Localization of the mandibular canal in Brachycephalic dogs using computed tomography

Journal of Veterinary Dentistry, Fall, v. 26, n. 3, p. 156-163, 2009
http://producao.usp.br/handle/BDPI/1626

Downloaded from: Biblioteca Digital da Produção Intelectual - BDPI, Universidade de São Paulo
Localization of the Mandibular Canal in Brachycephalic Dogs Using Computed Tomography

Lenin Arturo Villamizar Martinez, MV, MSC; Marco Antonio Gioso, MV, MSC, PhD; Cristian Marcelo Villegas Lobos, MS; Ana Carolina Brandão de C. Fonseca Pinto, MV, MSC, PhD

Summary:

For some surgical procedures in veterinary dentistry including exodontia, orthognathic surgery, orthopedic surgery, oncologic surgery, and for the placement of dental implants, it is important to know the accurate location of the neurovascular structures within the mandibular canal. The aim of this research was to determine the course of the mandibular canal in the mandible and its relationship with other anatomical structures in brachycephalic dogs using computerized tomography. Mandibles from 10 brachycephalic cadaver dogs were evaluated. Measurements were taken in relation to the lingual, vestibular, alveolar crest, and ventral surfaces. These measurements indicated that the mandibular canal descends slightly from the mandibular foramen to the molar area, decreasing the distance of the mandibular canal from the mandibular ventral border. The mandibular canal is slightly closer to the lingual surface than the vestibular surface except in the molar tooth region. The mandibular canal continues in a rostral direction occupying the ventral region of the mandibular body, reaching its maximum distance from the alveolar crest at the level of the first molar and fourth premolar teeth. In the third and fourth premolar tooth region, the mandibular canal maintains a similar distance between the vestibular and lingual borders; then, at the level of the second premolar tooth, the distance of the mandibular canal from the lingual and ventral border increases before its termination at the mental foramen. The study reported here documents the feasibility of using CT to determine the location of the mandibular canal in relation to bony and dental parameters. Although the difference in mandible size of the group of brachycephalic dogs reported here resulted in broad ranges of measurements, it is clear that the MC course may vary between individual dogs. J Vet Dent 26(3); 156 - 163, 2009

Introduction

For some surgical procedures in veterinary dentistry including exodontia, orthognathic surgery, orthopedic surgery, oncologic surgery, and for the placement of dental implants, it is important to know the accurate location of the mandibular canal in order to prevent injury to its neurovascular structures within the mandibular canal. The mandibular canal begins at the mandibular foramen, just ventral to the temporalis muscle insertion at the medial surface of the mandibular ramus. The mandibular canal courses rostrally through the mandibular body until its termination at the mental foramina located on the lateral surface of the rostral mandible near the roots of the second premolar and canine teeth. Radiographically, the mandibular canal appears as a radiolucent linear image along the ventral aspect of the mandible in relation to the tooth roots.

Computed tomography (CT) has become an important non-invasive diagnostic tool that complements other techniques (intraoral radiography and conventional radiography) to improve the diagnosis and pre-surgical planning in dental small animal procedures. The CT is a diagnostic imaging technique which employs the X-ray and computer software to form a cross-sectional image. This image represents a transverse slice of an object in two dimensions and can have different degrees of thickness (0.5, 1, 2, 5 and 10-mm). CT allows visualization of structures that are inside an object without overlapping. The tomograph is composed basically of the scanning gantry, patient table, operator console or work station, and the x-ray controller (Fig. 1).
The scanner gantry is a mechanism that contains the x-ray tube and is opposite the electronic x-ray detectors. Differences between the earliest and the latest tomographs include the increment, amount, and quality of x-ray detectors. There have been 4 generations of tomographs, followed by the spiral and multi-slice CT scanning systems. The 1st generation scanners had a single detector; 2nd generation scanners had 5 to 50 detectors; 3rd generation scanners had 200 to 1000 detectors; and, the 4th generation scanner had 300 to 4000 detectors. Currently, the spiral and multi-slice CT systems have special features allowing for slices with 1-mm and submillimetric (0.5 mm) reconstructions improving the resolution and detail of the tissue image.

