EVALUATION OF VESTIBULAR BONE THICKNESS OF THE MANDIBLE IN RELATION TO THE MANDIBULAR CANAL: RETROSPECTIVE CBCT STUDY

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ABSTRACT

Introduction: In implantology, in the area of the mandible, during the implantation and the collection of autogenous bone structures of the lateral part of the mandible, it is necessary to pay attention to the position of the mandibular canal, nervus alveolaris inferior and foramen mentale. The best radiographic technique of imaging during various analyses is cone beam computed tomography (CBCT) providing the exact identification of anatomic structures and having the capability to provide accurate measurement and enlargement, high resolution without artefacts. The aim of the study was to evaluate the vestibular bone thickness of the mandible in relation to the mandibular canal and to determine is there dental status-related difference.

Methods: Out of 700 examined CBCT images, 217 CBCT images that satisfied inclusion criteria of the study were analyzed. The measurement was conducted by Sidexis program on the cross section of the CBCT image. The measurement of vestibular bone thickness was performed by measuring the distance from the lateral wall of the mandibular canal to the buccal surface of the mandibular compact bone covering the region of the second premolar, the first and the second molar.

Results: T-test revealed a statistically significant difference in vestibular bone thickness on the left side ($p = 0.028$) between dentate and partially edentulous patients in the area of distal root region of the second molar, where dentate patients (5.825) had, on average, larger vestibular bone thickness compared to partially edentulous patients (5.326).

Keywords: mandible, vestibular bone thickness, CBCT

Introduction

Surgical interventions in the area of the mandible demand certain precaution measures considering the anatomic structure of the mandible, as well as its vascularization and innervation. In implantology, in the area of the mandible, during the implantation and the collection of autogenous bone structures of the lateral part of the mandible, it is necessary to pay attention to the position of the mandibular canal, nervus alveolaris inferior and foramen mentale, as well as arteries and veins going through the mandibular canal so that, during the intervention, iatrogenic injury of these structures would not occur. (1-7) During surgical placement of implants, if the size of the bone is not sufficient for the implantation, numerous surgical interventions are conducted in order to compensate the bone for the placement of implant. One of the ways of bone compensation is compensation with the help of autogenous bone graft which can be harvested intraorally and extraorally. (8) Other ways of compensation of the volume of bone are guided bone regeneration as well as osteogenesis of alveolar distraction. (9)

The extraoral autogenous bone graft harvesting implies getting bones the most frequently from the area of iliac crest and it entails numerous disadvantages such as: higher costs, greater time consumption, hospitalization of patients, general anaesthesia, walking difficulties, pain, scars in the bone removal area. (8,10) The extraoral bone harvesting may involve taking of bone graft from other parts of the body such as the calvary, tibia or ribs. The intraoral bone harvesting offers more advantages in relation to the extraoral bone harvesting. The advantages are: better surgical approach, shorter time of surgery, general anesthesia not needed, elimination of the need of hospitalization, no scars, more comfortable for a patient. Also, bone harvesting from the area of maxillofacial region provides better biological benefits for augmentation. (8) This implies bone harvesting, most frequently from the area of the ramus of the mandible, but also the corpus, the mandibular symphysis, the residual ridge of the mandible and the process of the coronoideus. (8,11-14) Disadvantages of intraoral bone grafts are mainly temporary, among which the following are described: short-term disorder of the sensibility of lips, mucosa, skin or teeth, limited opening of the mouth, pain, changes in facial contours. Complications differ depending on the mandible area from which the bone graft is harvested. (15-20)

Considering the benefits of intraoral bone grafts, this manner of bone formation is increasingly used. However, by inadequate recognition of vital structures such as the lower alveolar nerve and mental opening, an injury of these structures can occur entailing certain consequences such as neurosensory changes of chin, lower lip, pain, stiffness, changes in senses; during the harvesting of bone grafts from the mandible or with osteotomy, as the alveolar nerve is closer to the buccal cortex of the mandible, the quality of the bone is smaller, the neurosensory disorders are more expressed, and women are especially more susceptible to the occurrence of these disorders. (7, 21-23) In order not to cause an injury of nerves, arteries and veins by intraoral bone harvesting, implantations and numerous other surgical interventions in the mandible area, a doctor of dental medicine must be familiar with the anatomic characteristics of the mandible as well as with pathological conditions and traumatic sequelae creating unfavorable conditions for the implantation that can lead to compromised physiological relations of the anatomic structures of the mandible. Prior to any surgical technique planned to be performed in the area of the mandible, with the aim of identification of the exact location of the anatomic structures, it is necessary to make appropriate radiographic imaging. (24, 25)

