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Location and course of the mandibular canal in dentate patients: morphometric study using cone beam computed tomography

Short title: Location the mandibular canal in dentate patients: using CBCT

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ABSTRACT

The morphometric characteristics of the mandibular canal (MC) may vary according to the characteristics of the population studied. Correct location of the MC is fundamental for the indication and planning of different dental treatments, and it is therefore essential to have clinical parameters indicating its approximate location. The aim of this study was to describe the location and course of the MC by morphometric relations in the mandibular body, from the mental foramen to distal of the first molar, in dentate adult patients. We analysed 55 cone beam computed tomography (CBCTs) of male and female patients, aged over 18 years and with fully dentate to the first molar. In each CBCT we selected five coronal sections (A-E) of the mandibular body at different levels using the teeth as references. We determined different morphometric measurements in each section to relate the MC with the corticals of the mandibular body (m1, m2, m3, m4), their orientation to

lingual (F) and the thickness of the mandibular corticals (B1, B2 and B3). The distance between the MC and the alveolar crests was greater in males than in females in all the sections. In general, in all the hemiarches, the MC courses away from the vestibular cortical of the mandible (and in some cases significantly towards the lingual cortical) from anterior to posterior in the mandibular body. In the left hemiarch of dentate females the MC describes a descent in the molar zone within the mandibular body. Any intervention in the mandible must be carried out with extreme caution to avoid damaging the vasculo-nervous bundle which passes through the MC. CBCT is the best tool currently available for the planning and execution of surgical procedures, and is the only tool in clinical use which allows the precise course of the MC to be identified.

Key words: mandibular canal, cone-beam computed tomography, chilean population, localization

INTRODUCTION

The mandible is an uneven, mobile bone, located in the inferior posterior part of the face. It provides the seating of the inferior teeth, and together with the hyoid bone it forms the skeleton of the floor of the anatomical mouth [5]. It is considered to consist of three parts: a medial part, the body; and two lateral parts, the rami. The mandibular canal (MC) crosses the body and ramus on each side of the mandible. This conduit originates in the medial face of the mandibular ramus and courses to inferior and anterior, describing an anterior superior curve. It may constitute a conduit with well-defined walls, or describe a trajectory through the trabeculae formed of spongy bone tissue [20].

Due to the MC's anatomical location, relations and variations, its integrity may be altered during different dental procedures, such as third molar surgery, endodontics or osseointegrated implants, causing damage to the nervous and vascular elements contained in the canal [19]. Results of different studies confirm that some anatomical characteristics of the MC are variable, depending on the population studied [21]. These morphological variations in the MC were described decades ago, and range from the presence of bifurcate, trifurcate and even accessory canals to variations in their form, size and position [8, 9, 14, 17].

Correct location of the MC is fundamental for indication, planning and prognosis of different dental treatments, and can be effected using different imaging techniques which provide relevant information and allow variations of the MC to be detected in good time. It is important to preserve the integrity of the MC because it contains the vasculo-nervous bundle which is responsible for the irrigation and sensory activity of the mandibular tissues, such as the lips, gums and teeth [13, 8]. Cone-beam computed tomography (CBCT) offers a three-dimensional reproduction of the area studied [24], and therefore allows precise diagnoses for implant operations, assessment of pathologies and periodontal lesions, endodontics, etc. [15]. Knowledge of both “normal” mandibular morphology and the “variations” which may occur is indispensable for correct dental practice [19]. In this field, it is also indispensable to have clinical or intraoral references to allow the approximate location of the MC in the mandibular body to be estimated. The object of the present study was therefore to describe the location and course of the MC by morphometric relations within the mandibular body, from the mental foramen to distal of the first molar, by CBCT examination, using the teeth of adult subjects with continuous dental arches as a reference.

