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Different methods to evaluate mandibular alveolar ridge in Cone Beam Computed Tomography images in pre-implant surgery assessments

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ABSTRACT

Presently in our country, the measurement ofalveolar bone in Cone Beam Computed Tomography (CBCT) images is done by oral and maxillofacial radiologists. Most of theclinicians in implant treatment plan,use the measurements provided by radiologist in the CBCT images.The aim of this study is to discover the method approved by most clinicians according to the various methods of linear measurement of alveolar bone. Initial cross-sectional image from different areas of lower jaw was chosen by three radiologists and threeperiodontists. Several measurementswere specified for each of the ridges. The ridges and measurement methods were numbered. 342 dentists comprising 39 radiologists, 85 maxillofacial surgeons, 106 periodontists and112 general dentists selected their desired method for each of the ridges. Pearson chi square test was used for data analysis. Most of the participants in ridges1, 2 and 4 selected method number 1 (41.8 and 48 and 67.5% respectively). Majority of the participants in ridges number 3 and 5 chose method 2(50 and 28.4% respectively). The most suitable method for clinicians in each area can be useful in radiologist s measurement in CBCT slices.

Keywords: Cone Beam Computed Tomography (CBCT), Alveolar Ridge

INTRODUCTION

Currently, CBCT is used in determining the buccolingual width of alveolar ridge and height of bone available to place implants[1-3]. CBCT effectively brings together prosthetic and surgical considerations which are important for beauty, restorative and prosthetic indices [4].

Bone quantity is determined by recording the height and width of the alveolar bone and morphology of ridge. Cross-sectional image is very valuable in the design phase before surgery due to showing of the faciolingual height and width ofridge. Ridge width measurements help to select implant diameter. The biggest fixtures that can suitably provide maximum support and distribution of masticatory forces are chosen by measuring the height of the ridge. Certain restrictions which are as a result of anatomical differences in different areas of jaws should be considered[5]. Minimum suitable diameter of implant for a successful treatment is 4mm. Implant with a diameter of 2.5 to 3.5 mm can be used for placing in lateral teeth area. The exception of this law is in cases of bruxism[6]. Minimum required bone on the facial side of implant is 0.5 mm and 1 mm implant in the lingual side [7]. As a result, the minimum required buccolingual width for implant placement is about 5.5 mm.

Different areas of the jaws require special precautions during implantation. For example implant placement in inferior alveolar nerve canal can have complications such as numbness, pain and changes in sense. Therefore, damage to this structure should be avoided during implant surgery[6].

Ridge weakening follows a specific pattern with tooth loss that results in crestal bone thinning and change in angle of the remaining residual ridge [8].

Weakening of the edentulous mandibular alveolar ridge outwards has slope and the longer the edentulous term, the wider is the ridge[9]. Altered anatomy of residual ridge causes problems during surgery for correct angle of implant or insufficient bone thickness on the labial implant. Likelihood of such problems is more in the anterior jaw [6].

Regarding these anatomical constraints, the quantities provided by radiologists to clinicians for the measurement of alveolar bone height and width on the CBCT slices can vary. Fathoming the measurement criteria preferred by most clinicians for the pre-implant assessment of alveolar bone, permits radiologists, consideringthem in the measurements given to clinicians in CBCT slices. So it conduces to avoid mistakes in implant surgery due to inconsistency with the radiologist measurements in CBCT slices. Calculated values of alveolar bone quantity by the radiologist should be applicable for clinicians to implant placement.

Objectives

The aim of this study is to evaluate the most suitable method of alveolar bone linear measurement in CBCT images for implant placement in different areas of the jaws.