The best radiographic technique of imaging in implantology during various analyses is cone beam computed tomography (CBCT) providing the exact identification of anatomic structures, having the capability to provide accurate measurement and enlargement, high resolution without artefacts. The radiation dose is lower compared to the usual CT scans, while the conventional radiography interprets a two-dimensional representation of the mandibular canal, with shortcomings of the third dimension by limited enlargement, reproducibility of details and distortion. (26-29) The accuracy of CBCT imaging has been confirmed by the use of different CBCT scanners. (30-34)

The aim of the study was to evaluate the vestibular bone thickness of the mandible in relation to the mandibular canal and to determine whether there is dental status-related difference.

Materials and methods

It was accessed the database of CBCT images taken at the School of Dental Medicine at the University of Sarajevo in the period from 2017 to April 2020, taken for various dental purposes. Out of 700 examined CBCT images, 217 CBCT images from 110 females and 107 males were analyzed satisfying inclusion criteria of the study.

Inclusion criteria included the following:

1. acceptable image quality

2. representation of the entire mandible

3. clearly detectable and represented nervus alveolaris inferior

The exclusion included the following:

1. irregular volume of the bone and presence of pathological changes in the measurement region such as cysts, tumors, periapical lesions

2. presence of the mandible fracture

3. disturbed course and continuity of nervus alveolaris inferior

4. Impacted and semi-impacted teeth in the measurement region

5. Patients younger than 14 years

Patients were divided in two groups: fully dentate patients and partially edentulous patients.

CBCT images were taken by using an ORTHOPHOS SLX imaging unit. The nominal power output of this device is 2kW at 90 kV / 16mA, nominal frequency 50Hz / 60Hz. The tube voltage is 60-90kV (for 90kV max.12mA) and the power in tube is 3-16mA (for 16mA max.69kV). The frequency of generation of creating a high voltage is 40-120kHz. The time of exposure to image is a maximum 14.9 s. Entire filtration of X-ray tube is > 2.5 mm Al / 90 IEC 60522 0.3 mm Cu. The size of the focal point towards IEC 60336, measured in the central X-ray, is 0.5 mm.

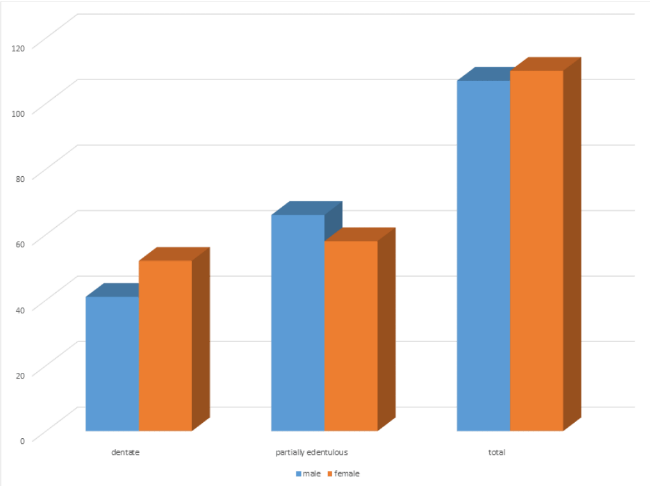
The measurement was conducted by Sidexis program on the cross section of the CBCT image. The measurement procedure involved previous mapping of the nervus alveolaris inferior, and subsequently in the region of the second premolar, of the first and second molar with the help of ruler and protractors on the cross-sectional intersection, following the tooth axis and / or roots axis, the vestibular bone thickness was measured (spongiosis + cortical plate), by measuring the distance from the lateral wall of the mandibular canal to the buccal surface of the mandibular compact bone. The measuring points along the alveolar nerve of interest were: the center of the second premolar (35 and 45) as well as the centers of the first and second molars, but also the areas of the mesial and distal roots of the first (36M, 46M, 36D and 46 D) and second molars on both sides of the mandible (37D and 47D). With partially edentulous patients in areas where teeth were missing, measurements were conducted only at measuring points that marked the “center of the tooth” and they were determined by reconstruction methods used in implantology. The smallest vestibular thickness of the mandible was recorded as the shortest possible value between the two mentioned distances, that is, the measurement was carried out under the angle of 90 degrees.

