Original Article

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Measurements of the mandibular canal by multidetector computed tomography

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Abstract

Aim: The aim of this study was to investigate the measurements of the mandibular canal in different patterns of reabsorbed alveolar ridges, using multidetector computed tomography in order to evaluate the relationship of the mandibular canal with the cortex of the mandible remains. **Methods:** Central cross-sectional slice of 30 edentulous alveolar ridges in the mandibular first molar region of otherwise healthy patients using multidetector computed tomography were analyzed. Horizontal and vertical lines were performed tangent to the corticals of the mandible and mandibular canal. Fisher's exact test, Spearman test and linear regression were used for statistical analysis. Significance level for all statistical tests was 95%. **Results:** The height of the mandible and the distance of mandibular canal to superior cortical in males were significantly higher when compared with females ($p<0.05$). When the height of the mandibular bone was correlated to the classification of edentulous jaws, significant differences were observed when comparing the three types (III, IV and V) as well as between III and IV type. **Conclusions:** The results of the present study show that the measurements for dental implant placement in the posterior region of the mandible are affected by the different patterns of bone resorptions. It was also demonstrated the importance of the computed tomography in the process of planning dental implant placements.

Keywords: bone, mandibular canal, computed tomography, mandible, measurements.

Introduction

For preoperative planning of mandibular implant placement, precise evaluation of bone size and morphology is important. The size of the selected implant depends on the height and width of available bone and the location of the mandibular canal[1]. Physiological absorption of the edentulous alveolar ridge will reduce the distance between the bone crest and the cortical of the mandibular canal. The measures obtained in panoramic and periapical radiographs do not accurately correspond to the reality. The mandibular canal could be lateralized and not necessarily in the center of the mandible body, requiring a specific preoperative radiologic examination for better management of the case[1-2].

Placement of endosseous implant in the appropriate position to allow creation of an aesthetic prosthesis depends on bone volume, height and density. Bone

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density and height can both be estimated by radiographic evaluation, using conventional tomography and periapical or panoramic radiographs[2]. Computed tomography (CT) scan by image reconstruction has been used to investigate periapical injuries and its relation to the mandibular canal[3] and due to its property to trustily reconstruct bone anatomy, represents an excellent adjunct to the evaluation of the actual position of the mandibular canal within the mandible[4].

Multidetector CT (MDCT) is considered one of the most valuable imaging modalities for preoperative procedures because it allows the acquisition of fast, reliable and reproducible images. Each anatomical structure can be viewed in the three orthogonal planes (axial, coronal, sagittal), overlapping of surrounding anatomical structures can be eliminated and a three-dimensional reconstruction of the evaluated structure can be done. In comparison with cone beam computed tomography, the greatest advantage of MDCT is the optimal contrast resolution, allowing differentiation between hard and soft tissues[5]. CT was considered a high-dose technique for a long time, but with the development of MDCT and low-dose protocols tailored for diagnosis, doses below 0.15 mSv are achievable[6].

It is important to measure bone volume to avoid injuries in the alveolar inferior nerve resulting from implant surgery. The trajectory of the mandibular canal at the site of implant placement may alter sensation of the lower lip due to inferior alveolar nerve injury and it is one of the most serious complications of mandibular implant surgery[7-8].

The aim of this study was to investigate the measurements of the mandibular canal in different patterns of resorbed alveolar ridges, using MDCT in order to evaluate the relationship of the mandibular canal with the cortex of the mandible remains.

Material and methods

Data were collected from the data bank of a radiology center. All patients enrolled at this evaluation were conducting MDCT examination as a procedure of their treatment planning for rehabilitation with titanium implants. Therefore, no radiation was imposed to the patient to obtain the study data. All patients gave written informed consent for the examination and use of data for the research protocols.

A retrospective study was conducted from more central cross-sectional slice of 30 edentulous alveolar ridges in the mandibular first molar region of otherwise healthy patients using MDCT. The mandibles were evaluated using noncontrasted exams performed in high resolution helical CT device (CT Synergy Helicoidal; General Eletric Company, Milwaukee, WI), The examination was performed with the patient in supine position (slice thickness 0.625 mm and increment of 0.625 mm, field of view of 15.8cm, bone filter, 120 kV and 200 mA). Each coronal slice was analyzed on the CT workstation monitor (Advantage Workstation 3.1 Ultra 10sm GE Medical Systems, USA), under dim lighting conditions, by one oral and maxillofacial radiologist with more than 10 years experience in CT.