MATERIALS AND METHODS

This is an observational study in which CBCT imagesof patients who had been referred to Shahid Beheshti radiology department during 2012 and 2013 for implant treatment were used. CBCT images were obtained by New Tom VGi (Verona, Italy) device. The Images had magnification of 1: 1 and gray scale 16-bit. The size of field of view in scans carried outwas from the smallest 6 × 6 cm to the largest 15 × 15 cm. Voltage used in scan is 110 kV . No patients underwent imaging only for the purpose of study and all patients had indications of CBCT prescription for implanttherapy. Among these images, cross-sectional images of five ridges from different regions of the jaws with anatomical variation were chosen by agreement of three radiologists and three periodontists. To prepare reconstructed cross-sectional and panoramic images from the axial point, On-Demand 3D software (CyberMed, Seoul, South Korea) was used. These anatomic sites were considered in selected images: the inferior alveolar canal, lingual undercut in the area under mylohyiod ridge, mental foramen premolar in the mandible, incisive canal in mandibular canine area and lingual foramen in the anterior mandible. Selected images had optimum contrast and density and low metal artifacts. Furthermore, the opposite jaw teeth in selected cross-sectional profile was visible. Thus, cross-sectional images of 10 ridges were selected, which included the following:

Ridge 1: Cross-sectional image of the mandibular molar, the inferior alveolar canal and the lingual undercut Ridge related to mylohyiod ridge areas (Figure 1.a).
Ridge 2: Cross-sectional image of the mandibular, the inferior alveolar canal and lacking lingual undercut related to ridge mylohyiod ridge areas (Figure 1.b).
Ridge 3: Cross-sectional image of the mandibular premolar and mental foramen areas (Figure 1.c).
Ridge 4: Cross-sectional image of the mandibular canine and incisive canal (Figure 1.d)
Ridge 5: Cross-sectional image of the incisor mandibular and lingual foramen (Figure 1.e)

Figure 1. Cross-sectional images selected from different areas of the lower jaw. a: Ridge number one. b: Ridge number two. c: Ridge number three. d: Ridge number four. e: Ridge number five

In preparing all of the above cross-sections, the jaw was in such a position that direction ofthe considered sections fit the direction of implant entering .The curve related to rebuilding panoramic image was drawn parallel to the buccal and lingual plates. There are various methods for linear measurement of alveolar bone in different books. According

to Figure (2.A), Grondahl HG has cited four methods of linear measurement of alveolar bone for posterior mandibular region [10]. In the method employed by Miles DA as shown in Figure (2.B), measuring thickness of the alveolar bone was limited to cancellous bone and thickness of buccal and lingual cortical bone has not been calculated [11]. White SC and Pharoah MJ, according to figure (2.C), measured the ridge height from crest and calculated width of the ridge thickness to be a few millimeters lower than the top of the crest[5].

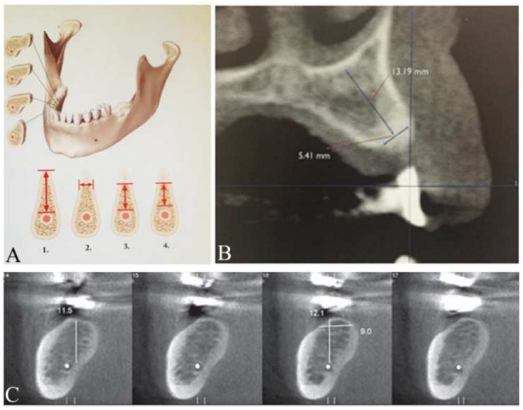

Figure 2. Types of measurement methods, A: Four measurement methods in the posterior mandible, according to Grondahl HG [11].B: measurement method of Miles DA [12]. C: Methods of measurement provided by White SC and Pharoah MJ [5]