The statistic software IBM SPSS Statistics 23 was used to conduct the statistic tests, as well as for the calculation of descriptive statistics. Excel 2013 was used to create graphs in descriptive statistics. Considering different variables, comparisons and size of samples of certain groups and sub-groups, test used within the study included: t-test for independent variables, post-hoc (Bonferroni).

Results

A total of 217 examinees participated in research, out of which 93 examinees were fully dentate and 124 examinees were partially edentulous. The average age of dentate patients was 26.31 years (minimum 14 and maximum 67 years), partially edentulous 44.36 years (minimum 19 and maximum 72 years).

Graph 1 shows the number of patients divided according to sex and dental status.



Graph 1.
Number of patients divided according to sex and dental status

Tables 1 shows the mean values of vestibular bone thickness in dentate and partially edentulous patients.

As shown in Table 2., the vestibular bone thickness did not differ between dentate and partially edentulous patients for following measuring points: second premolar (35 and 45), mesial root of the first molar (36M and 46M), the distal root of the first molar (36D and 46 D), and the mesial root of the second molar (47M and 37M).

Patients		Vestibular thickness on the right side		Vestibular thickness on the left side	
	Measuring points	Mean	Std. dev	Mean	Std. dev
Dentate	tooth center 45	4.2653	1.13226	4.3161	1.03599
	mesial root 46	5.6805	1.14493	5.7149	1.12388
	tooth center 46	6.0142	1.12357	5.9941	1.23003
	distal root 46	6.2126	1.20777	6.1988	1.26778
	mesial root 47	6.0444	1.45977	6.1900	1.34601
	tooth center 47	6.1232	1.50903	6.1612	1.40054
	distal root 47	5.6895	1.47323	5.8251	1.42357
Partially edentulous	tooth center 45	4.5950	1.48346	4.1355	1.27427
	mesial root 46	5.7928	1.26833	5.6535	1.48611
	tooth center 46	6.2094	1.25022	5.8090	1.34210
	distal root 46	6.1056	1.36646	5.9695	1.34263
	mesial root 47	5.4611	1.49810	5.7525	1.57368
	tooth center 47	5.5911	1.29879	5.8610	1.58062
	distal root 47	4.7989	1.35929	5.4540	1.49830

Table 1.
Mean values of vestibular thickness of the mandible on the both side according to dental status

Measuring points	t - statistics	p - value
right - tooth center 45	- 1.145	0.254
left - tooth center 35	- 0.709	0.479
right - mesial root 46M	- 0.307	0.759
left - mesial root 36M	0.062	0.951
right - distal root 46D	0.509	0.612
left - distal root 36D	0.900	0.370
right - mesial root 47M	0.557	0.578
left - mesial root 37M	1.750	0.082
right - distal root 47D	1.456	0.147
left - distal root 37D	2.223	0.028*

Table 2.
Results of t – test (differences between vestibular bone thickness between dentate and partially edentulous patients);
* Statistical significance at the level of 5 %

T-test (Table 2) revealed a statistically significant difference in vestibular bone thickness on the left side ($p = 0.028$) between dentate and partially edentulous patients in the area of distal root region of the left second molar, where dentate patients (5.825) had larger vestibular bone thickness compared to partially edentulous patients (5.326).