All MDCT images of the bone sections were categorized according the criteria of Cawood and Howell (1988)[9] edentulous jaws classification: I - dentate, II - immediately post extraction, III - well-rounded ridge form, adequate in height and width, IV - knife-edge ridge form, adequate in height and inadequate in width, V - flat ridge form, inadequate in height and width and VI - depressed ridge form, with some basilar loss evident.

Horizontal and vertical lines were performed tangent to the cortical plates of the mandible and mandibular canal. The outcome variables were the linear distances (cm) between mandible width and height, mandibular canal width and height, distance of the mandibular canal to buccal, lingual, superior and inferior cortical plates of the mandible and the distance of the mandibular canal to the higher point of the alveolar ridge (Figure 1). Images were re-evaluated after a four-month interval and intraobserver agreement was calculated, demonstrating high reproducibility (Kappa index = 0.95).

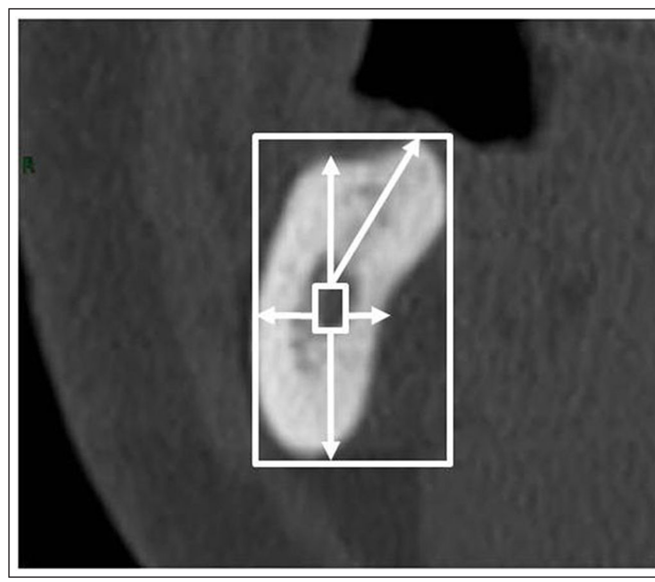

Fig. 1. Central coronal MDCT slice showing the measurements of the mandibular canal and mandibular bone.

Data were analyzed using the SAS 9.1 software (SAS Institute, Cary, NC, USA). Descriptive parameters were given as mean and standard deviation (SD). Significant differences between comparable measurements were tested for gender and classes of the edentulous jaws with Fisher's exact test. Spearman test was used to evaluate the correlation between variables with biological plausibility. Linear regression was used to determinate the best fit between the variables. Significance level for all statistical tests was set at 95%.

Results

Table 1 shows the classification of the edentulous jaws according to Cawood and Howell (1988)[9]. The most prevalent classes were III, IV and V. The mean and standard deviation (SD) of the measurements are summarized in the Table 2.

Table 1. Distribution of the bone sections studied according Cawood and Howell (1988)[9] edentulous jaws classification.

Class	Number of cases (%)
I	0 (0%)
II	0 (0%)
III	12 (40%)
IV	7 (23.3%)
V	11 (36.4%)
VI	0 (0%)

Table 2. Mean and SD of the measurements in MDCT images.

Measurements	Mean (SD)
Width of the mandible (WM)	1.680 (±0.05)
Height of the mandible (HM)	2.133 (±0.06)
Width of the mandibular canal (WMC)	0.250 (±0.01)
Height of the mandibular canal (HMC)	0.250 (±0.01)
Distance of the mandibular canal to buccal cortical (MC-BC)	0.610 (±0.03)
Distance of the mandibular canal to lingual cortical (MC-LC)	0.820 (±0.04)
Distance of the mandibular canal to superior cortical (MC-SC)	1.253 (±0.05)
Distance of the mandibular canal to inferior cortical (MC-IC)	0.623 (±0.03)
Distance of the mandibular canal to the higher point of the alveolar ridge (MC-HPAR)	1.493 (±0.06)

(*) SD, Standard deviation.

The differences between males and females regarding mandible width and height, mandibular canal width and height, distance of the mandibular canal to buccal, lingual, superior and inferior cortical plates of the mandible and the distance of the mandibular canal to the higher point of the alveolar ridge are presented in Figure 2. The height of the mandible in males was significantly higher when compared to females ($p<0.05$). However, the mandibular canal width in females was significantly higher when compared to males ($p<0.05$). The width of the mandible and the distance of the mandibular canal to the higher point of the alveolar ridge were higher in females, but not statistically significant.