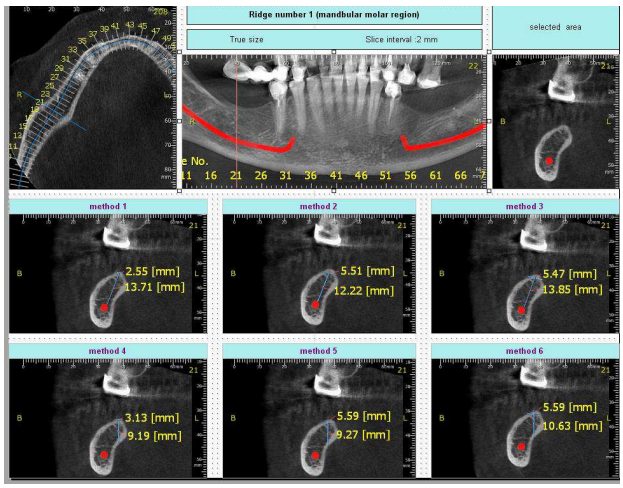

Figure 3-Six specified methods for measurement in the ridge number one

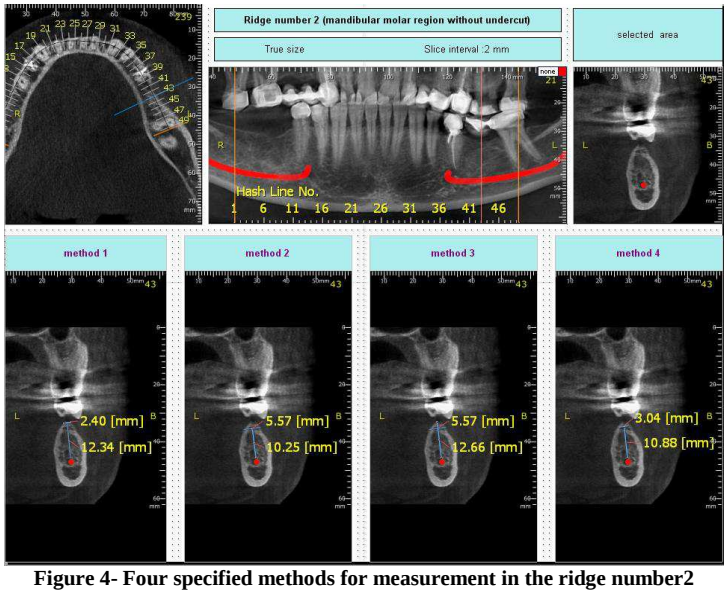

Figure 4- Four specified methods for measurement in the ridge number2

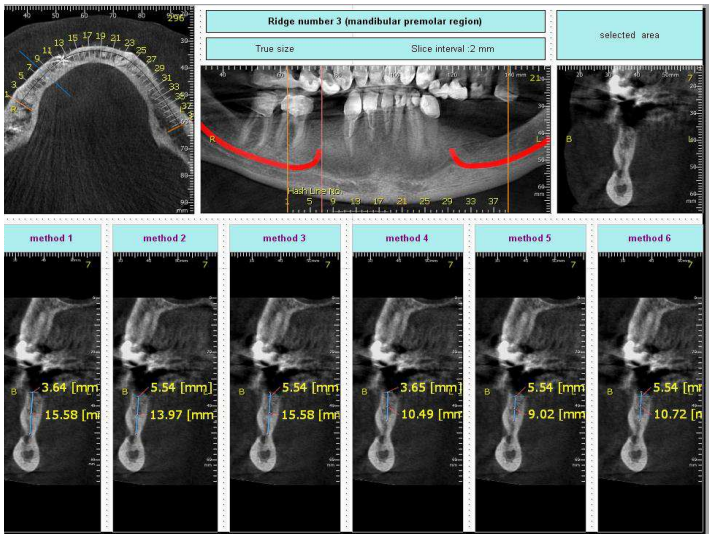

Figure 5- Six specified methods for measurement in the ridge number

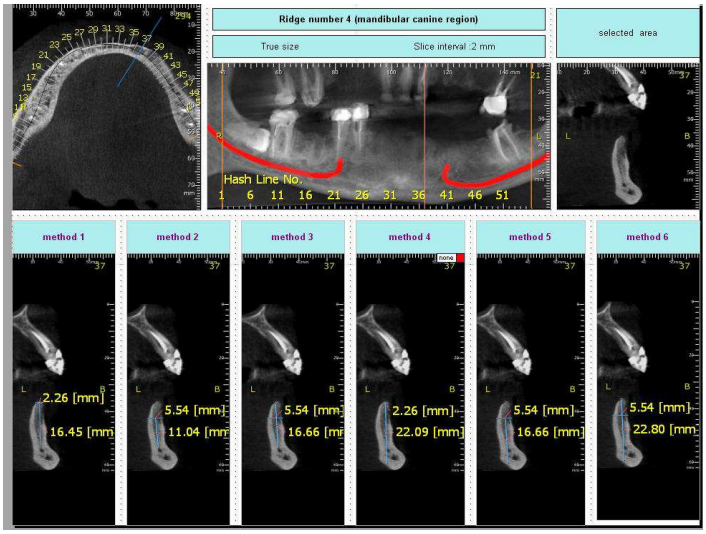

Figure 6- Six specified methods for measurement in the ridge number

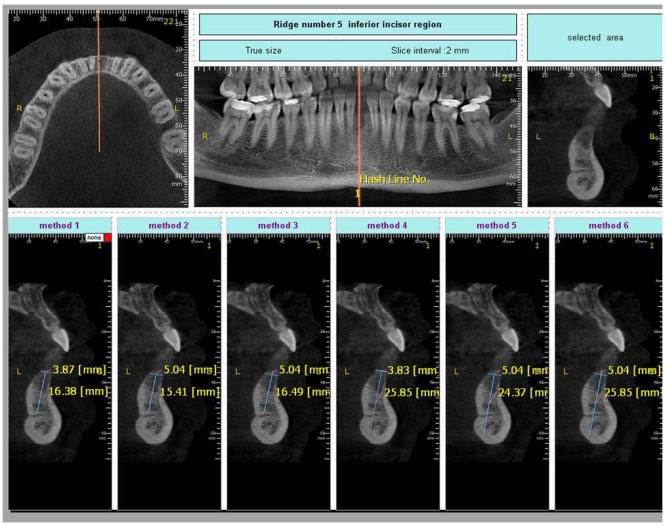

Figure 7- Six specified methods for measurement in the ridge number

Given the anatomical barriers mentioned in the five CBCT image selected from cross-sectional views of toothless ridge in different areas of jaws, different methods of measurement on each of the ridge were identified by agreement of three radiologists and three periodontists, expert in implant treatment as well as available resources and books (5, 6, 10, 11). The methods were presented with a number (such as Method 1, Method 2...).

The measurement methods specified in the selectedridges are presented in Figures 3 to 8.

A usual CBCT report that normally provides a CBCT request for dentists was prepared for each ridge which included a panoramic view of the related jaw, cross-sectional view of the considered ridge without measurement and an axial section. In addition to these views, different methods of measurement were determined by their number. Then, these images along with measurement methods were shown to radiologists, periodontists, maxillofacial surgeons and general dentists who work in the field of implant to choose their preferred method in each ridge among the persistent methods.Using a pilot study with consideration of 0.05 errorand test power of 80% using the software PASS, sample size was calculated as 340 people.To analyze the data, each of the specialties in the study employed first descriptive statistics such as frequency for stating preference of each method and then Pearson chi-square test was used to analyze the data and examine significant differences between expertises regarding preference for a specific method. No patient underwent imaging only for the purpose of study and all patients had indications of CBCT prescription for implant therapy. The people were not compelled to participate in the study. They were assured that their data will remain confidential and will only be analyzed collectively, not individually.

RESULTS

A total of 342 dentists participated in this study. Participants comprised 112 general dentists, 85 maxillofacial surgeons, 106 periodontists, and 39 oral and maxillofacial radiologists. Among 342 total participants, 80 were females and 262 were males. (Table1).