Based on results of the post hoc test shown in Table 3, a statistically significant difference ($p<0.0001$) exists in the values of vestibular bone thickness, in dentate patients, except for groups of teeth: 46M-47C, 46C-46D, 46D-47D, 36M-36C, 36M-37M, 36M-37C and 36C-36D.

In partially edentulous patients, the vestibular bone thickness differs ($p<0.0001$) between the area of second premolar and mesial root of the first molar and between the area second premolar and center of the first molar, on both sides of mandible. Also, there is statistically significant difference for vestibular bone thickness between measuring points: second premolar and distal root of the first molar on the left side.

Groups of teeth - Dentate	p - value
45 46M	<0.0001
45-46C	<0.0001
45-46D	<0.0001
45 47M	<0.0001
45-47C	<0.0001
45-47D	<0.0001
46M-46C	<0.0001
46M-46D	<0.0001
46M-47C	0.023
46C-46D	0.014
46D-47D	0.001
47M-47D	<0.0001
47C-47D	<0.0001
35-36M	<0.0001
35-36C	<0.0001
35-36D	<0.0001
35-37M	<0.0001
35-37C	<0.0001
35-37D	<0.0001
36M-36C	0.006
36M-36D	<0.0001
36M-37M	0.005
36M-37C	0.021
36C-36D	0.004
37M-37D	<0.0001
37C-37D	<0.0001

Table 3.
Results of post hoc tests: differences between vestibular bone thickness between different measuring points for dentate patients

Groups of teeth - Partially edentulous	p - value
45-46M	<0.001
45-46C	<0.0001
45-46D	0.002
47M-47D	0.007
47C-47D	0.004
35-36M	<0.0001
35-36C	<0.0001
35-36D	<0.0001
35-37M	.009
35-37C	0.006
35-37D	0.071
37C-37D	0.002

Table 4.
Results of post hoc tests: differences between vestibular bone thickness between different measuring points for partially edentulous patients

Discussion

The position of the mandibular canal within the mandible is highly variable and a clear consensus regarding its position does not exist. Different authors have observed its course considering different reference points, different age, sex, dental status (6, 35, 36)

This research, by measuring the value of vestibular bone thickness as distance from the lateral wall of the mandibular canal to the buccal mandibular compact bone, indicates to us the course of the mandibular canal. The higher the values of vestibular bone thickness at a certain measuring point are, the more distant is the mandibular canal from the outer (vestibular) surface of the mandible. The value of vestibular bone thickness is the highest in the area of the first molar, and the thinnest in the area of the second premolar. This finding is in agreement to some extent with those of Sghaireen *et al.* who also found the lowest values of vestibular bone thickness in the area of the second premolar, but the highest ones in the area of the second molar. These authors measured the distance from the buccal and lingual surface of the mandibular compact bone to the nervus alveolaris inferior, and the distance from the top of the alveolar ridge to the nerve. They found that the mean values of vestibular bone thickness in the area of the second premolar in partially edentulous totalled 2.08 mm on the right side and 1.70 mm on the left side, and in dentate patients 2.14 mm on the right and 1.74 mm on the left side. (37)

The highest thickness of the vestibular bone in dentate patients considering the right side is in the area of the distal root of the first molar (6.21 mm), being the same on the left side (6.19 mm). In partially edentulous patients, the highest value of vestibular bone thickness is also in the area of the second molar, specifically on the right side in the area of the tooth center (6.20 mm) and on the left side in the area of the distal root (5.96 mm). The values of vestibular bone thickness are increasing going distally then falling down from the distal root of the second molar. Regardless of dentate or partially edentulous patients, the alveolar nerve is at the distal root of the first molar slightly more distant from the outer surface of the bone of the mandible in relation to other areas. The research conducted by Koivisto *et al* shows that vestibular bone thickness is also the highest in the area of the second molar. The highest mean vestibular bone thickness totalled 5.4 mm in the area of the mesial root of the second molar, being the smallest at the position of the second premolar with a value of 2.6 mm. (37) The maximum mean value in this study is higher compared to the results of the maximum mean value in the research by Koivisto *et al*. These differences of mean values at the same positions of the measuring points among different researchers may be a consequence of racial differences, age and other differences as well. (38) Al-Siweedi concluded that ethnic affiliation impacts all measurements in his study, inclicing the buccolingual position of the mandibular canal, and Levine *et al.* drew the same conclusion (39,6)