In order to acquire a single transverse image, the x-ray tube turns at 180 or 360° around the patient providing radiation that reaches the tissues in a transverse plane in relation to the long axis of the patient. The radiation emitted from the x-ray tube is limited by the collimator in 1, 2, 5 or 10-mm increments and corresponds to the slice thickness. Between 200 and 500 x-ray projections are performed to get a single image. The radiation that reaches the patient is attenuated due to the differences between the tissue densities. The x-ray differences after exiting the body are collected and converted to an electrical signal by electronic detectors aligned in the opposite side of the x-ray source into the gantry (Fig. 2). This electrical signal is converted to a digital signal that is manipulated in the work station.

In the earliest tomographs (1st, 2nd, and 3rd generation) the detectors turned around the patient with the x-ray source at the same time. Beginning with 4th generation tomographs, the detectors were fixed around the circumference of the gantry with only the x-ray tube turning around the patient. Current tomographs possess greater numbers of detectors and are fixed to the gantry drastically decreasing the acquisition time and the x-ray exposure time required to scan a specific area to form a single transverse image. The time to acquire a single transverse image is about 1-second. The digital matrix on the computer allows the operator to reconstruct many slices with thickness ranging from 0.5 to 2-mm, improving the resolution and the tissue detail in the tomogram.

The digital computed matrix is formed by pixels with different intensities of light. Since the tissue slice is a 3-dimensional image (width, height, length), each pixel represents a volume unit (voxel) with length corresponding to the thickness established by the operator. On the computer screen, the image appears in black, white, and a wide range of greys; where each tone of grey has a specific number or Hounsfield Units (HU). Using the Hounsfield scale, values range from -1000 HU for air (black) to +3000 HU for metal (white). The CT intensity of water in this scale is 0 HU.

The relevance of the Hounsfield scale is that the operator can manipulate the image using the image window to produce more contrast and to increase the grey scale. The level window (center of the density scale) also can be manipulated and shows the attenuation values and which organ structures are represented in the medium shades of grey in a specific window. Thus, the operator can use basically 3 windows (soft tissue window, bone tissue window, and lung tissue window) with its respective level windows in order to visualize minor changes in the densities of a tomogram.

Some 3rd generation tomographs employ reconstruction imaging for bony or soft tissue in order to get the maximum detail and spatial resolution on small bones and discrete areas.
tomograph device increases the acquisition time and number of x-ray projections while enhancing image features.

CT imaging has an important role in the different disciplines of human dentistry, especially in the area of endosteal dental implants. It allows measuring the amount of alveolar bone (morphovolumetric evaluation) using cross-sectional views (three-dimensional), enhancing the information obtained from two-dimensional radiographs. CT imaging of the mandible allows precise localization of the mandibular canal before a procedure is performed on the mandible in order to prevent permanent injuries or damage to the structures that are within the canal. The major uses for CT in veterinary dental practice are the evaluation of facial trauma (fractures), neoplasia, and temporomandibular joint assessment. The aim of this research was to determine the course of the mandibular canal in 10 brachycephalic dogs by means of CT.

Materials and Methods

Ten heads of brachycephalic dog (6 Boxers, 2 Bulldogs, 2 Pugs) cadavers were used. Dog sex and weight were not considered. The cadavers were recovered from the Pathology Department of the Veterinary School of the University of São Paulo (USP) and the Control Zoonosis Center for São Paulo (Brazil). The cadavers used in this work were donated by the owners to the veterinary school in order to perform several research projects. The study protocol was approved by the Ethical Committee of the faculty of Veterinary Medicine and Zootechnology of São Paulo University.

The heads were submitted for oral examination using a periodontal probe in order to determine the presence of periodontal disease. Dogs with periodontal pocket depths > 4-mm and/or clinical attachment loss exposing the furcation and tooth roots in mandibular teeth were not considered for the study. Only the dogs with healthy periodontium were used for CT examination. Mandibular size was referenced in each mandible by measuring the distance between the mesial surface of the canine tooth and distal surface of the first molar tooth (Fig. 3). The periodontal evaluation and mandibular measurements were recorded in a patient dental chart.