Table 1 -Frequency of people participating in the research based on expertise and gender

Study groups	Number	percentge
General dentists:		
Men	95	84.8
Women	17	15.2
total	112	100
Oral and maxillofacial surgeon:		
Men	75	88.2
Women	10	11.8
total	85	100
Periodontists:		
Men	82	77.4
Women	24	22.6
total	106	100
Radiologists:		
Men	10	25.6
Women	29	74.4
total	39	100

The results of frequency and percentage of selecting any of the measurement methods in five ridges by any of the experts are shown in Tables 2 to 6. In all ridges, the ratio of selecting methods in different expertise was tested by Pearson chi-square test.

Table 2 -Frequency of selected measurement methods for Ridge 1

		methods						total
Study groups		1	2	3	4	5	6	
General dentists	number	53	35	0	14	8	2	112
	percent	47.3%	31.2%	.0%	12.5%	7.1%	1.8%	100.0%
surgeons	number	60	23	0	0	2	0	85
	percent	70.6%	27.1%	.0%	.0%	2.4%	.0%	100.0%
periodontist	number	29	49	14	9	5	0	106
	percent	27.4%	46.2%	13.2%	8.5%	4.7%	.0%	100.0%
radiologists	number	1	30	2	3	3	0	39
	percent	2.6%	76.9%	5.1%	7.7%	7.7%	.0%	100.0%
total	number	143	137	16	26	18	2	342
	percent	41.8%	40.1%	4.7%	7.6%	5.3%	.6%	100.0%

P-value=0.000

Table 3- Frequency of selected measurement methods for Ridge 2

Study groups		methods				total
		1	2	3	4	
General dentists	number	65	47	0	0	112
	percent	58.0%	42.0%	.0%	.0%	100.0%
surgeons	number	59	23	0	3	85
	percent	69.4%	27.1%	.0%	3.5%	100.0%
periodontist	number	40	51	6	9	106
	percent	37.7%	48.1%	5.7%	8.5%	100.0%
radiologists	number	0	20	4	15	39
	percent	.0%	51.3%	10.3%	38.5%	100.0%
total	number	164	141	10	27	342
	percent	48.0%	41.2%	2.9%	7.9%	100.0%

P-value=0.000

Table 5- Frequency of selected measurement methods for Ridge 4

		methods						total
Study groups		1	2	3	4	5	6	
General dentists	number	32	52	0	16	12	0	112
	percent	28.6%	46.4%	.0%	14.3%	10.7%	.0%	100.0%
surgeons	number	28	46	2	5	4	0	85
	percent	32.9%	54.1%	2.4%	5.9%	4.7%	.0%	100.0%
periodontist	number	31	57	1	6	5	6	106
	percent	29.2%	53.8%	.9%	5.7%	4.7%	5.7%	100.0%
radiologists	number	5	16	2	6	10	0	39
	percent	12.8%	41.0%	5.1%	15.4%	25.6%	.0%	100.0%
total	number	96	171	5	33	31	6	342
	percent	28.1%	50.0%	1.5%	9.6%	9.1%	1.8%	100.0%

P-value=0.000

Table 6- Frequency of selected measurement methods for Ridge 5

Study groups		methods						total
		1	2	3	4	5	6	
General dentists	number	41	49	2	17	3	0	112
	percent	36.6%	43.8%	1.8%	15.2%	2.7%	.0%	100.0%
surgeons	number	30	23	2	23	5	2	85
	percent	35.3%	27.1%	2.4%	27.1%	5.9%	2.4%	100.0%
periodontists	number	24	49	3	16	8	6	106
	percent	22.6%	46.2%	2.8%	15.1%	7.5%	5.7%	100.0%
radiologists	number	2	12	9	5	7	4	39
	percent	5.1%	30.8%	23.1%	12.8%	17.9%	10.3%	100.0%
total	number	97	133	16	61	23	12	342
	percent	28.4%	38.9%	4.7%	17.8%	6.7%	3.5%	100.0%

P-value=0.000

DISCUSSION

Dental implants are the best choice in treatment of missing teeth. The success of dental implant is hinge on the quantity and quality of jaw bone [12], therefore, accurate measurement of alveolar process is important[13]. The best imaging to evaluate all possible locations for implants is CBCT [14, 15].