MATERIALS AND METHODS

The present is a descriptive, retrospective, cross-sectional study in 55 CBCTs of patients attended at the Dental Teaching Clinic of Universidad de La Frontera (Temuco, Chile). The study was approved by the Scientific Ethics Committee (CEC) of Universidad de La Frontera (Folio no. 015/2014). The identities of the patients were not revealed and the only information provided was their age and sex. The images were taken as part of the diagnosis and planning of dental treatment of these patients, using a PAX Zenith 3D tomograph (Vatech Co., Gyeonggi-Do, Korea) with 120 kV, 9 mA, FOV (field of view) 12 x 9 cm and voxel size 0.12 mm. The following inclusion criteria were applied: male and female patients, aged over 18 years and with permanent dentition complete to the first molar in each mandibular hemiarch. The following were exclusion criteria: patients with signs of orthognathic surgery, presence of mandibular implants, presence of pathological mandibular lesions or periapical lesions which compromised the view of any segment of the mandibular canal.

The measurements were taken with the CBCT software and carried out by two previously trained examiners, with a specialist in dentomaxillofacial radiology. The examiners were calibrated by repeated independent measurement of 10% of the total sample and calculation of the intraclass correlation coefficient (ICC).

Multi-plane reconstructions (MPR) of the CBCT of each hemiarch were used and the MC identified in each. First of all, the position of the occlusive plane with respect to the horizontal was rectified in sagittal view (Figure 1.A), while the entrance of the mental foramen was located and the sagittal axis was rectified to pass through this foramen and the lingula (vestibulo-lingual orientation from mesial to distal; Figure 1.B). Using a tool in the CBCT software, the mandibular canal was defined throughout its course by 3 specific points (mental foramen, curve of the loop of the mentonian nerve and prior to the loop) and 4 to 5 equidistant points in the canal towards the lingula (Figure 1.C).

To establish the relations and morphometric measurements of the MC, the entrance of the mental foramen was located in the axial view of the CBCT, and cross-sections of its course were taken using the “curve” tool. The sections were taken with a thickness of 1 mm and at 1 mm intervals. The points defining the position of the mandibular canal were rectified in each coronal section (Figure 1.D). Then the following coronal sections were selected to establish specific morphometric measurements:

- section A: long axis of the second premolar (Figure 2.A)
- section B: interradicular zone of the second premolar and first molar (Figure 2.B)
- section C: long axis of the mesial root of the first molar (Figure 2.C)
- section D: sulcus zone of the first molar (Figure 2.D)
- section E: distal of the first molar (Figure 2.E)

Finally, the following morphometric measurements were determined in each of these sections (Figure 3):

- m1: distance between the most superior point of the cortical of the MC and the projection of the alveolar crests.
- m2: distance between the most vestibular point of the MC and the vestibular mandibular ridge.
- m3: distance between the most lingual point of the MC and the lingual mandibular ridge.
- m4: distance between the most inferior point of the MC and the basal mandibular ridge.
- F: angle formed by the straight lines of measurements m1 and m3.

- Thickness of the vestibular (B1), lingual (B2) and basal (B3) corticals of the mandibular body.

The data were recorded in a Microsoft Office Excel spreadsheet. Descriptive analysis of the data was carried out to determine the means and standard deviations. The Kolmogorov-Smirnov normality test, the t-test for independent samples, ANOVA and post hoc tests of Bonferroni and Tukey were applied. The Mann-Whitney U test for independent samples was also applied, and the Kruskal-Wallis test for the ANOVA. The data were analysed using the IBM SPSS Statistics Programme (version 23.0). A value of $p < 0.05$ was selected as the threshold of statistical significance.

RESULTS

The sample included 55 CBCTs of patients (22 male and 33 female) with mean age 27 ± 10.43 years (25.64 ± 10.46 years for males 27.91 ± 10.47 years for females). 52 right and 48 left mandibular hemiarches were examined. In the analysis of inter-examiner concordance, the ICC was 99% (very good). Table 1 summarises the data describing the location of each coronal section (A, B, C, D and E) in the course of the MC within the mandibular body. Table 2 summarises the means of the different measurements (m1, m2, m3, m4, B1, B2, B3 and F) in each coronal section analysed (A, B, C, D, E), grouped by sex and side of the mandible.

Analysis of the morphometric relations of the MC in the mandibular body in the same coronal section

In section A (long axis of the second premolar), the mean value of m1 (distance to superior of the MC) was significantly greater in males than in females ($p=0.003$). For the rest of the measurements (m2, m3, m4, F, B1, B2 and B3), no significant differences were found between males and females ($p=0.911$, $p=0.145$, $p=0.130$, $p=0.238$, $p=0.405$, $p=0.065$ and $p=0.012$ respectively).

