to the apex of the next tooth, it was noted with a +, e.g. 305 + 306. In some cases the foramen was located between two teeth and extended to the next tooth, e.g. 304-305 + 306.

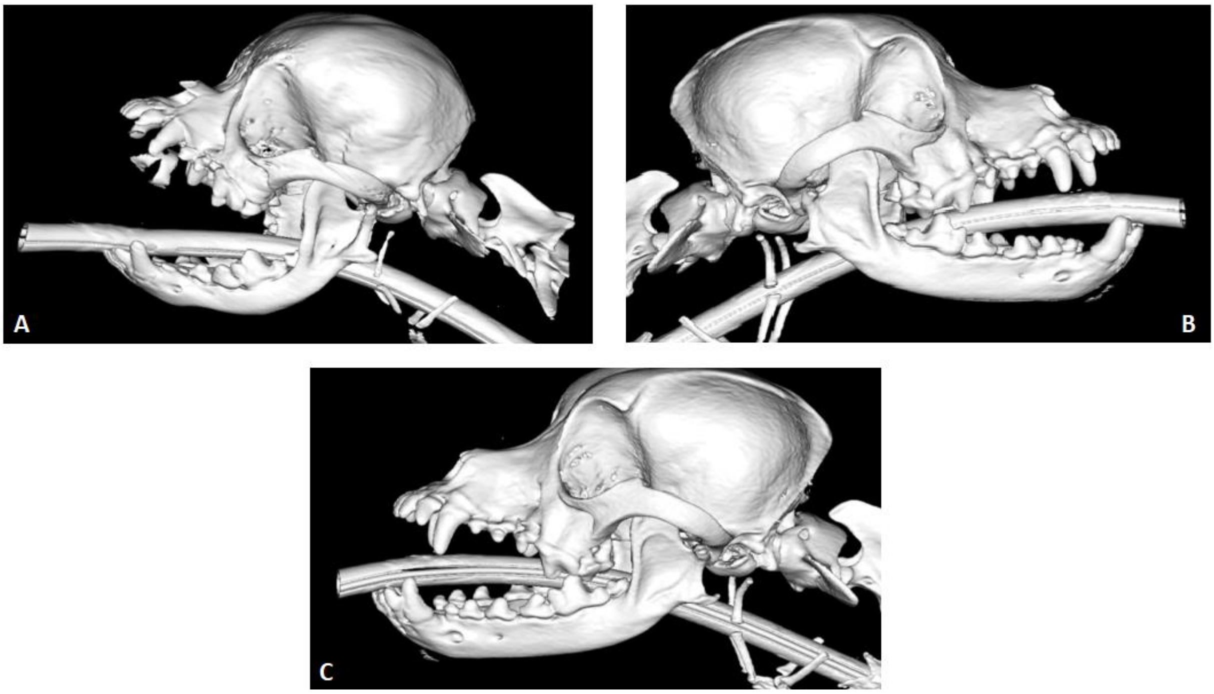

Figure 5 Scoring System caudal foramen CT, A =1 difficult, B = 2 easy, C = 3 excellent

Analysis of the data

To answer the research questions, several analyses were performed. All analyses were performed using IBM SPSS Statistics 26 [e].

Number and location of mental foramina

Frequency tables, including the frequencies of the different locations and number of foramina, were created. These frequency tables were used to investigate the prevalence of a caudal mental foramen, and to investigate the exact location of the middle and caudal mental foramina with respect to hard tissue landmarks.

CT versus IOR

10 Dogs had IOR of the area of the mental foramina as well as a CT of the skull. Another 3 dogs were excluded because either the skull was not completely scanned (n = 1) or because extensive periodontal disease made assessment impossible (n = 2). This sample size was too small for statistical analysis of CT versus IOR. Therefore, it was decided to make frequency tables of the scores of the caudal foramina, to compare CT and IOR.