In the pre implants surgical design, the existing bone quality is determined by recording the height and width of alveolar bone and morphology. By measuring current height, the biggest fixture that can suitably provide maximum support and distribution of masticatory forces is selected. Most of morphological views such as bone undercuts that are not directly visible in clinical examinations become visible with cross-sectional imaging [5, 6]. Mylohyoid ridge is an anatomic landmark in mandible. The area under the mylohyiod ridge is undercut. This ridge is sharp and evident in molar areas and almost disappears in the anterior region [6, 7].

Tolstunov described four alveolar jaw bone areas as functional areas with special anatomical features and bone loss pattern. He also explained anatomical obstacles in each of these areas [16].

In Ridge numbered 1,in molar area of mandibular alveolar ridge, method number one and two were most suitable.In method number one, maximum height of alveolar bone is calculatedfrom the top of ridge to the upper border of alveolar canal. It appears that discerning the maximum bone height in this area has been an important factor for

clinicians, however in method number 3 the measured bone height is also similar to method number one, but none of maxillofacial surgeons and dentists considered this approach as a suitable method. The difference between these two methods is in the evaluation of the alveolar bone width. Buccolingual width at the top of the ridge is calculated in method 1whereas; the width of the ridge is measured in method 3 where there is adequate alveolar bone thickness for implant. Thus, the crestal ridge thickness and maximum height of alveolar ridge are important factors for general dentists and maxillofacial surgeons in CBCT measurements. None of maxillofacial surgeons, radiologists and periodontists chose method 6. From the combination of these findings, it may be concluded that participants prefer the height to be calculated from the place of width measurement (It is not seen in methods 3 and 6) so that they can use resulting numbers to select the length and width of implant. Among radiologists, method 4 and 5 were the most selected methods after method 2. In these methods, the height to lingual undercut is calculated and a so they are more conservative than methods 1 and 2 since if clinicians , according to this measurement of radiologist, select implant height, perforation of the lingual undercut does not occur, but if clinician, according to the sizes of the alveolar ridge bone height in methods 1 and 2, chooses a bigger implant and does not place it in correct direction , there will be a risk of perforation from lingual undercut.

Four measurements were determined in ridge number 2.General dentists and maxillofacial surgeons considered method1 as most suitable way of measuring the dimensions of the alveolar ridge. The maximum alveolar height is ascertained in method 1. This height is also determined in method 3, but none of the general dentists and maxillofacial surgeons chose it; and among periodontists, the least selected method was method number 3.The width of alveolar bone at the top ridge is a specific anatomicallocation for clinicians and has been calculated in method 1while in method 3 the width of the alveolar bone below the top of the ridge is measured and the number of millimeters between this place and top of the ridge is not clear. Among radiologists method number 4 was the second most selected method after method 2. The width of cancellous bone between cortical borders in the upper part of the ridge was measured in this method [12], but this method was not of interest to the other three groups because the importance of total thickness of cortical and cancellous bone is more than thickness of just cancellous bone in implant treatment.

Ridge number 3, premolar region of the mandible is in the area of mental foramen. Six measurement methods were determined. The majority of participants considered method 2 as a better method. The second appropriate method among surgeons, dentists and periodontists was method1 in which the maximum height of bone from the top of the ridge to the upper border of the mental foramen was calculated and alveolar bone thickness at the ridge top was measured. None of the general dentists, maxillofacial surgeons and radiologists chose method 6. Also none of the general dentists considered method 3 appropriate. Therefore, from these findings it can be concluded that the four groups preferred the height to be measured from the place where the width of alveolar bone is determined. Moreover, four groups tended to measure the height to the upper border of mental hole within the foramen bone (not to the same level as the entrance hole in the alveolar bone buccal surface which can be seen in methods 4 to 6) . Of course among radiologists method 4, was the most chosen method after method 2, which appears to be as a result of a conservative attitude to this area; and a height of the alveolar ridge is given to clinician that in case of choosing dimensions of implant according to that has less risk for damage to the mental nerve.

