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A MORPHOLOGICAL STUDY OF THE MANDIBULAR CANAL IN PARTIALLY EDENTULOUS PATIENTS

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Abstract. Background: The inferior alveolar nerve is the one of the largest branches of the mandibular division of the trigeminal nerve and it is vulnerable during surgical procedures of the mandible, especially during impacted third molar removal and implant placement procedures. Purpose: The present study aims to clarify the 3-dimensional positioning of the mandibular canal in partially edentulous patients by evaluating a series of Cone-Beam Computed Tomography (CBCT) data. Material and method: For this study we evaluated 136 patients (66 women, 70 male), aged 18-86, who consecutively presented to the Oral Implantology Clinic from the Central Clinical Emergency Military Hospital, Bucharest, Romania, between November 2008 - December 2009 for various dental treatments. The inclusion criteria were: presence of terminal bilateral mandibular edentations (group 1) or presence of lateral edentations on one side of the mandible associated with terminal edentations on the opposite side (group 2). Within the two groups, we analyzed the shape of the mandibular body, dividing it into two mandibular morphological types, and we determined the mandibular canal's position through the quantification of the distances to the superior border of the alveolar process, to the buccal cortical plate and to the oral plate. Results: In group 1, the average bone height above the mandibular canal was 11.98 mm, while in group 2 it was 13.07 mm for the mandibular morphological type 1 and 16.88 for the mandibular morphological type 2. Regarding the bucco-lingual position of the mandibular canal, in group 1, the mean distance from the mandibular canal to the buccal plate was 4.14 mm, while the mean distance to the lingual plate was 3.20 mm. In group 2 we found slightly higher distances. Conclusions: In order to avoid injury of the inferior alveolar neurovascular bundle during surgical implant placement procedures, both the vertical distance to the mandibular canal and the buccal-oral positioning of the mandibular canal need to be determined pre-operatively. Patients with termino-terminal mandibular edentations present a significant vertical bony resorption compared to the patients with latero-terminal edentation. This study provides essential data for developing a clinical algorithm of preoperative risk assessment in patients undergoing implant surgery within both the posterior and the anterior mandible, in order to minimize intra- or post-operative complications, such as inferior alveolar nerve damage.
Keywords: edentulous patients, surgical implant

Introduction

The inferior alveolar nerve is the one of the largest branches of the mandibular division of the trigeminal nerve and it is vulnerable during surgical procedures of the mandible, especially during impacted third molar removal and implant placement procedures. An injury to the inferior alveolar nerve may cause a temporary or permanent loss of tactile sensation of the lower lip and chin. In a study performed in 2005 by Robert et al., which consisted of sending a postal survey to 86% of the Oral and Maxillofacial surgeons in California regarding the instances of injury to the branches of the trigeminal nerve, 94.5% of the

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surveyed surgeons reported cases of injury to the inferior alveolar nerve during mandibular impacted third molar removal [Robert, 2005]. As such, the dimensions and location of the mandibular canal are factors which decisively contribute to designing a correct treatment plan.

Background

The classic approach to oral surgery addresses the mandibular canal in particular when it comes to planning mandibular posterior dental implant treatment [Naitoh, 2009]. Still, it has been reported that the inferior alveolar nerve may extend beyond the mental foramen as anterior loops [Arzouman, 1993]. Watanabe et al. confirm these observations, estimating the prevalence of the anterior loop at 55%, with a distance from the alveolar crest to the anterior loop of 17.1 ± 3.5 mm [Watanabe, 2009]. Solar et al. recommend reserving a safe distance of at least 6 mm anterior to the mental foramen for implant placement. [Solar, 1994]. These data avow the importance of evaluating the mandibular canal's position in the surgical implant procedures in the anterior mandible as well.

Purpose

The present study aims to clarify the 3-dimensional positioning of the mandibular canal in partially edentulous patients by assessing the Cone-Beam Computed Tomography (CBCT) investigations of 136 patients. This study provides essential data for developing a clinical algorithm of preoperative risk assessment in patients undergoing implant surgery within both the posterior and the anterior mandible, in order to minimize intra- or post-operative complications, such as inferior alveolar nerve damage.