Additional analysis of the CT examinations
A Shapiro-Wilk test was performed for number of foramina left and right, to determine if the data was normally distributed. Tests for both sides were significant, meaning the data was not normally distributed. Subsequently, histograms were made, which showed the data was approximately normally distributed. Therefore it was decided to work with tests for normally distributed data. Levene's test of equality of error variances did not have any significance for both the left and right side. Therefore, two two-way analysis of variances (ANOVA's) were performed to investigate if the number of foramina were influenced by the skull shape and the size of the animal. In the first ANOVA, the dependent variable was the number of foramina left and the independent variables were skull shape and size of the animal. In the second ANOVA, the dependent variable was the number of foramina right and the independent variables were skull shape and size of the animal. Bonferroni corrections were used to correct for multiple testing. Pair wise comparisons were performed to determine between which groups there was a significant difference.

Results

For CT, 141 dogs were included in this study of which 78 were male (37 intact, 41 castrated) and 63 female (14 intact, 49 castrated). These dogs were of 56 different breeds. 35 Dogs were brachycephalic and 106 dogs were mesaticephalic. 44 Dogs were classified as small, 36 as medium, 57 as large and 4 as very large. In one dog it was not possible to detect mental foramina. This dog was excluded. For IOR, 53 dogs were included which were from 28 different breeds. 13 Dogs were brachycephalic and 40 dogs were mesaticephalic. 22 Dogs were classified as small, 15 as medium, 13 as large and 3 as very large.

Number of foramina

The number of foramina (depicted in Table 1) was based on the number seen on the CT scans (Figure 6). The prevalence of two foramina (a rostral and middle foramen) was 11.4% for the right side and 12.1% for the left side, while the prevalence of three foramina (rostral, middle and caudal) was 65.5% for the left side (L) and 68.3% for the right side (R). Accessory mental foramina have also been found. There were cases in which four foramina occurred (20.1% L and 18.0% R) and sometimes even five (0.7% L and 2.2% R) or six (0.7% only L).
The prevalence of a caudal mental foramen left (the cumulative percentage of 3, 4, 5 (and 6) foramen) was 87.0% and for the right it was 88.5%.%.

	Left		**Right**	
Number	Frequency	Valid Percentage	Frequency	Valid Percentage
1	1	0.7	-	-
2	17	12.2	16	11.5
3	91	65.5	95	68.3
4	28	20.1	25	18.0
5	1	0.7	3	2.2
6	1	0.7	-	-
Missing	1		1	
Total	140	100	140	100