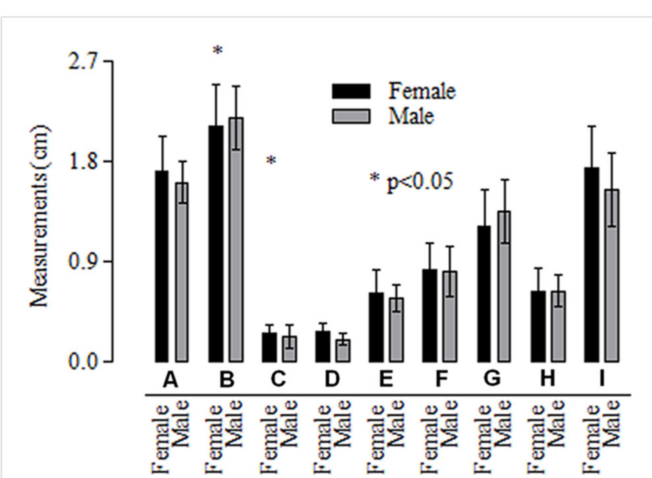

Fig. 2. Stratification of the measurements used in this study according to gender: mandible width (A) and height (B), mandibular canal width (C) and height (D), distance of the mandibular canal to buccal (E), lingual (F), superior (G) and inferior (H) corticals of the mandible and the distance of the mandibular canal to the higher point of the alveolar ridge (I).

When the height of the mandibular bone was correlated to the classification of edentulous jaws, there were significant differences when comparing the three types (III, IV and V) as well as between III and IV types. There was no significant difference between types IV and V's edges height. Type III mandibular bone height had a higher value (mean = 2.383 cm), followed in a descending order by type V (mean = 2.0 cm) and type IV (mean = 1.914 cm) (Figure 3).

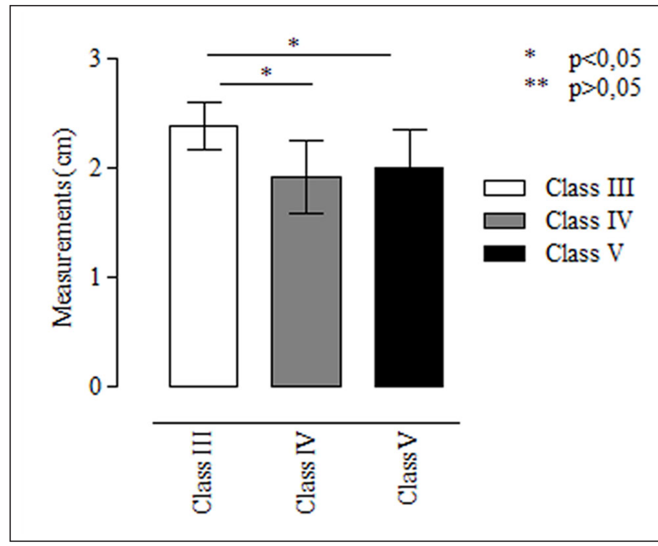

Fig. 3. Association between the classification of edentulous jaws - III, IV and V - and the measures of mandibular bone height.

Comparing the three types (III, IV and V) with all measurements performed in this study, statistically significant differences were found in the mandibular bone height and the distance of the mandibular canal to the superior cortical (alveolar ridge). The other measurements and types of edentulous jaws showed no statistical differences (Figure 4).

It was found that the greater the horizontal diameter of the mandibular bone, the greater the vestibular ($r^2=0.646$;

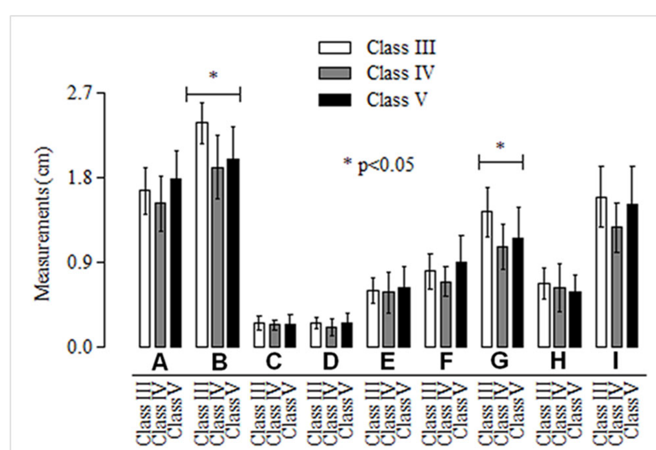

Fig. 4. Association between the types of edentulous jaws (III, IV, V) and the measurements of the mandible width (A) and height (B), mandibular canal width (C) and height (D), distance of the mandibular canal to buccal (E), lingual (F), superior (G) and inferior (H) corticals of the mandible and the distance of the mandibular canal to the higher point of the alveolar ridge (I).