Material and method

For this study we evaluated 136 patients (66 women, 70 male), aged 18-86, who consecutively presented to the Oral Implantology Clinic from the Central Clinical Emergency Military Hospital, Bucharest, Romania, between November 2008 - December 2009, for various dental treatments. All subjects agreed to the anonymous usage of their morphological data for academic study. The studied group age and sex repartition is shown in table I.

All subjects were scanned using a Cone-Beam Computed Tomography (CBCT) machine – iCat (Imaging Sciences International), and the CT data were analyzed using dedicated software – iCatVision. We used the same scanning protocol for all patients:

- sensor dimension – 20 X 25 cm
- grayscale resolution – 14 bit
- voxel dimension – 0.250 mm
- acquisition time – 13.9 seconds
- 120 KV, 5 mA
- number of acquired images – 528

All subjects were similarly positioned, with the occlusal plane in close proximity to the horizontal positioning laser beam, which was parallel to the orbital-auricular horizontal; the vertical positioning beam was placed on the patient's mid line.

All CT images were analyzed and evaluated for the presence/absence of the inclusion criteria – the presence of terminal bilateral mandibular edentations (group 1) or the presence of lateral edentations on one side of the mandible, and terminal edentations on the opposite side (group 2). After assessing all the CBCT images in our clinic, we selected the 26 patients who matched the inclusion criteria for the study. Group 1 consisted of 13 patients (26 mandible sides). Group 2 included 13 patients (26 mandible sides).

Objectives

1. Determining the height of the bone above the mandibular canal in partially edentulous patients.

2. Determining the bucco-lingual positioning of the mandibular canal, by measuring the distance from the mandibular canal to the buccal and lingual bony walls of the mandible.

We determined the mandibular canal's position through the quantification of the distances to the

Age range	18-28 y.o.	29-38 y.o.	39-48 y.o.	49-58 y.o.	59-68 y.o.	69-78 y.o.	79-88 y.o.	Total
Female	19	18	6	17	6	0	0	66
Male	12	17	11	15	12	2	1	70

Table I. Age and sex repartition of the patients who underwent screening for this study superior border of the alveolar process (distance 1), to the buccal cortical plate (distance 2) and to the oral plate (distance 3) – figure 1.

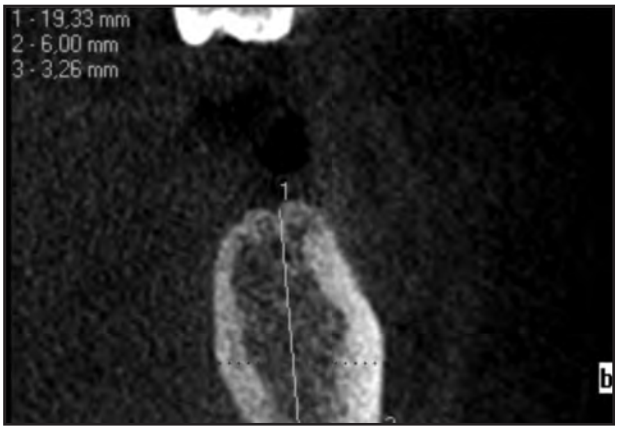

Figure 1. Determining the mandibular canal's position through the quantification of the distances to the superior border of the alveolar process (distance 1), to the buccal cortical plate (distance 2) and to the oral plate (distance 3)

We evaluated the relation between the alveolar process and the submandibular fossa, classifying the mandibular hemiarcades into 2 morphologic types, according to the mandible's aspect on axial section:

type 1 – round-oval shape (figure 2 A)

type 2 – lingual concavity (figure 2 B)