TABLE 1. NUMBER OF FORAMINA LEFT AND RIGHT

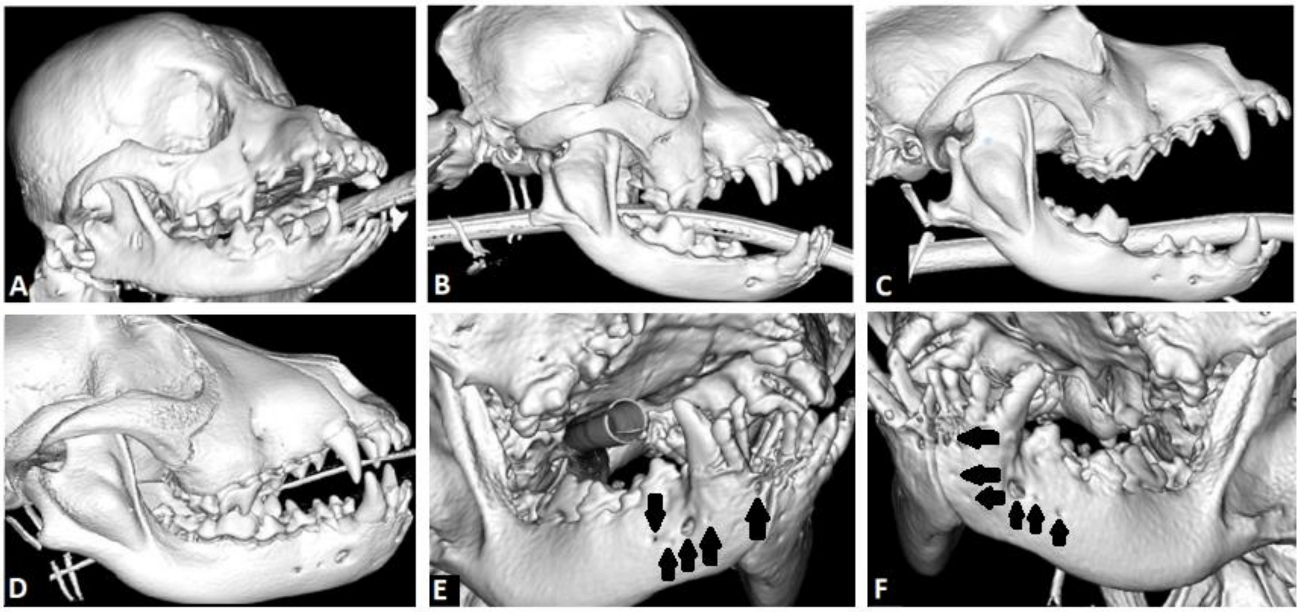

Figure 6 Number of foramina. A = no foramina were identified, B = 2 mental foramen, C = 3, D = 4, E = 5 and F = 6

Location of the foramina

On the left mandible; the middle mental foramen was most often located apical of the area 305-306 (both 305 and 306) (39.3%). In 22.1% of the 140 cases it was located apical between 305 and 306, in 17.1% it was located only apical of 306 and in 15.7% it was only located apical of 305.

The caudal mental foramen was, in 77.9% of the cases, located apical of the 307. In 5.0% of the cases it was located between 306 and 307 and in 2.1% of the cases between 307 and 308.

On the right mandible; the middle mental foramen was most often located apical of the area 405-406 (both 405 and 406) (37.1%). In 27.2% of the cases it was located apical of 406 and in 22.9% of the cases it was located apical between 405 and 406. In 10.0% of the cases it was located only apical of the 405.

The caudal mental foramen was located apical of the 407 in 79.3% of the cases. In 3.6% of the cases it was apical between 406 and 407 and in 2.1% of the cases between 407 and 408. An overview of the locations left and right is depicted in Table 2.

Left:	Middle		Caudal		Right:	Middle		Caudal	
Location	Frequency	Valid Percentage	Frequency	Valid Percentage	Location	Frequency	Valid Percentage	Frequency	Valid Percentage
304-305	2	1.4							
304-305+305	1	.7							
304-305+306	1	.7							
304+305+306	1	.7							
305	22	15.7			405	14	10.0		
305-306	31	22.1			405-406	32	22.9		
305+306	55	39.3			405+406	52	37.1		
305+306-307	1	.7							
306	24	17.1	1	.7	406	39	27.9	1	.7
306-307			7	5.0	406-407	1	.7	5	3.6
307			109	77,9	407			111	79.3
307-308			3	2.1	407-408			3	2.1
					408			2	1.4
n.t.b	1	.7			n.t.b	1	.7	1	.7
x	1	.7	20	14.3	x	1	.7	17	12.1
Total	140	100	140	100		140	100	140	100

TABLE 2. LOCATION OF THE MIDDLE AND CAUDAL MENTAL FORAMEN, LEFT AND RIGHT. X = NOT PRESENT

In the case of accessory mental foramen (Table 3), the AMF can be found in 9.3% (R) to 10.0% (L) of the cases between the middle and caudal mental foramen. In 7.1% (L) to 7.9% (R) of the cases the AMF was located apical in the area of the canines. In 0.7% (R) to 2.9% (L) of the cases the AMF was located caudally of the caudal mental foramen. If 5 foramina were present, three times both a rostral AMF and middle AMF were found and once two rostral AMFs. In the case of 6 foramina, two rostral AMFs and a middle AMF were found.