In section B (interradicular zone of the second premolar and first molar), the mean values of m1, m3 (distance to lingual of the MC), m4 (distance to inferior of the MC) and B2 (thickness of the mandibular lingual cortical) were significantly greater in males than in females ($p=0.001$, $p=0.002$, $p=0.002$ and $p=0.004$ respectively). For the rest of the

measurements (m2, F, B1 and B3), no significant differences were found between males and females ($p=0.077$, $p=0.178$, $p=0.530$ and $p=0.255$ respectively).

In section C (long axis of the mesial root of the first molar), the mean values of m1, m3, m4 and B3 (thickness of the mandibular basal cortical) were significantly greater in males than in females ($p=0.000$, $p=0.050$, $p=0.007$ and $p=0.034$ respectively). On the other hand, the mean value of m2 (distance to vestibular of the MC) was greater in females than in males ($p=0.039$). For the rest of the measurements (F, B1 and B2), no significant differences were found between males and females ($p=0.160$, $p=0.916$ and $p=0.285$ respectively).

In section D (sulcus of the first molar), the mean values of m1 and m4 were significantly greater in males than in females ($p=0.000$ and $p=0.000$ respectively). For the rest of the measurements (m2, m3, F, B1, B2 and B3), no significant differences were found between males and females ($p=0.193$, $p=0.063$, $p=0.263$, $p=0.994$, $p=0.196$ and $p=0.072$ respectively).

Finally, in section E (distal of the first molar), the mean value of m1 was significantly greater in males than in females ($p=0.020$). On the other hand, for the rest of the measurements (m2, m3, F, B1, B2 and B3), no significant differences were found between males and females ($p=0.806$, $p=0.418$, $p=0.144$, $p=0.812$, $p=0.570$ and $p=0.108$ respectively).

In this study no significant differences were found in the measurements of any given section between the left and right sides of the mandible.

Analysis of the morphometric relations of the MC in the mandibular body between the different coronal sections

When the right hemiarch was analysed in males, only the mean value of m2 (distance to vestibular of the MC) showed significant differences between the different sections such that A<D ($p=0.008$) and E ($p=0.000$); B<D ($p=0.009$) and E ($p=0.000$) and C<E ($p=0.012$). In the case of m3 (distance to lingual of the MC), significant differences were found between the sections such that A>B>C>D>E ($p=0.005$ in all cases). These two results suggest that the MC courses away from the vestibular cortical of the mandible and towards the lingual cortical, from anterior to posterior in the mandibular body. Likewise for B2 (thickness of the mandibular lingual cortical) significant differences were found

between the sections such that $A > B > C > D > E$ ($p=0.033$ in all cases), showing thinning of the cortical to posterior.

When the left hemiarch was analysed as above in males, the mean value of m2 showed significant differences between the different sections such that $A < D$ ($p=0.016$) and E ($p=0.000$); $B < E$ ($p=0.000$) and $C < E$ ($p=0.004$). This indicates that the MC courses away from the vestibular cortical of the mandible from anterior to posterior in the mandibular body. Likewise for B2 significant differences were found between the different sections ($p=0.025$), such that the mean values of sections A, B and C were the highest (2.3 ± 0.3 mm, 2.7 ± 1.1 mm and 2.3 ± 0.5 mm respectively).

When the right hemiarch was analysed in females, the mean value of m1 (distance to superior of the MC) showed significant differences between the different sections such that $B < C$ ($p=0.042$) and $B < D$ ($p=0.043$). This suggests that the MC is more distant from the alveolar crests in the zone of the first molar. Likewise m2 presented significant differences between the different sections such that $A < C$ ($p=0.001$), D ($p=0.000$) and E ($p=0.000$); $C < E$ ($p=0.029$) and $B < E$ ($p=0.000$). This suggests that the MC courses away from the vestibular cortical of the mandible from anterior to posterior in the mandibular body.