$p<0.05$) and lingual ($r^2=0.675$; $p<0.05$) width. Linear regression analysis also demonstrated that there was a linear interaction between the horizontal diameter and vestibular width ($r^2=0.417$) and lingual ridge width ($r^2=0.455$). Although positive correlation was observed between the mandibular bone horizontal diameter and the distance to the highest point of the ridge ($r^2=0.188$), the interaction between these two variables was weaker (Figure 5).

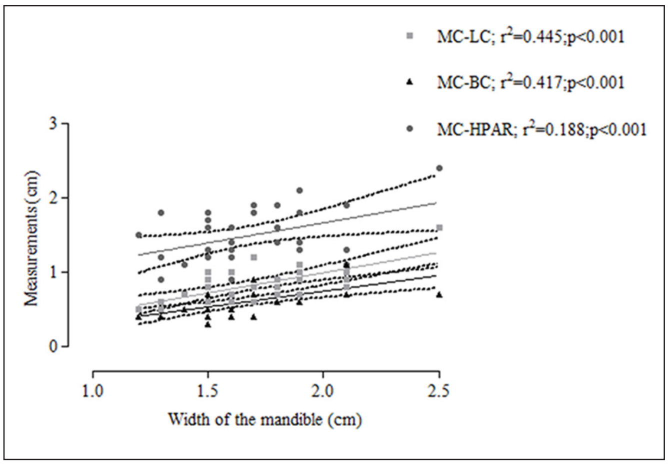

Fig. 5. Association between the width of the mandibular bone and the distance from the mandibular canal to lingual cortical (MB-LC), the distance from the mandibular canal to buccal corticals (MC-BC) and the distance from the mandibular canal to the higher point of the alveolar ridge (MC-HPAR).

A positive correlation could be noticed between the increased vertical distance and the increment of the superior ($r^2=0.821$; $p<0.05$) and inferior heights ($r^2=0.423$; $p<0.05$), as well as the distance of highest point of the alveolar ridge ($r^2=0.634$; $p<0.05$). Linear regression between the vertical diameter and the distance to the highest point of the alveolar ridge ($r^2=0.402$) and the superior height ($r^2=0.673$) showed a strong positive association (Figure 6).

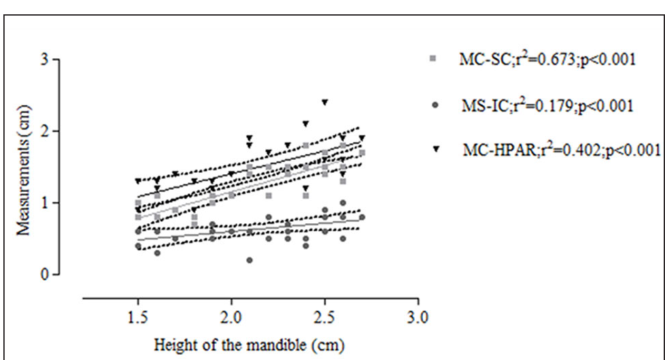

Fig. 6. Association between the height of the mandible and the measurements of the distance from the mandibular canal to superior cortical (MC-SC), the distance from the mandibular canal to inferior cortical (MC-IC), and the distance from the mandibular canal to the higher point of the alveolar ridge (MC-HPAR).

The distance of the highest point on the alveolar ridge is directly correlated with the superior height ($r^2=0.897$; $p<0.05$) and the lingual weight ($r^2=0.537$; $p<0.05$). A strong linear interaction was observed between the distance to the highest point of the alveolar ridge and the superior height ($r^2= 0.804$), though, a weak positive association between the first and the last variable ($r^2=0.288$) (Figure 7).

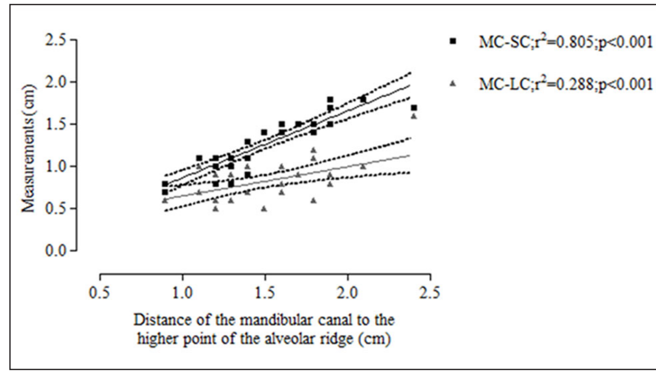

Fig. 7. Association between the distance from the highest point on the alveolar ridge and the distance from the mandibular canal to superior cortical (MC-SC) and the distance from the mandibular canal to lingual cortical (MC-LC).