Safaee *et al* measured the distance of the mandibular canal from the outer cortex of the lingual and vestibular sides of the mandible. They have concluded that the canal approaches the lingual side by going posteriorly and that the highest vestibular bone thickness is in the area of the second molar. (40)

In their research, Valdec *et al* found that the mean value of bone thickness between the mandibular canal and the buccal surface of the mandibular cortical plate was approximately 4 mm directly posterior to the mental foramen. That distance increased up to the value of about 6 mm in the first 30 mm distally from the mental foramen and then decreased to about 3 mm at the most posterior measurement at the level of the mandibular foramen. According to those results, it is clearly seen that the mandibular canal is moving away from the buccal cortex by going from the mental foramen and then probably at the position of the first or second molar (as it is the case in this study) it reaches maximum values of distance from the buccal mandibular cortex and then it approaches the buccal cortex in lateral segments. (41)

Dentate patients have the highest mean values of vestibular bone thickness, and slightly lower values were found in partially edentulous patients. However, we have detected a statistically significant difference between dentate and partially edentulous patients only for vestibular bone thickness measured in the distal root of the second right and left molar. Kilic *et al* investigated different positions of the mandibular canal in relation to different reference points as well as the position in the buccolingual direction in different groups of patients according to dental status. They obtained results showing that the canal for dentate, partially edentulous and edentulous patients, varied considering different measuring points, and in some segments, there was a difference between the position of the canal in different patients. In some segments that difference did not exist, and no precise conclusion has been made regarding the exact position of the canal in the buccolingual direction and the thickness of the buccal wall of the mandible at the place of passing of the mandibular canal in three different groups of patients. (42)

Conclusion

"The safe zone" of surgical intervention does not exist because each patient is an individual for himself, but the area of the distal root of the first molar is a point of orientation in clinical conditions, whereby chances of iatrogenic injury of the nervus alveolaris inferior are smaller. Whenever possible before any mandible surgery, it would be desirable to do perform CBCT scan.

