Original Article

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Morphological analysis of posterior mandibular lingual concavity and risk assessment for lingual plate perforation for standard implant placement

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Objectives: To determine the prevalence and dimensions of lingual concavity in the posterior mandibular area of the alveolar ridge with adequate dimensions for standard implant placement by cone-beam computed tomography and evaluate the risk of lingual plate perforation by virtual implant placement.

Materials and Methods: The 208 cross-sectional images (102 patients) of the second premolar and first molar area with adequate dimensions for standard implant placement in both dentate and edentulous condition were selected. The ridge morphology above the inferior alveolar canal 2 mm was classified into 3 types; concave, parallel, and undercut type. The undercut type were further measured by using the implant planning software (coDiagnostiX®) in following topics; vertical distance from the top of crest to the deepest point of lingual concavity (V), concavity depth (D) and concavity angle (θ). The 10 mm-length virtual implants were used to determine the risk of lingual plate perforation.

Results: The undercut type was found more than 30% in every tooth location (33.70% in second premolar and 42.30%in the first molar area). The highest prevalence of undercut type (50.9%) was found at the dentate first molar area. For the dimensional parameters of lingual concavity, there were no relationships between V, D, θ with age, gender, dentate status, and tooth type. The 7% of the virtual implants in the first molar area were found to be ≤ 1mm from the lingual plate which showed the statistically significant incidence of perforation ($P<0.05$).

Conclusions: The lingual concavity is commonly found in the posterior mandibular area. The risk of lingual plate perforation incidence was remarkable in the mandibular first molar area. Therefore, it is advisable to take the CBCT prior to the dental implant treatment in the posterior mandibular area especially on the first molar area, even in the case with adequate alveolar ridge dimension.

Keywords: Lingual concavity, Lingual plate perforation, Posterior mandible, Ridge morphology

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Introduction

Dental implant treatment is now accepted as one of the most successful and reliable solutions to help patients with tooth loss. Due to recent developments in implant dentistry, the principal of implant placement is shifted from the surgical driven position into the prosthetic driven position. This means that the position and orientation of the implant should be aligned following the planned final restoration [1]. To achieve a successful outcome, a good treatment plan is crucial. Therefore, it is necessary to obtain precise preoperative examination which can lead to the proper diagnosis and result in good treatment plan [2].

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In the area of posterior mandible, there are critical anatomies where clinicians must be cautious during implant surgery. The lingual aspect of posterior mandible contains many vital structures. it is highly vascularized and has the depression of submandibular fossa which is called lingual concavity [3, 4]. The deep extension of the concavity can be considered as a potential risk factor for the lingual plate perforation during the drilling osteotomy and implant placement [5, 6]. If the perforation occurs, it can lead to various degrees of complication and compromise the result of implant treatment [7-9].

Before the implant placement, the surgeon can initially perceive the shape and width of the ridge from the clinical examination, and evaluate the vertical ridge height and position of the adjacent vital structure from intraoral and panoramic radiographs [10]. When the estimated alveolar ridge from the radiograph shows the adequate height for standard implant placement, the surgeon may decide to evaluate the ridge width with caliper device or by palpating to avoid the cost and radiation exposure to the patient. However, a precise evaluation of the lingual concavity on posterior mandibular area by palpation is hard to be obtained due to the attachment of mylohyoid muscle in this area. Three-dimensional imaging should be used for evaluating [11].

Of all the three-dimensional imaging modalities, cone beam computed tomography (CBCT) is highly recommended. It can provide information about bone morphology and bone quantity in all directions. The CBCT image has no superimposition and rarely distort. It also takes less scanning time and radiation dose than medical CT [12-14]. The American Academy of Oral and Maxillofacial Radiology (AAOMR) suggested the use of CBCT as a current image modality of choice for preoperative cross-sectional imaging of potential implant sites [11].

There were many previous studies that assessed the morphology of the posterior mandible by using CBCT image to find the prevalence of the lingual concavity [4, 6, 15-17]. To our knowledge, none of them have evaluated the dentate and edentulous conditions separately. Normally, the ridge shape can be reshaped after the tooth extraction. It was reported that the major change generally occurs in the first 12 months after the extraction and two-thirds of bone loss can occur within just 3 months [18]. Therefore, the study of the ridge morphology of the dentate and edentulous posterior mandibular area should be emphasized. The present study aimed to determine the prevalence and dimensions of lingual concavity in the posterior mandibular area of the alveolar ridge with adequate dimensions for standard implant placement in both dentate and edentulous condition and evaluate the risk of lingual plate perforation by virtual implant placement. This data could be beneficial for considering the proper examination for treatment planning and could be applied to use for both the conventional and immediate implant placement techniques.