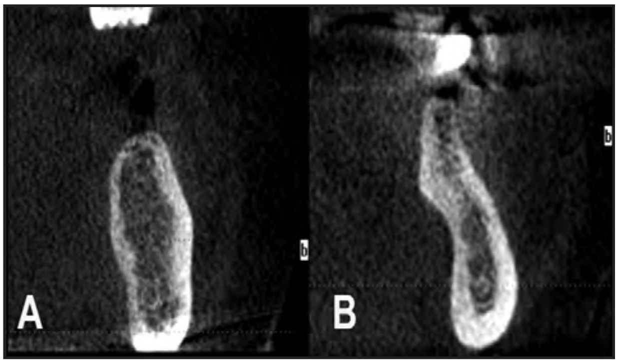

Figure 2. The morphological types examined. A – type 1 – round-oval shape; B – type 2 –lingual concavity

In order to evaluate the dynamic evolution of the mandibular canal's position in its course from the mandibular foramen to the mental foramen, we performed the 3 measurements in 3 distinct areas of the mandible:

region A – 2 mm distally to the mental foramen

region B – 10 mm distally to the mental foramen – corresponding to the first molar region

region C – 22 mm distally to the mental foramen – corresponding to the second molar region (figure 3).

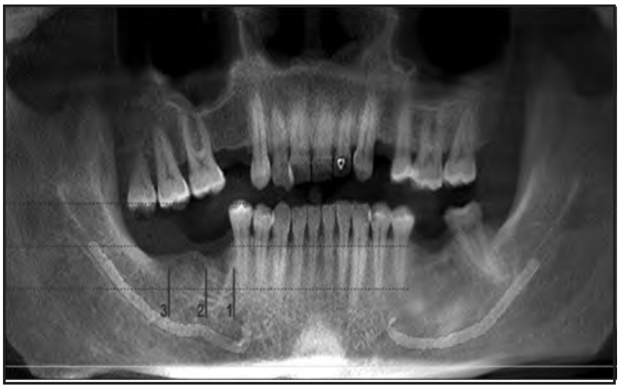

Figure 3. CT panoramic image displaying the areas where we performed the measurements (the blue vertical lines) and the course of the mandibular canal from the mandibular foramen to the mental foramen (violet)

We determined the course of the mandibular canal through the body of the mandible, quantifying its position relative to the internal and external sides of the mandible (figure 4).

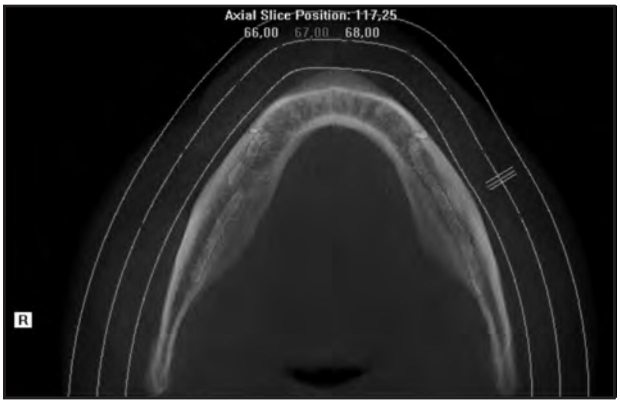

Figure 4. Transverse CT section of the mandibular body. The course of the mandibular canal is highlighted in purple

Results

Our imagistic evaluation of the mandibular canal's position generated interesting results. Within the first group (26 mandible sides) with terminal bilateral mandibular edentations), we identified 11 mandible sides belonging to the type 1 morphologic shape (round-oval on axial section) and 15 mandible sides belonging to the type 2 morphologic mandible (half-moon shape on cross-section images, with the concavity towards the lingual aspect).

Within group 2, (type II Kennedy edentations, with one or more modifications), our results indicated an equal prevalence of the two morphologic types – 13 type 1 mandible sides, 13 type 2 mandible sides.

In our study on the positioning of the mandibular canal within the body of the mandible relative to the superior edge of the alveolar process and the buccal and oral cortical plates, we evaluated the differences in localization between the two groups of patients – patients with Kennedy class I edentations and patients with Kennedy class II mandibular edentations.

The evaluation of the bony height above the mandibular canal in group 1 (the available vertical bone in the latero-terminal segment of the mandible) did not display significant differences between the two mandibular morphologic types nor did it vary between the different regions of the mandible.