References

1. Ozturk A, Potluri A, Vieira AR. Position and course of the mandibular canal in skulls. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;113:453-8.
2. Angelopoulos C, Thomas SL, Hechler S, Parissis N, Hlavacek M. Comparison between digital panoramic radiography and cone-beam computed tomography for the identification of the mandibular canal as part of presurgical dental implant assessment. J Oral Maxillofac Surg. 2008;66:2130-5.
3. Pyun JH, Lim YJ, Kim MJ, Ahn SJ, Kim J. Position of the mental foramen on panoramic radiographs and its relation to the horizontal course of the mandibular canal: A computed tomographic analysis. Clin Oral Implants Res. 2013;24:890-5.
4. SimontonJD,AzevedoB,SchindlerWG,Hargreaves KM. Age-andgender-related differences in the position of the inferior alveolar nerve by using cone beam computed tomography. J Endod. 2009;35:944-9.
5. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006;72:75-80.
6. Levine MH, Goddard AL, Dodson TB. Inferior alveolar nerve canal position: A clinical and radiographic study. J Oral Maxillofac Surg. 2007;65:470-4.
7. Juodzbalys G, Wang HL, Sabalys G. Anatomy of mandibular vital structures: part I—mandibular canal and inferior alveolar neurovascular bundle in relation with dental implantology. J Oral Maxillofac Res. 2010;1(1):2.
8. Karl E. Mish: Cotemporary Implant Dentistry, Third edition, Missouri: Mosby Elsevier, 2008.
9. Aloy-Prósper A, Peñarrocha-Oltra D, Peñarrocha-Diago A.M, Peñarrocha-Diago M. The outcome of intraoral onlay block bone grafts on alveolar ridge augmentations: A systematic review. Med Oral Patol Oral Cir Bucal. 2015;20(2):e251-e258.
10. Sethi A, Kaus T, Cawood JI, Plaha H, Boscoe M, Sochor P. Onlay bone grafts from iliac crest: a retrospective analysis. Int J Oral Maxillofac Surg. 2020:49(2):264-271.
11. Mittal Y, Jindal G, Garg S. Bone manipulation procedures in dental implants. Indian J Dent. 2016; 7(2): 86-94.
12. Sittitavornwong S, Gutta R. Bone graft harvesting from regional sites. Oral Maxillofac Surg Clin North Am. 2010;22:317–330.
13. Khoury F. Bone augmentation in oral implantology. London: Quintessence; 2007.
14. Kim YK, Hwang JW, Lee HJ, Yun PY. Use of the coronoid process as a donor site for sinus augmentation: a case report. Int J Oral Maxillofac Implants. 2009;24:1149–52.
15. Cordaro L, Torsello F, Tindara Miuccio M, Mirisola di Torresanto V, Eliopoulos D. Mandibular bone harvesting for alveolar reconstruction and implant placement: Subjective and objective cross-sectional evaluation of donor and recipient site up to 4 years. Clin Oral Implants Res. 2011;22:1320–6.
16. Rabelo GD, de Paula PM, Rocha FS, Jordão Silva C, Zanetta-Barbosa D. Retrospective study of bone grafting procedures before implant placement. Implant Dent. 2010;19:342–50.
17. Reininger D, Cobo-Vázquez C, Monteserín-Matesanz M, López-Quiles J. Complications in the use of the mandibular body, ramus and symphysis as donor sites in bone graft surgery. A systematic review. Med Oral Patol Oral Cir Bucal. 2016 Mar; 21(2): e241–e249.
18. Uchida Y, Yamashita Y, Goto M, Hanihara T. Measurement of anterior loop length for the mandibular canal and diameter of the mandibular incisive canal to avoid nerve damage when installing endosseous implants in the interforaminal region. J Oral Maxillofac Surg. 2007;65(9):1772–9.
19. Nkenke E, Schultze-Mosgau S, Radespiel-Troger M, Kloss F, Neukam FW. Morbidity of harvesting of chin grafts: a prospective study. Clin Oral Implants Res. 2001;12(5):495–502.

20. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: comparison of donor site morbidity and complications. Clin Implant Dent Relat Res. 2003;5(3):154–60.

21.Yoshioka I , Tanaka T, Khanal A, Habu M, Kito S, Kodama M, Oda M, Wakasugi-Sato N, Matsumoto-Takeda S, Fukai Y, Tokitsu T, Tomikawa M, Seta Y, Tominaga K, Morimoto Y. Relationship Between Inferior Alveolar Nerve Canal Position at Mandibular Second Molar in Patients With Prognathism and Possible Occurrence of Neurosensory Disturbance After Sagittal Split Ramus Osteotomy. J Oral Maxillofac Surg. 2010;68(12):3022-7.

22. Yoshioka I, Tanaka T, Habu M, Oda M, Kodama M, Kito S, Seta Y, Tominaga K, Sakoda S, Morimoto M. Effect of bone quality and position of the inferior alveolar nerve canal in continuous, long-term, neurosensory disturbance after sagittal split ramus osteotomy. J Cranio-maxillofac surg 2012;40(6):e178-e183.

23. Rich J, Golden B.A, Phillips C. Systematic review of preoperative mandibular canal position as it relates to postoperative neurosensory disturbance following the sagittal split ramus osteotomy. –Int J Oral Maxillofac Surg. 2014; 43(9):10761081.

24. Rueda S, Gil JA, Pichery R, Alcañiz M. Automatic segmentation of jaw tissues in CT using active appearance models and semi-automatic landmarking. Med Image Comput Comput Assist Interv. 2006;9(Pt 1):167-74.

25. de Oliveira Júnior MR, Saud AL, Fonseca DR, De-Ary-Pires B, Pires-Neto MA, de Ary-Pires R. Morphometrical analysis of the human mandibular canal: a CT investigation. Surg Radiol Anat. 2011;33(4):345-52.

26. Chaudhary ML, Anchalia S, Sharma V. Evaluation of Inferior Alveolar Canal and its Variations using Cone Beam CT-scan. IJARS. 2018;7(1):15-20.