Materials & Methods

Patient selection and image acquisition

CBCT images of posterior mandible with FOV 6cm x 6cm were acquired from the archived database of the Oral and Maxillofacial Radiology Clinic in our institute from January 2017 to December 2018. All the images were obtained by CBCT machine (3D Accuitomo, J. MORITA CORP.) which was set at 90kVp, 5mA. The data were saved in DICOM format. The implant planning software (coDiagnostiX®) was used to measure the parameter of ridge morphology and generate virtual implant placement. The study protocol was reviewed and approved by the responsible committee on human experimentation of our institute.

Inclusion criteria

1. The mandibular second premolar and first molar area must be presented in the CBCT image.

2. the mandibular second premolar and first molar area can be presented as dentate, partially, or completely edentulous area.

2.1. The tooth had to be in normal position (the imaginary line connecting the cusp tip of canine, central groove of premolars, and molars was generally smooth) and normal occlusion.

2.2. In the edentulous case, the teeth anterior and posterior to the edentulous area must be presented and in normal position.

3. The investigated site had to have adequate dimensions for standard implant placement.

3.1. The vertical bone height had to be ≥ 12 mm from the alveolar crest to the superior border of inferior alveolar canal (IAC).

3.2. The edentulous area had to have buccolingual width at crestal level ≥ 6mm at premolar site or ≥ 7mm at molar site.

3.3. The edentulous area had to have the mesiodistal distance at crestal level ≥ 7mm at premolar site or ≥ 8mm at molar site.

4. Minimum age of 18 years old due to the complete development of jaws.

5. The outline of the mandible and IAC had to be clearly identified.

6. The opposing maxillary tooth must be presented to provide information for implant angulation.

Exclusion criteria

1. Images were unclear or presented artifacts.

2. The bone pathology was presented in the posterior mandible region.

3. Images showed torus mandibularis or exostosis at the investigated site.

4. Images showed grafted alveolar ridge at the investigated site.

5. Images showed the permanent mandibular second premolar or first molar which partial erupted or did not have fully formed apex.

6. The implant was placed adjacent to the investigated site.

Image analyses

1. Classification of ridge morphology

Alveolar ridges were classified into 3 types as the criteria of Chan et al [4]. The evaluation of the ridge morphology was done only on the area above the superior border of IAC 2mm.

- Convergent ridge type (C type): the ridge with the bucco-lingual width reduction from the base to the crest which is absent of undercut (Figure 1-a and Figure 2-a).
- Parallel ridge type (P type): the ridge with generally buccal and lingual side parallel to each other (Figure 1-b and Figure 2-b).
- Undercut ridge type (U type): the ridge with the bucco-lingual width expansion from the base to crest, showing the undercut on lingual side (Figure 1-c and Figure 2-c).

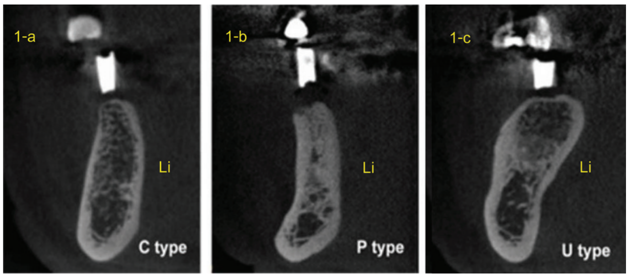

Figure 1 Three types of cross-sectional ridge morphology on edentulous ridge: C, P, U types.

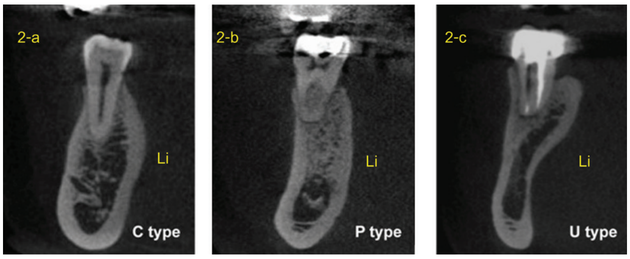

Figure 2 Three types of cross-sectional ridge morphology on dentate ridge: C, P, U types.

The prevalence of each ridge type was evaluated by a 10-year experience oral and maxillofacial radiologist and a well-trained dentist who was in the master's program in oral implantology. 2 examiners were calibrated with 30 samples then worked separately. Any disagreements between examiners were discussed and resolved to give conclusive findings. The Cohen's kappa was calculated to demonstrate the inter-observer reliability.