Left:	Middle		Caudal		Right:	Middle		Caudal	
Location	Frequency	Valid Percentage	Frequency	Valid Percentage	Location	Frequency	Valid Percentage	Frequency	Valid Percentage
306	10	7.1			406	6	4.3		
306-307	7	5.0	1	.7	406-407	3	2.1		
307-308			1	.7	406+407	3	2.1		
					407	3	2.1		
308			2	1.4	408			1	.7
x	123	87.9	136	97.1		125	89.3	139	99.3
Total	140	100	140	100		140	100	140	100

TABLE 3. LOCATION OF THE MIDDLE AND CAUDAL MENTAL AMFS, LEFT AND RIGHT. X = NOT PRESENT

CT versus IOR

Score 3 (excellent to identify) was scored most often on CT: in 82.9% (L) and 86.4% (R) of the cases. Score 3 was scored on IOR in 11.3% (L) and 18.9% (R) of the cases. On IOR, score 2 (easy to identify) was most often scored, in 37.7% (L) and 30.2% (R) of the cases, compared to 2.1% (L and R) on CT. On IOR, score 1 (difficult to identify) was scored in 24.5% (L) and 22.6% (R) of the cases, compared to 1.4% (only L) on CT (Table 4). On the IOR, the percentage of the scores included both parallel and lateral views (Table 5).

	Left		Right	
Score	Frequency	Valid Percentage	Frequency	Valid Percentage
1	2	1.4	-	-
2	3	2.1	3	2.1
3	116	82.9	121	86.4
x	19	13.6	16	11.4
Total	140	100	140	100

TABLE 4. SCORING OF THE CAUDAL MENTAL FORAMINA ON CT, LEFT AND RIGHT. (0 = UNABLE TO IDENTIFY, 1 = DIFFICULT TO IDENTIFY, 2 = EASY TO IDENTIFY, 3 = EXCELLENT TO IDENTIFY, X = NOT PRESENT)

	Left		Right	
Score	Frequency	Valid Percentage	Frequency	Valid Percentage
1	13	24.5	12	22.6
2	20	37.7	16	30.2
3	6	11.3	10	18.9
x	14	26.4	15	28.3
Total	53	100	53	100

TABLE 5. SCORING OF THE CAUDAL MENTAL FORAMINA ON IOR, LEFT AND RIGHT. (0 = UNABLE TO IDENTIFY, 1 = DIFFICULT TO IDENTIFY, 2 = EASY TO IDENTIFY, 3 = EXCELLENT TO IDENTIFY, X = NOT PRESENT)

Difference in number of foramina for different skull shapes and sizes of the animal

On the left mandible: the effect of size of the animal on the number of foramina *(F (3,130) = 2.709; p= .048)* was significant. After Bonferroni correction this effect was not significant. The effect of skull shape *(p=.703)* was not significant. There was no interaction between size of the animal and skull shape *(p=.756)*.

On the right mandible: the effect of size of the animal on the number of foramina *(F (3,130) = 6,245; p = .001)* was significant, even after Bonferroni correction. *Partial* η^2 *(Partial Eta Squared) = 0.126*. Partial Eta Squared is a measure of the size of the effect. The effect found is a medium to large effect.[16] This means that the effect of the size of the animal on the number of foramina (on the right mandible) is medium to large. Pairwise comparisons gives a significant difference between small and medium dogs *(p = .004)* and between small and large dogs *(p = .002).* Mean numbers of foramina are shown in Table 6.
The effect of skull shape *(p =.998)* was not significant. There was no interaction between size of the animal and skull shape *(p =.328)*

	Left		Right	
Size	**Mean**	**Std. Error**	**Mean**	**Std. Error**
Small	2.858	.103	2.770	.090
Medium	3.278	.125	3.259	.109
Large	3.225	.152	3.354	.133
Very large	3.000	.374	3.167	.328

TABLE 6. MEAN NUMBER OF FORAMINA PER SIZE CATEGORY

Discussion

The objective of this study was to investigate the prevalence of a caudal mental foramen and to determine the location of it. In addition, the aim was to determine if IOR was an efficient method to visualize the caudal mental foramen, compared to CT.

Number of foramina

This study shows that three mental foramina is the most common in dogs, instead of two foramina as was expected. A caudal mental foramen is present in 87.0% (L) and 88.5% (R) of the dogs. Thus, it seems that a third foramen is not 'accessory', but normal. The prevalence of a caudal mental foramen is therefore not comparable to that of humans. Another remarkable finding is that a fourth mental foramen occurs in 20.0% (L) and 17.9% (R) of the cases. In some cases even five or six foramina have been found on one side.