Finally when the left hemiarch was analysed in females, significant differences were found between the sections for m1, with the highest mean values in sections B, C and E ($p=0.000$, $p=0.030$ and $p=0.001$ respectively). In the case of m2, significant differences were found between the different sections such that $A > B > C > D > E$ ($p=0.000$ in all cases). For m3, significant differences were also found between the different sections such that $A > B > C > D > E$ ($p=0.000$ in all cases). These two results indicate that the MC courses away from the vestibular cortical of the mandible and towards the lingual cortical, from anterior to posterior in the mandibular body. Finally, for m4 and F significant differences were found such that $A > E$ ($p=0.035$ and $p=0.041$, respectively for each measurement).

DISCUSSION

Carrying out highly complex and invasive procedures in the mandible requires the dentist to be familiar with all the anatomical structures in the area of the intervention site. Thus analysing the anatomical course and relations of the MC represents one of the most

important tasks for the clinician intervening in this zone. CBCT has proved to be a valuable support tool for the planning and programming of these challenging treatments, since it is a very sensitive means of locating and identifying the MC [2, 11]. CBCT provides the clinician with the necessary information on the thickness, dimension and location of the MC in relation to other structures [12], allowing damage to be avoided to the vasculo-nervous bundle which runs close to the tooth roots [1]. CBCT has been reported to be very superior to panoramic radiography in both specificity and sensitivity [23, 3]. When panoramic radiography is used, it has to be borne in mind that it presents a certain discrepancy in the thickness of the structures [18].

The locations observed in our study for the emergence of the MC are very similar to those reported by other authors [7, 6, 25], with the mental foramen found in the area between the first and second premolars. In all the hemiarches examined in our study, the mental foramen was found to medial of the mesial root of the first molar.

In our study, CBCT was used to assess the morphometric relations of the course of the MC within the mandibular body of dentate subjects. To do this, distance relations were established with the alveolar crests and the mandibular corticals (vestibular, lingual and basal), and the thicknesses of the cortical bones of the mandibular body were also reported. Our results indicate that to distal of the first molar, the MC describes a sinuous course approaching the lingual cortical of the mandible. This is confirmed by the findings of Muñoz *et al.*, [16], who described the location of the MC, viewed frontally towards the coronal section of the mandibular body, as coursing closer to the lingual cortical towards the retromolar space. Other authors, such as Dominguez *et al.*, [4], who analysed CBCTs, and Sîrbu *et al.*, [22], who analysed CBCTs and dry mandibles, also reported similar results. In our analysis, none of the morphometric measurements or relations of the MC indicating its location with respect to the corticals of the mandibular body presented any significant differences between the left and right hemiarches, either in males or females. This finding should be compared with that of Kawashima *et al.*, [10] who reported that the distance between the MC and the vestibular cortical of the mandible (vestibular thickness) was significantly smaller in the right side than the left, in both males and females.

Our results also indicate that, in females at least, the MC courses at a greater depth (further from the alveolar crests) in the molar zone; this may coincide with the findings reported by Sîrbu *et al.*, [22], who described a descendant trajectory from the second

molar towards the first molar and then slightly ascendant towards the second premolar. It should be noted that in classical descriptions the course of the MC in this area is described as coursing obliquely downwards and forwards towards the region of the premolars [5].

CONCLUSIONS

Our results contribute to characterisation of the course of the MC in the mandibular body, which may vary depending on the characteristics of the population and the state of individual dentition. The MC presents an antero-posterior course which could be considered oblique from vestibular to lingual and sinuous in the supero-inferior plane, as it deviates away from the alveolar crests in the molar zone. In general, the course of the MC is similar in both hemiarcs of the mandible, although population-related differences may exist. Finally the thicknesses of the mandibular body measured from the corticals to the MC were found to be consistently greater in males than females, however it must be considered that age may play a determining role in this respect.

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Table 1. Location of the coronal sections carried out in the course of the MC in the mandibular body. The table shows the mean distance of the sections from the mental foramen (emergence of the MC), grouped according to whether they are to mesial or distal of the foramen, or coincide with it (distance 0 mm). It also shows the number of cases or hemiarches in which each section was to mesial or distal of the mental foramen, or coincident with it.