In group 2, the median distance between the mandibular canal and the superior edge of the alveolar process varied according to the mandibular morphologic type within the group of morphologic type 1 mandibles, also varying with the evaluated region. Table II displays the measurement results, comparative for the 2 groups.

Our results showed a significant difference in the average bone height between the two groups. In patients with morphological type 1 mandibles the difference was 1.09 mm, while in patients with morphological type 2 mandibles, the difference between the two groups was 4.91 mm.

We also quantified the differences occurring in group 2 patients between lateral and terminal edentations. The difference between the two edentation types was not significant (1.4 mm) – table III.

Regarding the buccal-lingual positioning of the mandibular canal, we found no significant differences between the two groups. In group 1, the mean distance from the mandibular canal to the buccal plate (B) was 4.14 mm, while the mean distance to the lingual plate (L) was 3.20 mm. In group 2 we found slightly higher distances from the mandibular canal to the buccal plate than to the lingual plate – table IV.

Discussions

The positioning of the mandibular canal can be investigated both through its superior-inferior location [Watanabe, 2009; Liu, 2009] and through its buccolingual location [Gowgiel, 1992; Levine, 2007] by means of imaging techniques [Arzouman, 1993; Liu, 2009] and by anatomic dissection [Arzouman, 1993; Solar, 1994; Gowgiel, 1992].

As imaging techniques used for identifying the mandibular canal, we mention: the panoramic radiography (classic or digital) [Atieh, 2010], the periapical radiography [Lindh, 1992], tomography [Angelopoulos, 2008], hypocycloidal tomography [Lindh, 1992], computed tomography [Watanabe, 2009], 3D-MPR MRI [Nasel, 1998; Ferretti, 209] or multi-projection narrow beam radiography (MNBR), which enables stereoscopic examination of the elements of the oral cavity [Tammisalo, 1992]. Out of the mentioned imaging techniques, the ones involving a minimal radiologic exposure for the patient are the panoramic radiographs and the CBCT.

A study on the imagistic techniques available for the identification of the mandibular canal compared the direct panoramic images, the digital panoramic images and the CBCT reformatted panoramic images. Compared to the classic or digital panoramic radiographs, the CBCT reformatted panoramic images were free of magnification or superimposition of neighboring structures and therefore the iCat CBCT images outperformed the

	Region A		Region B		Region C		Average	
	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Group 1	12.67	12.93	11.81	11.75	11.46	11.22	11.98	11.97
Group 2	14.69	17.67	12.85	16.28	11.67	16.68	13.07	16.88

Table II. The average bone height above the mandibular canal (millimeters)

Group 2	Region A	Region B	Region C	Average
Lateral edentation	16.35	15.47	15.21	15.67
Terminal edentation	16.01	13.66	13.14	14.27

Table III. Average bone height above the mandibular canal in mandibles with lateral and terminal edentations (group 2), in millimeters digital panoramic images in the identification of the mandibular canal [Angelopoulos, 2008].

Available bone height above the mandibular canal

The available literature data regarding the height of the alveolar process above the mandibular canal display similar results. In 2009, Watanabe et al. published a study on the topography of the mandibular canal, evaluating its position in relation to the alveolar crest on CT images and on dry mandibles, both dentate and edentulous. The distance from the superior border of the mandibular canal to the alveolar crest was found to be 17.4 ± 3.1 mm in the mental foramen region and 15.3 ± 3.1 mm in the second molar region [Watanabe, 2009].

Levine et al. have assessed the distance from the alveolar crest to the roof of the mandibular canal in dentate patients. The mean height was found to be 17.4 ± 3.0 mm in the lower first molar region [Levine, 2007].

Our study was performed on 26 patients with terminal and latero-terminal edentations, assessing the average distance from the mandibular canal to the alveolar crest in the posterior mandible. The bone resorption following tooth extraction is important in this region due to poor bony vascularization, direct food impact and especially due to wearing removable partial dentures. For these reasons we studied the available bone dimensions in partially edentulous patients, potential candidates for dental implant placement.