27. Sanjana R, Poornima C, Mahesh Kumar TS, Balaji P and Mutreja D. Assessment of accuracy and reliability of linear measurements of CBCT- An *in vitro* study. Indian Journal of Applied Radiology. 2017;4:1

28. Naitoh M, Yoshida K, Nakahara K, Gotoh K, Ariji E. Demonstration of the accessory mental foramen using rotational panoramic radiography compared with cone-beam computed tomography. Clin Oral Implants Res. 2011;22(12):1415-19.

29. Bornstein M.M, Lauber R, Sendi P, Arx T. Comparison of Periapical Radiography and Limited Cone-Beam Computed Tomography in Mandibular Molars for Analysis of Anatomical Landmarks before Apical Surgery. J Endod. 2011;37(2):151-7.

30. Waltrick KB, Nunes de Abreu Junior MJ, Corr^ea M, et al. Accuracy of linear measurements and visibility of the mandibular canal of cone-beam computed tomography images with different voxel sizes: an in vitro study. J Periodontol 2013;84:68–77.

31. Timock AM, Cook V, McDonald T, et al. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J Orthod Dentofacial Orthop 2011;140:734–44.

32. Hashem D, Brown JE, Patel S, et al. An in vitro comparison of the accuracy of measurements obtained from high- and low-resolution cone-beam computed tomography scans. J Endod 2013;39:394–7.

33. Sherrard JF, Rossouw PE, Benson BW, et al. Accuracy and reliability of tooth and root lengths measured on cone-beam computed tomographs. Am J Orthod Dentofacial Orthop 2010;137:100–8.

34. Shokri A, Shakibaei Z, Langaroodi AJ, Safaei M. Evaluation of the mandibular canal visibility on cone-beam computed tomography images of the mandible. J Craniofac Surg 2014;25:e273-7.

35. Nair UP, Yazdi MH, Nayar GM, Parry H, Katkar RA, Nair MK. Configuration of the inferior alveolar canal as detected by cone beam computed tomography. J Conserv Dent. 2013;16:518-21.

36. Watanabe H, Mohammad Abdul M, Kurabayashi T, Aoki H. Mandible size and morphology determined with CT on a premise of dental implant operation. Surg Radiol Anat. 2010 Apr;32(4):343-9. doi: 10.1007/s00276-009-0570-3. Epub 2009 Oct 8.

37. Sghaireen MG, Srivastava KC, Shrivastava D, Ganji KK, Patil SR, Abuonq SR, Mousa MA, Dar-Odeh N, et al. A CBCT Based Three-Dimensional Assessment of Mandibular Posterior Region for Evaluating the Possibility of Bypassing the Inferior Alveolar Nerve While Placing Dental Implants. Diagnostics 2020;10(406): 1-17. doi:10.3390/diagnostics10060406

38. Koivisto T, Chiona D, Milroy L.L, McClanahan B.S, Ahmad M, Bowles R. W. Mandibular Canal Location: Cone-beam Computed Tomography Examination. J Endod. 2016;42(7):1018-21.

39. Al-Siweedi SY, Nambiar P, Shanmuhasuntharam P, Ngeow WC. Gaining surgical access for repositioning the inferior alveolar neurovascular bundle. ScientificWorldJournal 2014;(2014):1-11.

40. Safaee A, Mirbeigi S, Ezoddini F, Khojastepour L, Navab-Azam A. Buccolingual course of the inferior alveolar canal in different mental foramen locations: A cone beam computed tomography study of an Iranian population. Int J Appl Basic Med Res. 2016;6(4):262-266.

41. Valdec S, Borm M.J, Casparis S, Damerau G, Locher M, Stadlinger B. Vestibular bone thickness of the mandible in relation to the mandibular canal—a retrospective CBCT-based study. International Journal of Implant Dentistry 2019; 5:37.

42. Kilic C, Kamburo˘glu K, Ozen T. et al. The position of the mandibular canal and histologic feature of the inferior alveolar nerve. Clinical Anatomy. 2010; 23(1): 34–42.