For ridge 4, canine mandible area, six measurements were determined. The majority of participants considered method1 as the best method. According to the figure of ridge, adequate thickness of bone for implants with least diameter is obtained at a considerable distance from the top of the crest, which is not desirable. Also incisive canal is considered as an impressive landmark by the majority of clinicians. Method 2 in which the width of the bone is calculated where there is adequate thickness of alveolar bone to implants with a minimum diameter and the height from there to the upper border of incisive canal is measured, was the second choice among radiologists, maxillofacial surgeons and general dentists. The second method chosen among periodontists was method 4 that has calculated the width at the top and height from the top ridgeto inferior border of the mandible. Thus, it appears that periodontists prefercrossing from Incisive branch.Methods 3 and 6 are the least chosen methods by the participants, so majority of radiologists and clinicians prefer to measure height from place where width of the buccolingual ridge is determined (this is not observed in methods 6 and 3). Considering the overall findings, it can be concluded that for most radiologists and clinicians, incisive canal is an important anatomic landmark that encroaching upon it during implant surgery should be avoided as much as possible.

Incisive canal is a bone canal in anterior mandibule that is extended bilaterally from mental foraminato lateral teeth. In one study it was discovered that in some patients the size and location of the Incisive canal may alter the treatment plan in mandible, so that in a case with large Incisive canal, implant placement was avoided in the area between the two mental holes [17].

For ridge 5, in the lower incisor region, six measurement methods were determined. Most of the clinicians considered method 2 as suitable method for measuring this area.In this regard, there was an agreement among general dentists, periodontists, and radiologists. Most of them chose method 2. Therefore, clinicians who perform implant surgery generally prefer methods number 1 and 2. In both methods, the height measurement to lingual foramen has been done, so it appears that clinicians prefer to refrain encroaching on the lingual hole during implant surgery.

During implant placement in anterior mandible, lingual foramina are often ignored and it appears a low clinical risk is associated with them [18]. Lingual holes include two or more holes in the midline mandible. The location and size of these holes are quite varied [6]. Alveolar bone between mental foramina area are considered as relatively safe areas for surgical implants. But recent studies have revealed that not respecting some structures in this area including lingual holes leads to complications after surgery. Damage to the arteries thatpass through the lingual holes can lead to edema. In such cases, pressure is applied to the lingual mandible to stop bleeding and when the bleeding stops, antibiotics and steroids should be prescribed[18, 19]. Thus, if bleeding is observed in this area during implant surgery, clinicians should consider the possibility of damage to the sublingual artery branches that goes into the lingual hole. When lingual holes have diameter more than 1 mm in CBCT images before implant surgery, clinicians should be aware of this vascular damage[19]. In method number1 buccolingual width of the ridge was calculated at the top. In method 2 which is the most suitable method for majority of radiologists, general dentists and periodontists, buccolingual width of the ridge has been presented where there is adequate thickness for placing the narrowest implant and ridge height from this place to upper border of lingual hole has been calculated. In total, methods 3 and 6 were the least selected methods. Thus from all the data, it can be concluded that for the 4 previous ridges investigated, clinicians prefer the height to be measured from place where buccolingual width of ridge is specifiedand all four expert groups consider that encroaching lingual hole in the anterior mandible should be avoided.Surgeons preferred passing through the lingual hole more than other groups.

CONCLUSION

From the findings of the study, it can concluded that the methods of measurement in anatomic areas are different from clinicians' view and it is recommended that radiologists should perform measurements based on that.

It seems there is no agreement between radiologists and clinicians on the linear measurement of alveolar bone. It is suggested that clinicians do their desired measurement on the CBCT images and for this purpose CDs can be used along with the images. Holding workshops can also be useful.

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