CBCT Section	Location of the section relative to the mental foramen		
	To mesial	Coincident (distance 0 mm)	To distal
Section A	4.38 ± 2.23 mm; n=36	n=24	3.77 ± 2.32 mm; n=40
Section B	2.78 ± 1.57 mm; n=14	n=8	5.76 ± 3.08 mm; n=78
Section C	2 mm; n=1	n=3	9.96 ± 4.37mm; n=96
Section D	n=0	n=0	13.09 ± 4.75 mm; n=100
Section E	n=0	n=0	18.41 ± 4.78 mm; n=100

Table 2. Mean and standard deviation of the measurements (m1, m2, m3, m4, B1 B2, B3 and F) in each of the different coronal sections carried out in the course of the MC, grouped by sex and side.

Measurement	Coronal section	Female		Male	
		Left	Right	Left	Right
m1	A	16.2 ± 2.7	16.3 ± 1.7	17.8 ± 4.0	18.0 ± 1.6
	B	17.9 ± 2	17.9 ± 2	19.6 ± 1.9	19.1 ± 1.9
	C	16.7 ± 1.9	16.4 ± 2.6	18.3 ± 1.7	18.1 ± 1.6

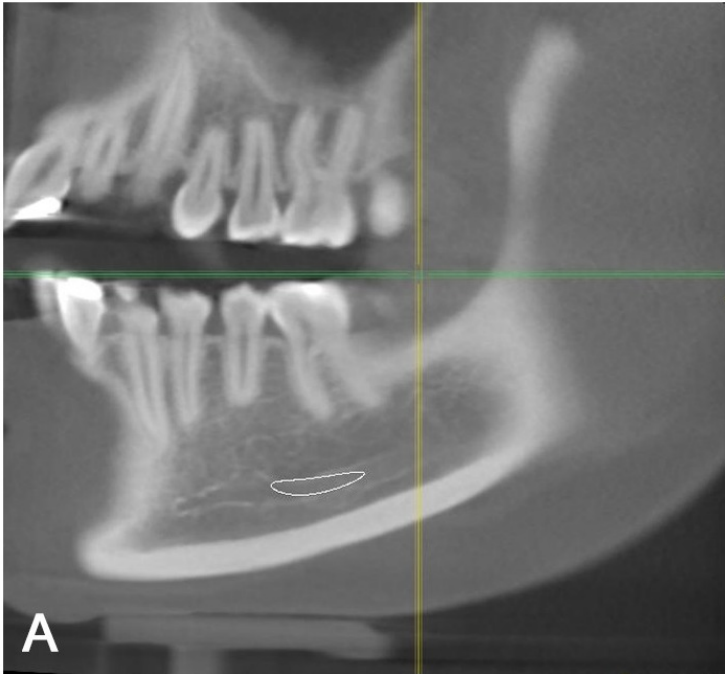
	D	16.3 ± 2.1	16.4 ± 2	18.1 ± 1.5	17.6 ± 2.1
	E	17 ± 2	17.3 ± 2	18.4 ± 1.5	18.3 ± 1.6
m2	A	3.2 ± 0.8	3.2 ± 1.2	3.4 ± 1.0	2.9 ± 1.4
	B	3.8 ± 1	4.1 ± 1.2	3.9 ± 1.2	3.1 ± 1.4
	C	4.7 ± 1	4.7 ± 1.3	4.3 ± 1.6	4.0 ± 1.1
	D	5.2 ± 1	5 ± 1.2	5.1 ± 1.2	4.5 ± 0.9
	E	5.6 ± 1.1	5.6 ± 1.4	5.8 ± 1.4	5.2 ± 0.9
m3	A	4.2 ± 1.2	4.6 ± 2	5.2 ± 1.3	5.0 ± 2.1
	B	3.9 ± 1.3	3.7 ± 1.3	5.0 ± 1.5	4.5 ± 1.8
	C	3.3 ± 1.3	3.3 ± 1.2	4.2 ± 1.6	4.0 ± 1.2
	D	3 ± 1.4	2.9 ± 1.1	3.2 ± 1.3	3.5 ± 1.2
	E	2.6 ± 1.3	2.5 ± 1.1	2.8 ± 1.5	2.9 ± 1.4
m4	A	8.8 ± 1.7	8.4 ± 1.6	9.1 ± 1.7	9.3 ± 2.4
	B	8.2 ± 1.8	8 ± 2	9.6 ± 2.5	9.7 ± 2.2
	C	7.9 ± 1.8	7.7 ± 2	9.0 ± 2.7	8.8 ± 2.4
	D	7.5 ± 1.8	7.5 ± 1.9	9.1 ± 2.0	9.0 ± 2.9
	E	7.3 ± 1.8	7.1 ± 1.8	8.5 ± 2.3	8.8 ± 2.6
B1	A	2.4 ± 0.4	2.3 ± 0.4	2.6 ± 0.6	2.4 ± 0.3
	B	2.4 ± 0.3	2.6 ± 0.8	2.5 ± 0.3	2.3 ± 0.5
	C	2.4 ± 0.3	2.4 ± 0.3	2.4 ± 0.4	2.3 ± 0.3
	D	2.5 ± 0.4	2.4 ± 0.4	2.4 ± 0.4	2.4 ± 0.3
	E	2.4 ± 0.4	2.5 ± 0.4	2.6 ± 0.8	2.4 ± 0.3
B2	A	2.2 ± 0.5	2.5 ± 1.0	2.3 ± 0.3	2.4 ± 0.2
	B	2.2 ± 0.6	2.1 ± 0.3	2.7 ± 1.1	2.4 ± 0.6
	C	2.1 ± 0.5	2.2 ± 0.4	2.1 ± 0.5	2.5 ± 0.6
	D	2.1 ± 0.6	2.0 ± 0.4	2.3 ± 0.9	2.2 ± 0.4
	E	2.0 ± 0.5	1.9 ± 0.4	1.9 ± 0.5	2.1 ± 0.5
B3	A	3.9 ± 0.8	3.9 ± 0.8	4.3 ± 0.6	4.3 ± 0.7
	B	3.9 ± 0.7	3.9 ± 0.8	4.0 ± 1.2	4.3 ± 1.2
	C	3.9 ± 0.6	3.8 ± 0.4	4.3 ± 1.0	4.2 ± 1.3
	D	3.9 ± 0.7	3.8 ± 0.6	4.0 ± 1.2	4.3 ± 1.2
	E	3.8 ± 0.7	3.8 ± 0.6	4.2 ± 0.9	4.1 ± 1.3