The tomographic examinations were made in the Image Service of the Veterinary Hospital of the Veterinary and Zootechnology School of the University of São Paulo (USP), Brazil. The mandibular CT images were made using a 3rd generation tomograph. The images were photographed with a multiformat camera and recorded on 35 x 43-cm size film after processing.

The adjustment technique was 120 kV, 22 mA, and 4.8-seconds of acquisition time. The thickness of slices was 2-mm. The transverse tomographic slices were done at the level of the mental foramina; second, third, and fourth premolar teeth; first, second, and third molar teeth; and, the mandibular foramen. A bony reconstruction was performed to improve bone detail.

The transverse slices were made using the dental roots of each tooth as a reference. The heads were positioned with the ventral border of the mandible and the mandibular canal as close as
possible to the horizontal plane in relation to the tomograph table. The axial slices were made as perpendicular as possible to the mandibular canal in order to obtain high quality images. To achieve perpendicular slices in relation to the mandibular canal, it was necessary to angle the gantry in the mandibular foramen and molar tooth areas. A preliminary view similar to a digital radiograph was taken to obtain a lateral view of the mandibles to assist planning the choice of the specific areas where the slices would be performed (Fig. 4).

Several measurements were made using CT images in order to determine size and location of the mandibular canal in relation to the structures that surround it. Parameters included mandibular height; mandibular width; distance between mandibular canal (MC) and lingual surface; distance between MC and vestibular surface; distance between MC and ventral surface, distance between MC and alveolar crest (MC depth), and the distance between the MC and the roots. In some measurements that included the alveolar crest as a reference point, the tooth image appeared superimposed on bone. For such measurements, an imaginary line at the level of the alveolar margin between the dorsal edge of the vestibular and lingual surfaces was used as an estimate of the real alveolar crest level (Fig. 5). Statistical computing and graphics' software were used to determine and evaluate measurements.

**Results**

Ten mandibles of different brachycephalic dogs were analyzed. The mandibular length measurements ranged between 45.6 and 75.6-mm with an average of 70-mm.

The MC originated at the mandibular foramen on the medial surface of mandibular angle. The mandibular foramen location ranged (average) from 6.7 to 12.2-mm (10.1-mm) dorsal to the mandibular ventral border and from 0.8 to 1.8-mm (0.9-mm) towards the vestibular surface of the mandibular angle (Fig. 6). The mandibular canal continues rostrally through the molar and premolar region until its ends at the level of the second premolar tooth in the caudal, middle, and rostral mental foramina.

In the molar region, the height measurement (average) of the ten mandibles ranged from 10.2 to 27.4-mm (19.4-mm) and mandibular width range from 6.9 to 11.1-mm (9.15 mm). The MC ranged from 1.9 to 5.5-mm (2.8-mm) from the vestibular border; 0.7 to 3.7 mm (1.6-mm) from the lingual border; 2.7 to 8.4-mm (4.8-mm) from the mandibular ventral border; and, 2.2 to 16.4-mm (7.6-mm) from the alveolar crest.
Figure 7

Graph (A) showing the average of the measurements of each mandibular anatomical region in 10 brachycephalic dogs including distance from the ventral border of the mandible to the mandibular canal (MC) [red line]; MC depth from the alveolar crest [green line] in relation to mandibular height [black line]. Graph (B) showing the average of the measurements of each mandibular anatomical region in 10 brachycephalic dogs including distance from the lingual surface to the MC [green line]; distance from the vestibular surface to the MC (red line) in relation to mandibular width [black line].

Figure 8

Diagrammatic lateral view (A) showing the course of the mandibular canal based on average measurements (Table 2). It reaches its maximum depth in relation to the alveolar crest at the level of the first molar and fourth premolar teeth. The mandibular canal (MC) increases in distance from the ventral mandibular border as it approaches the middle mental foramen. Diagrammatic dorsoventral view (B) of the MC located slightly closer to the lingual surface than the vestibular surface caudal to the molar region based on average measurements (Table 2). The distance between the MC and the lingual and vestibular borders of the mandible is similar in the third and fourth premolar tooth region. At the level of the second premolar tooth, the distance between the MC and the mandibular lingual surface increases before terminating at the mental foramina.