Discussion

An adequate dental treatment is based on comprehensive planning, which includes the use of imaging studies to assist on diagnosis. Imaging examinations have an important role to a successful treatment. The preoperative evaluation for implant therapy should consider the height and width of the bone, degree of corticalization, density of mineralization and amount of cancellous bone. Panoramic radiography is a the supplementary examination initially requested to implant surgery, however, because the two-dimensional image, this does not provide specific diagnostic information about the relationship of anatomical structures, thus, are necessarily a more accurate exam to a provide a higher operative safety[2].

The mandibular canal is an anatomical structure used as reference to surgical approaches in the jaws. Extractions of third molars, implant placement, orthognathic surgery, reduction and fixation of fractures in various areas of the mandible are examples of procedures performed in close proximity to this canal, what increases the risk of injury to the inferior alveolar nerve[10].

The use of CT for dental implant planning has been strongly advocated over the past decades[2,11] due to its superiority to conventional radiographs[12] and even when compared with conventional tomography. This can be attributed to three-dimensional visualization of the bone structures in CT scans[13]. Lindh (1995)[14] compared the accuracy of measurements of two panoramic devices and three tomographic techniques. In all image modalities the distance between the superior border of the mandibular canal and the alveolar crest, the height of the mandibular canal and the distance between the mandibular base and the inferior border of the mandibular canal were measured. The values from the tomographic images deviated less from the panoramic images measurements. The observers underestimated the distances related to the mandibular canal, except for hypocycloidal tomography. The mean height of the mandibular canal was

3.0 mm, with a standard deviation of 0.7 mm. Height values of the mandibular canal were similar to those found in the present study.

It has been observed in dentate individuals, using CT, that the mean distance from the mandibular canal to the alveolar crest was 17.4 mm[15]. In similar and recent studies, Watanabe et al. (2010)[16] and de Oliveira-Junior et al. (2010)[17] measured the height of the mandible and distance of the mandibular canal to the superior cortical of the mandible in dentate and edentulous MDCT cross-sectional scans in a inferior first molar region. Comparing these studies with our findings, the distances were higher than in the present study, which is justified by the presence of teeth, not occurring the physiological bone resorption.

Paes et al. (2007)[18] evaluated the accuracy of relative measurements from the roof of the mandibular canal to the alveolar crest in MDCT and single-slice CT. MDCT has a more accurate method and a higher reproducibility. It helps in the analysis of important anatomical landmarks for the planning of dental implants, namely the mandibular canal pathway and alveolar crest height.

According to the degree of bone resorption, significant changes may occur in relation to facial muscles and facial height, but the distance between the mandibular canal to mandibular cortex remains stable[19]. In the present research, performed in 30 mandibles, the distance of the mandibular canal to the inferior bone cortical diminished when the level of ridge resorption became more severe. In type III, the mean was 0.68 cm, followed by 0.62 cm in type IV and type V at 0.58 cm.

When anatomic structures and ridge resorption limit the placement of a standard implant, the clinician can use short implants or bone graft augmentation. In edentulous alveolar bone ridges less than 0.5 mm wide bone graft augmentation is required prior to implant placement. Crestal ridge bone augmentation is an alternative bone expansion technique that can be used to augment the atrophic maxilla and mandible prior to implant placement[20]. Short implants can also be placed to avoid the use of grafts, but it must always be taken into account when using these implants that a minimum bone height of 7-8 mm is needed anyway and that bone quality is a critical factor[21].

Inferior alveolar nerve injury can result from traumatic local anesthetic injections, during dental implant site preparation or placement, or poor surgical technique. During implant surgery, damage to the inferior alveolar nerve can occur when the twist drill or implant encroaches, transects, or lacerates the nerve. The insertion of implants close to the canal can compromise the success of the surgery. The contact with the neurovascular bundle can actually cause the non-integration of the implant or lead to sensory dysfunction. It is essential to obtain, especially in CT images, as much information as possible from the anatomic appearances and variations for a safer surgical procedure[22].

MDCT provides an excellent visualization and delineation of mandibular anatomy, which, in turn, allows establishing the buccolingual position and height of neurovascular bundle, as well as, evaluating the amount of bone available for correct placement of implant fixtures.

The results of the present study showed that the measurements for dental implant placement in the posterior region of the mandible are affected by the different patterns of bone resorption. Therefore, the surgeon and radiologist should be aware of the correct bone measurements in the preoperative planning for dental implant placement, being CT extremely important in this process to avoid intra- or postoperative complaints.

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