	A	88.9 ± 5.6	88.6 ± 5.8	91.4 ± 5.4	90.0 ± 8.0
	B	87.0 ± 5.8	87.1 ± 5.4	89.9 ± 6.0	87.7 ± 6.4
F	C	86.8 ± 5.7	87.6 ± 5.7	90.0 ± 6.0	87.8 ± 6.8
	D	86.6 ± 6.6	86.6 ± 6.2	89.4 ± 5.8	86.6 ± 6.3
	E	83.3 ± 7.5	84.0 ± 7.3	87.5 ± 7.5	84.9 ± 6.7

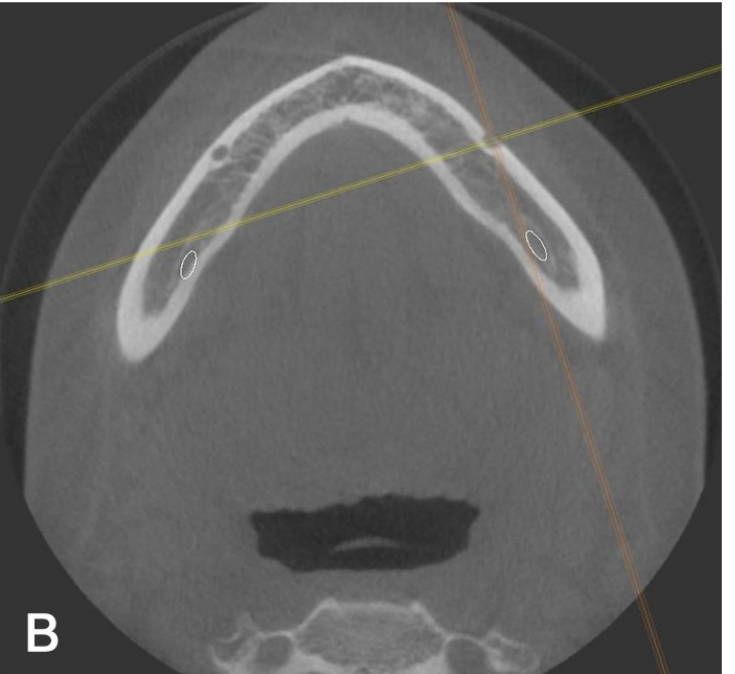
Figure 1. Rectification of the sagittal (A) and axial (B) planes of the CBCT. The measurements were taken in the resulting image of the coronal plane after the rectifications. Definition of the course of the mandibular canal (C). Use of the “curve” tool to carry out cross-sections in the course of the MC (D).