In the premolar region, the height measurement (average) of the ten mandibles ranged from 10.9 to 23.4-mm (17.0-mm) and mandibular width ranged from 7.2 to 12.2-mm (9.7-mm). The MC ranged from 1.7 to 4.1-mm (2.1-mm) from the vestibular border; 1.3 to 7.0-mm (2.5-mm) from the lingual border; 1.6 to 10.5-mm (3.2-mm) from the mandibular ventral border; and, 4.2 to 14.0-mm (8.3-mm) from the alveolar crest.

The middle mental foramen was located on the vestibular surface, ventral to the mesial root of the second premolar tooth. The foramen location (average) was from 5.5 to 13.4-mm (8.6-mm) dorsal to the mandibular ventral border; 3.4 to 7.4-mm (6.2-mm) from the lingual surface, and 2.3 to 9.0-mm (6.4-mm) from the alveolar crest (Table 1).

The average value reported in each region was calculated from the height and width averages for each measured location, as
well as the average of the measurements from the MC to the vestibular, lingual, ventral, and alveolar crest surfaces at each cross-sectional view using the dental roots in each region as a reference (Table 2).

These measurements indicate that the mandibular canal descends slightly from the mandibular foramen to the molar area, decreasing the distance of the MC from the mandibular ventral border. The MC is slightly closer to the lingual surface than the vestibular surface (until the molar region). The MC continues in a rostral direction occupying the ventral region of the mandibular body, reaching its maximum distance from the alveolar crest at the level of the first molar and fourth premolar teeth. In the third and fourth premolar tooth region, the MC maintains a similar distance between the vestibular and lingual borders; then, at the level of the second premolar tooth, the distance of the MC from the lingual and ventral border increases before its termination at the mental foramina (Figs. 7-12).

The mandibular canal course and the position of the dental roots were similar in each dog. However, there were several differences in one dog (pug) regarding the position of the roots of the mandibular first molar tooth and in relation (lingual and vestibular position) with the mandibular canal. Oral examination showed rotation of the fourth premolar tooth in this same dog (Fig. 13).

Discussion

The quality of the images obtained with CT could be affected by several factors: mandible position; incorrect scan technique; the use of a wrong window; and, level of reconstruction protocol. In order to maximize image quality and reproducibility, mandibles were positioned parallel to the horizontal plane in relation to the scanner table so that the tomographic slices were made perpendicular to the long axis of the mandibular body in a transverse plane. Bony reconstruction protocol, window for bony tissue, and 2-mm thick layers were implemented in order to obtain images with a high level of definition and greater detail.
Figure 12
Mandibular premolar region CT images showing transverse scans of the location of the mandibular canal (MC) in relation to the tooth roots: fourth mandibular premolar tooth distal root (A); and, third mandibular premolar tooth mesial root (B). The middle mental foramen (arrow) is located on the vestibular surface just ventral to the mesial root of the second premolar tooth premolar (C). The dental roots were located 1 to 2-mm from the mandibular canal.

Figure 13
CT transverse image of the mesial root of the first molar tooth in a pug (A). The root is located in the vestibular side of the mandibular canal (MC), almost occupying the entire medullary cavity. The MC is shifted towards the vestibular cortical bone. CT transverse image of the distal root of the fourth premolar tooth in a pug (B). The distal root (a) is located at the vestibular aspect of the MC, while the mesial root (b) of the same tooth is located at the lingual aspect of the MC.

In this study, CT was a valuable tool for morphovolumetric evaluation of the mandible in dogs. It allowed locating the mandibular canal and to elucidate its relation with the structures that surround it. Transverse tomographic images showed the course of the mandibular canal and its depth through the mandible body. In humans, the MC was located in contact with or very close to the lingual cortical plate through the molar and premolar regions. MC course in the group of brachycephalic dogs reported here was different and located slightly closer to the lingual surface except in the molar region.