In addition, in humans it has been found that AMF does not always appear symmetrical. In the study by Direk et al.[10] it was found that an AMF occurs more often on the right (66.7%) than on the left (33.3%), while in dogs this is quite symmetrical. One of more AMFs occur in 2.0 to 14.3% of the cases[10,11,12], compared to 20.2% (R) and 21.5% (L) in dogs.

Location

There appears to be quite some variation in the location of the middle mental foramina. The middle mental foramen is most often located apical of both 305 and 306 and 405 and 406. However, the middle mental foramen can also be found frequently between 305 and 306 and 405 and 406, or apical of only 306 and 406. The caudal mental foramen is most often located apical of the 307 and 407. Thus, this is in contrast of wat was found earlier; apical of the canines and the second premolars.[13] The locations of the mental foramina are similar left and right.

The location of the rostral foramina was not included in the answer to this main question. This is because it was expected that the rostral foramina would always be in the same location and that there would be more spread in location of the middle and caudal foramina. It seems that the rostral foramina are indeed fairly aligned, but there are also accessory foramina in the rostral area. The location of these rostral accessory foramina can vary. They appear to be mostly located ventrally of the rostral mental foramen or apical in the area of 304/404. This could be further investigated.

CT versus IOR

Because of the retrospective design of this study, it turned out that there were not enough patients that had IOR of the area of the mental foramen as well as a CT-scan of the skull. Thus, the sample size was too small to run statistics. Therefore, it was decided to compare the scores of ease of identification of the caudal foramina on CT and IOR in general. In this way, the scores of one individual are not compared, but a global estimation can be done to determine if IOR is an efficient method to visualize the caudal mental foramen, compared to

CT. The analysis showed that in 82.9% (L) and 86.4% (R) of the cases, a foramen was excellent to identify on CT (3D-mode), compared to 11.3% (L) and 18.9% (R) on IOR. Therefore, it can be concluded that IOR is not an efficient method to visualize the caudal mental foramina, in comparison with CT. However, it should be noted that the scoring system is quite subjective and the scores are assigned by a single observer. The results could have been different when a more trained observer would have done the image evaluations.

Another limitation of this study is that both the IOR and the CT scans were not made in a standardized way. Both types of imaging techniques were used for diagnostic and therapeutic purposes and not for this study.
The lack of standardization is more of a limitation when assessing the IOR than when assessing the CT examinations. The reason for this is that with CT the different images were combined to a 3D image, which eliminates some of the lack of standardization. The lack of standardisation in IOR causes variation in the distance between the animal and the X-ray beam, as well as the direction of the radiographic projection direction.[1,14] The location where the foramina are projected on IOR is very dependent on the recording direction (view: parallel or lateral). If the radiograph is taken in parallel direction, the X-ray beam runs parallel to the foramen, making the foramen darker on the image. In lateral shooting direction, the X-ray beam has to pass through more bone, projecting more bone over the foramen and therefore making the foramen less visible. However, even multiple pictures of lateral view of one patient are not always consistent in showing the mental foramina. For some patients, multiple images were available in lateral view, taken with slightly different angles. Sometimes there were no foramina visible on one radiograph, while they could be seen on the next. Thus, the chance of finding the foramina increases as more radiographs are available. Additionally, it might be interesting to investigate whether there is a difference in scoring between parallel and lateral radiographs. This was not investigated in this study because the group for IOR was relatively small and the data was analysed retrospectively. Furthermore, not every dog had radiographs in both parallel and lateral view. This could be included in a prospective follow-up study.
Another explanation for the difference in score for ease of identification between CT and IOR is that the radiographs regularly showed radiolucent areas that could pass as foramina. However, sometimes there were so many of them that it was unlikely that they were mental foramina or the radiolucent areas were in a location that made it unlikely that they were mental foramina. In the absence of a CT scan for comparison, it was not possible to determine whether or not it was a mental foramen. In these cases it was decided to note that the foramen could not be identified. For example, the foramen shown in Figure 4B has a remarkable location. It appears to be below 409. This is remarkable because this location was not further identified in this study. For this patient it would have been interesting to confirm with CT that this was in fact a mental foramen. Unfortunately, no skull CT was available for this patient. This demonstrates that IOR is not an efficient method to visualise the caudal mental foramina. This is in agreement with the conclusion of the study by Döring et al.[14] and Bar-Am et al.[15], who state that 3D imaging methods are more suitable for visualising various anatomical landmarks, including the mental foramina, than 2D imaging methods.