Figure 2. Measurements at the level of the second premolar (A), interradicular zone of the second premolar and first molar (B), mesial root of the first molar (C), level of the bifurcation of the first molar (D) and distal surface of the first molar (E).

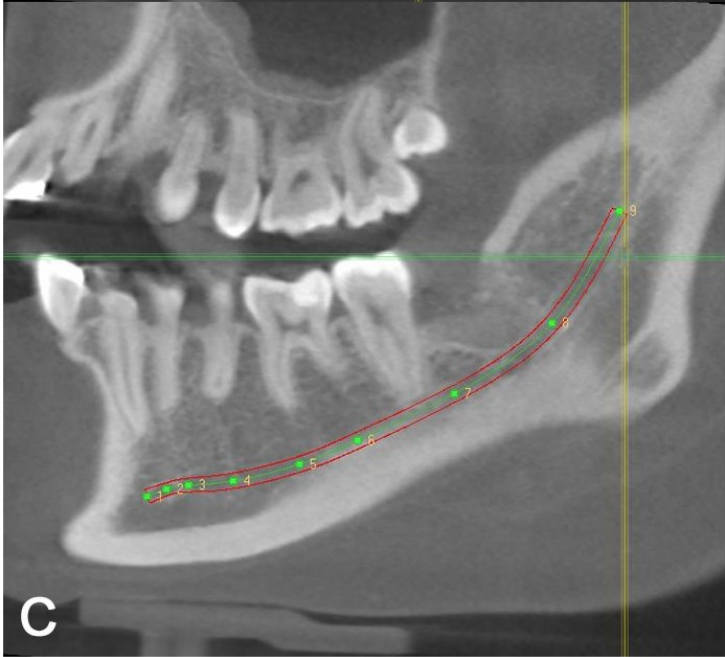
Figure 3. Morphometric measurements on each coronal sections of mandibular body (through MC course).



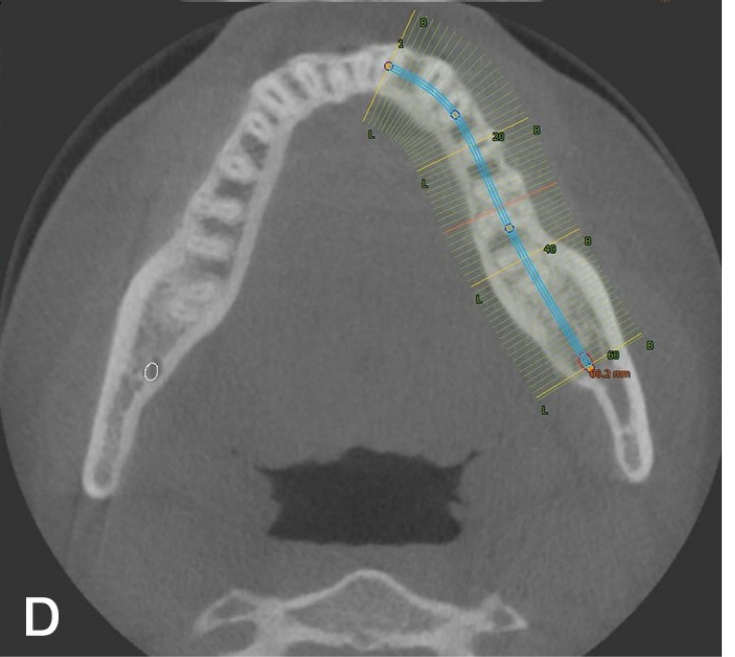
A



B



C



D