The close proximity of some roots, especially those of the fourth premolar and first molar teeth, to the vestibular or lingual aspect of the MC as in toy breeds including the pugs in this study might affect conventional dental techniques. Buccal cortical bone removal to facilitate extraction of fractured roots should be performed with care since roots, especially of rotated teeth, could be located on the lingual or vestibular aspect of the MC. In small dogs, where the MC appears in a lingual position in relation to the roots of the first molar tooth, use of the periodontal elevator should be limited to the mesial and distal aspects of the roots in order to avoid the buccal aspect and damage to the neurovascular structures of the MC (Fig. 14). Direct drilling (pulverization/atomization) of fractured or retained roots must be discouraged due the proximity of the MC and its contents.

Figure 14
CT transverse images of the mesial root of the first molar tooth. The periodontal elevator is located in a less preferred location on the lingual aspect of the root close to the mandibular canal (A). Distal (B) and mesial (C) locations of the periodontal elevator are preferred to minimize iatrogenic damage to neurovascular structures of the mandibular canal.
Although the use of dental implants and orthognathic surgery are relatively new modalities of therapy in clinical veterinary dentistry, dogs in particular have continuously been used as experimental models in different research studies aimed at human dentistry. These works generally involve the use of dental implants and devices used in orthognathic surgery that are usually placed in the mandibular region. Increasing interest in providing dental rehabilitation for canine patients using dental implants requires an exact knowledge of mandibular canal location.

The study reported here documents the feasibility of using CT to determine the location of the mandibular canal in relation to bony and dental parameters. Although the difference in mandible size of the group of brachycephalic dogs reported here resulted in broad ranges of measurements, it is clear that the MC course may vary between individual dogs. Additional studies are needed to document the location of the MC for dogs of different size and skull conformation. As more advanced maxillofacial surgical techniques are implemented in dogs, it is likely that the CT will become an important tool in preoperative planning, offering three-dimensional images that augment the two-dimensional images obtained by means of intraoral or panoramic radiographs.

Author Information
From the Department of Surgery, School of Veterinary Medicine and Zootechnologı; and, the Statistic Doctoral Program (Lobos), São Paulo University (USP), Brazil. Email: leninvet@usp.br

References

Table 1
Measurements for different mandibular regions in relation to the mandibular canal in 10 brachycephalic dogs.

<table>
<thead>
<tr>
<th>Mandibular region</th>
<th>Mandibular height (mm)</th>
<th>Mandibular width (mm)</th>
<th>Dist. Between MC and mandibular vestibular border (mm)</th>
<th>Dist. Between MC and mandibular lingual border (mm)</th>
<th>Mandibular canal depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular foramen</td>
<td>1.8 - 5.1 (3.52)</td>
<td>0.8 - 1.8 (0.9)</td>
<td>0.09 ± 0.24</td>
<td>1.63 ± 0.55</td>
<td>10.1 ± 1.79</td>
</tr>
<tr>
<td>Molar region</td>
<td>10.2 - 27.4 (19.39)</td>
<td>6.9 - 11.1 (9.15)</td>
<td>2.91 ± 0.73</td>
<td>1.63 ± 0.55</td>
<td>6.07 ± 1.07</td>
</tr>
<tr>
<td>Premolar region</td>
<td>10.90 - 23.4 (17.03)</td>
<td>7.2 - 12.2 (9.69)</td>
<td>2.79 ± 0.59</td>
<td>1.55 ± 0.47</td>
<td>5.36 ± 1.18</td>
</tr>
<tr>
<td>Middle mental foramen</td>
<td>16.8 - 20.4 (17.42)</td>
<td>8.4 - 12.5 (10.25)</td>
<td>3.22 ± 0.27</td>
<td>2.36 ± 0.63</td>
<td>4.97 ± 1.34</td>
</tr>
</tbody>
</table>

(M) Molar tooth; (PM) premolar tooth; (DR) distal root; (MR) mesial root; (MC) mandibular canal

Table 2
Measurements for different dental regions in relation to the mandibular canal in 10 brachycephalic dogs.