Assessment of CT
The assessment of the CT examinations was performed in a standardized manner as much as possible. Every dog was zoomed in equally. However, this was disproportionate to skull size. As a result, the skulls of large dogs were proportionally more zoomed in than those of small dogs. This made the small skulls more difficult to assess than large skulls. In a subsequent study, it is recommended to zoom in each skull a certain percentage. In this way, one

can zoom in proportionally and all skulls can evenly be assessed.
Furthermore, with the 3D mode it was not always possible to distinguish whether it was actually a foramen, or whether it was just a dent. For this, the multiplanar reconstruction (MPR) mode was used to see if there was a channel through the bone, and therefore a foramen.

Size of the animal and skull shape
This study showed that skull shape does not affect the number of mental foramina. In itself this is remarkable, because it would be expected that as the length of the jaw becomes shorter, as in brachycephalic dogs, there is less space for the structures present and therefore less foramina would occur in brachycephalic dogs. However, this is not the case. Also no interaction was found between the skull shape and the size of the animal. Thus, the mean number of mental foramina does not differ between the different size categories and skull shapes.

What is striking, is that there has been found an effect of the size of the animal on the number of foramina on the right mandible, but this effect has not been found on the left mandible. On the right it appears that dogs that are classified as small have significantly less foramina than dogs from the large or medium category. This can be explained because small dogs have a smaller skull, and therefore less space for mental foramina. It is remarkable that this effect was only found on the right. Especially because this is a medium to large effect, so one would expect to find this on the left as well. However, it should be noted that the effect has not been tested without the outliers. Without the outliers, the effect of the size of the animal on the number of foramina might not have been found significant. Additionally, it is interesting to mention that a difference between left and right has previously been found in the dog. In a study by Peralta et al.[17] it was found that of 4/5 unilateral clefts of the lip and the alveolus were found on the left side. Further research would be recommended to find out whether the effect of the size of the animal on the number of foramina is significant without the outliers and if it can also be found on the left.

Clinical significance
The question now arises whether these accessory mental foramina are clinically relevant. The study of Iwanaga et al.[11] has shown that the AMFs are clinically significant in humans. In this study it was found that only a nerve runs through a large part of the accessory mental foramina (15/20). In 4/20 there was only an artery passing through the accessory mental foramen and in 1 case there were both a nerve and an artery passing through the foramen. Chances are that this is also the case with dogs. A cadaveric study could be done to investigate this and confirm that AMFs are clinically significant in dogs.

As is well known in human dentistry, information about the frequency and location of accessory mental foramina is important to prevent damage to the mental nerves and blood vessels during surgery.[10] As little is known about this in dogs, more research will need to be done to find out how clinically relevant these accessory foramina are in dogs to prevent complications during surgery. Therefore, the results of this study should stimulate further research on the mental foramina in the dog.

Conclusion

In conclusion, this study showed that the vast majority of dogs have three mental foramina on either side, and that a caudal mental foramen can be considered normal. It appears that the most common locations on the left and right are comparable, but that there is some variation in the possibilities in terms of location. Furthermore, as has already been shown in previous studies, CT appears to be a more efficient method to visualize the mental foramina compared to IOR. In addition, it has been found that the size of the dog affects the number of foramina on the right side. Dogs in the "small" category have been found to have significantly less mental foramina on the right side than dogs in the "medium" or "large" category. To investigate whether in dogs, as in humans, the accessory mental foramina are clinically relevant more research should be done.

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Footnotes

a. PACS (picture archiving and communication system) Agfa Healthcare (2020), Mortsel, Belgium.
b. Siemens AG (2010), Munich, Germany
c. Gendex, type Oralix AC. Gendex Dental systems, Milano, Italy.
d. Visiquick. Thomas Monitor Systems (TMS), Amsterdam, The Netherlands.
e. IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.

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