Our results indicated a lower value of the bone height above the mandibular canal than that described by other field literature studies [Levine, 2007; Watanabe, 2009; Kilic, 2010]. Our study's measured mean height of alveolar bone above the mandibular canal was 11.97 mm in the class I Kennedy partially edentulous patients, and 14.97 mm in the class II Kennedy with 1 or more modifications partially edentulous patients. The 3 mm mean difference in bone height between the two groups is due to the vertical bone resorption in this area.

An interesting result was recorded in the second group (class II Kennedy with 1 or more modifications partially edentulous patients), where we observed a significant difference in the mean bone height above the mandibular canal between the two mandibular morphological types (as defined in the material and method section). We found the available bone in morphological type 2 mandibles (half-moon shape on cross-section images, with the concavity towards the lingual aspect) to be with an average of 3.81 mm higher than in the type 1 (oval shape) mandibles. We found the highest difference to be in the lower second molar region – 5.01 mm. We associate this difference to the different bone resorption patterns between the two morphological types. In human jaws, the resorption only affects the alveolar bone. While in the first morphological type the alveolar bone is positioned straight above the mandibular canal, in the second type, the alveolar process is shifted lingually, which results in a longer distance between the middle of the alveolar crest and the mandibular canal.

When assessing the available vertical bone, the clinician must take into consideration the morphological type of the mandible. In type 2 mandibles, an implant inserted in a correct position will be close to the submandibular fossa, being placed lingually to the mandibular canal (figure 5).

	Region A				Region B				Region C			
	Type 1		Type 2		Type 1		Type 2		Type 1		Type 2	
	B	L	B	L	B	L	B	L	B	L	B	L
Group 1	2.98	3.82	3.24	3.74	4.14	3.10	4.75	2.62	4.75	2.93	4.97	3.01
Group 2	3.19	3.92	3.16	3.97	4.89	3.04	4.91	2.60	5.79	3.26	5.37	2.70

Table IV. Distances from the mandibular canal to the buccal plate (B) and to the lingual plate (L) in morphological type 1 and type 2 mandibles (millimeters)

The bucco-lingual positioning of the mandibular canal

The superior-inferior location of the mandibular canal has been studied through conventional

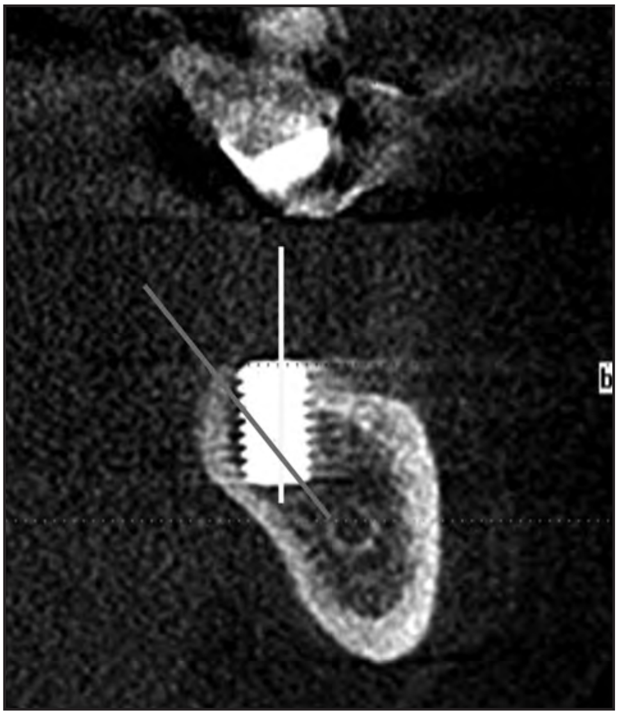

Figure 5. Implant insertion axis in type 2 mandibles: red line – incorrect axis; yellow line – correct axis

radiography, but the exact bucco-lingual position of the mandibular canal is still a matter of due research, as it requires more complex radiologic techniques (such as sections series, CBCT) in order to provide pertinent results [Kim, 2009

Imagistic techniques

An imagistic study on 50 subjects who had a radiographically identifiable mandibular canal and at least 1 mandibular first molar revealed average distances of 4.9 mm from the buccal cortical plate to the mandibular canal (varying with age and race – statistically relevant predictive factors). Elderly patients displayed smaller distances between the buccal plate and the mandibular canal [Levine, 2007].