<table>
<thead>
<tr>
<th>Mandible reference point</th>
<th>Mandibular height (mm)</th>
<th>Mandibular width (mm)</th>
<th>Distance between MC and mandibular vestibular border (mm)</th>
<th>Distance between MC and mandibular lingual border (mm)</th>
<th>Mandibular canal depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular foramen</td>
<td>-</td>
<td>3.52 ± 0.97</td>
<td>0.99 ± 0.24</td>
<td>1.63 ± 0.55</td>
<td>10.1 ± 1.79</td>
</tr>
<tr>
<td>3rd M</td>
<td>20.53 ± 4.26</td>
<td>9.1 ± 1.43</td>
<td>2.91 ± 0.73</td>
<td>1.63 ± 0.55</td>
<td>6.07 ± 1.07</td>
</tr>
<tr>
<td>DR - 2nd - M</td>
<td>19.87 ± 3.37</td>
<td>9.28 ± 1.36</td>
<td>2.91 ± 0.51</td>
<td>1.57 ± 0.53</td>
<td>5.36 ± 1.18</td>
</tr>
<tr>
<td>MR - 2nd - M</td>
<td>19.39 ± 3.40</td>
<td>9.14 ± 1.23</td>
<td>2.79 ± 0.59</td>
<td>1.55 ± 0.47</td>
<td>4.97 ± 1.34</td>
</tr>
<tr>
<td>DR - 1st - M</td>
<td>18.31 ± 3.71</td>
<td>8.96 ± 0.85</td>
<td>2.62 ± 0.94</td>
<td>1.56 ± 0.46</td>
<td>4.47 ± 0.78</td>
</tr>
<tr>
<td>MR - 1st - M</td>
<td>18.87 ± 4.08</td>
<td>9.27 ± 0.85</td>
<td>3 ± 1.37</td>
<td>1.9 ± 0.58</td>
<td>3.16 ± 0.52</td>
</tr>
<tr>
<td>DR - 4th - PM</td>
<td>18.74 ± 3.91</td>
<td>9.46 ± 0.89</td>
<td>2.39 ± 0.68</td>
<td>2.22 ± 0.59</td>
<td>2.75 ± 0.45</td>
</tr>
<tr>
<td>MR - 4th - PM</td>
<td>18.04 ± 3.56</td>
<td>9.28 ± 0.89</td>
<td>2.21 ± 0.17</td>
<td>2.36 ± 0.63</td>
<td>2.5 ± 0.49</td>
</tr>
<tr>
<td>DR - 3rd - PM</td>
<td>16.25 ± 2.59</td>
<td>9.4 ± 0.90</td>
<td>2.22 ± 0.27</td>
<td>2.28 ± 0.43</td>
<td>2.3 ± 0.44</td>
</tr>
<tr>
<td>MR - 3h - PM</td>
<td>15.86 ± 2.60</td>
<td>9.96 ± 1.10</td>
<td>2.36 ± 0.18</td>
<td>2.44 ± 0.92</td>
<td>2.05 ± 0.32</td>
</tr>
<tr>
<td>DR - 2nd - PM</td>
<td>16.27 ± 2.33</td>
<td>10.17 ± 1.33</td>
<td>2.11 ± 0.20</td>
<td>3.44 ± 1.59</td>
<td>3.74 ± 2.30</td>
</tr>
<tr>
<td>MR - 2rd - PM</td>
<td>17.05 ± 2.52</td>
<td>9.92 ± 1.24</td>
<td>1.56 ± 0.60</td>
<td>4.43 ± 2.11</td>
<td>5.97 ± 2.87</td>
</tr>
<tr>
<td>Middle mental foramen</td>
<td>17.42 ± 3.18</td>
<td>10.25 ± 1.23</td>
<td>0.00 ± 0.20</td>
<td>6.21 ± 1.26</td>
<td>8.61 ± 2.55</td>
</tr>
</tbody>
</table>

(M) Molar tooth; (PM) premolar tooth; (DR) distal root; (MR) mesial root; (MC) mandibular canal

1. General Electric MAX 640, General Electric Company Medical Systems, Milwaukee, WI
2. Kodak Ektascan M films, Brazilian Kodak Company ind. Ltda, SP, Brazil
3. Automatic processor RPX- OMAT, Eastman Kodak Company, Rochester, NY