A lingual position of the mandibular canal was significantly associated with higher risk of inferior alveolar nerve injury during the procedure of extraction of the third mandibular molar [Ghaeminia, 2009].

Evaluation through dissection

Kim et al. have determined the buccolingual location of the mandibular canal on 52 mandible sides, based on evaluating 3 coordinates: the distance from the root apex to the upper border of the mandibular canal, the distance from the lingual and buccal cortical bone to the mandibular canal, and the distance from the mandibular lower border to the lower border of the mandibular canal. Three morphologic types mandibular canal were identified: type 1 (70%), where the canal follows the lingual cortical plate; type 2 (15%), where the canal follows the middle of the ramus behind the second molar and the lingual plate passing through the second and first molars; and type 3 (15%), where the canal follows the middle or lingual one third of the mandible from the ramus to the body [Kim, 2009].

Longitudinal and cross-sectional dissections of 29 mandibles have evaluated the neurovascular bundle of the mandibular canal, identifying its close relation to the lingual cortical plate in its course up to the mental foramen. Anterior to the mental foramen, the neurovascular bundle was not a distinct entity and was located close to the labial cortical plate. In the body of the mandible, the neurovascular bundle was located about one centimeter above the mandibular inferior border. The distance from the lateral border of the neurovascular bundle to the external surface of the buccal plate was usually half a centimeter in the molar and premolar regions. The mandibular canal's structure was observed as being generated by a thin bony plate which macroscopically had more of an appearance of trabecular bone; in only a few mandibles was there a thin layer of cortical bone [Gowgiel, 1992].

One of the conclusions of Kim's study was that, in patients with insufficient bone height in the latero-terminal mandible region, long implants can be inserted providing we know the exact bucco-lingual position of the mandibular canal. In such cases, adjusting the implant's diameter and insertion axis can allow avoiding injury of the inferior alveolar neurovascular bundle [Kim, 2009]

Our study does not confirm this hypothesis. Our measurements performed on CBCT sections display a mean distance of 4.34 mm from the mandibular canal to the buccal plate for all 26 patients and 52 mandible sides investigated. Implant placing towards the buccal aspect of the mandibular border with lingual implant angulation can prejudice the transmission of the mastication forces to the alveolar bone, determining a potential marked bony resorption.

An indication for positioning the implants between the inferior alveolar neurovascular bundle and one of the bony cortical plates could be the insertion of implants in the close vicinity of the mental foramen. Therefore, the evaluation of CBCT sections can provide relevant data on the ascending course of the mandibular canal towards the mental foramen, an experienced practitioner being able to place the implant lingually to the mental foramen – figure 6.

Figure 6. Axial CBCT section – the implant was placed between the lingual cortical plate and the ascending course of the mandibular canal towards the mental foramen

The mean distance of 4.34 mm between the mandibular canal and the buccal plate, with higher values in the second lower molar region, indicates the safe distance in this area for procuring cortical bone grafts, needed for guided bone regeneration.

Conclusions

In order to avoid injury of the inferior alveolar neurovascular bundle during surgical implant placement procedures, both the vertical distance to the mandibular canal and the buccal-oral positioning of the mandibular canal need to be determined pre-operatively.

Patients with termino-terminal mandibular edentations present a significant vertical bony resorption compared to the patients with latero-terminal edentation.

The posterior region of the mandibular arcade can represent a donor area for cortical bone grafts due to the local ample distance to the mandibular canal. Still, we recommend that any surgical procedure in this region (implant placement, bone graft collection, extraction of impacted molars) be performed only after a CBCT imagistic evaluation.

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