2. Cross-sectional morphology assessment

The U type ridges were chosen. Only the areas above the IAC 2mm were measured for the concavity depth (D), the vertical distance from the crest to the deepest point of the lingual concavity (V), and concavity angle (θ). For the edentulous ridge, V was measured from the top of the bone crest to the deepest point of the lingual concavity (Figure 3-a). For the dentate ridge, V was measured from the top of lingual bone crest (Figure 3-b). The ridge measurement was performed twice in 4 weeks intervals by the well-trained dentist. Pearson's correlation test was used to demonstrate the intra-examiner agreement.

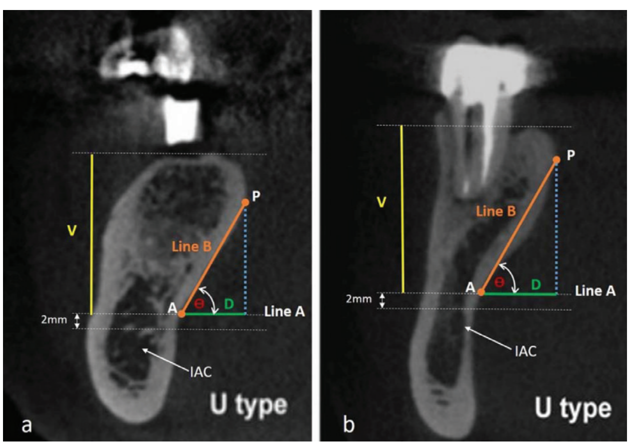

Figure 3 Demonstration of cross-sectional view showing the relevant measurements, point A: The deepest point of the lingual ridge in any area above the IAC for 2mm, point P: The most prominent point of lingual ridge, line A: Imaginary line extended from point A and parallel with inferior border of mandible, line B: The line connecting line between point A and point P, D: The horizontal distance from point A to point P in mm, V: The vertical distance of the perpendicular line from the bone crest to line A in mm, θ: The angulation between line A and line B in degrees.

3. Virtual implant placement for evaluating the risk of lingual plate perforation

The implant planning software (coDiagnostiX®) was used to simulate the implant placement in the alveolar ridge with lingual concavity (U type ridge). The virtual implant placement on the ridge with dentate and edentulous condition imitated the situation of the immediate and conventional implant placement, respectively. The tapered root form implants (Straumann® Bone Level Tapered Implant) with diameter 4.1mm for the premolar and 4.8mm for the molar were selected from the implant database available in the software. The implants were placed with regardless of the boundary of lingual cortical bone to evaluate the risk of lingual plate perforation. The size and position of the implants were set as following criteria.

In the case of dentate ridge, the immediate implant placement protocol was applied. Only the tooth that had the distance from the tips of the root to superior border of IAC ≥ 6mm was chosen. The length of the implant was not fixed but should be long enough to engage the bone below the socket for 4mm to ensure the primary stability of the implant [19, 20]. The implant was placed 1 mm subcrestally at the center of the replaced tooth. The implant angulation was parallel with the long axis of opposing tooth (Figure 4).

In the case of edentulous ridge, the conventional implant placement protocol was applied. The length of the implant was fixed at 10 mm. The center of the implant was placed along the imaginary line connected between the central grooves of the two adjacent teeth at crestal level. The implant angulation was parallel with the long axis of opposing tooth.

1. For one tooth loss (the mandibular second premolar or first molar tooth), The implant was placed mesiodistally at the middle of the ridge. The functional cusps of the opposing tooth had to locate at the center of the implant (Figure 5).

For both teeth loss, the mesiodistal space for mandibular second premolar was set to be 7 mm according to the mean width of this tooth [21]. Therefore, the rest of the space was belonged to the first molar implant (Figure 5). If the mesiodistal distance was ≥ 20mm, the location of each implant was considered again following the prosthetic driven implant position (Figure 6).

The events of the lingual plate perforation were recorded whenever the border of the virtual implant is out of the boundary of cortical bone or the distance between the implant outline and lingual cortical bone was ≤ 1mm. The perforation risks were verified from different cross-sectional and three-dimensional view. The evaluations were performed twice by the well-trained dentist in 4 weeks intervals. Pearson's correlation test was used to demonstrate the intra-examiner agreement.

Statistical analyses

The data were analyzed using SPSS Statistics 21.0 (SPSS Inc., Chicago, IL, USA). Chi- square test was calculated to evaluate the difference of prevalence among the ridge morphology. The correlation test and 2-sample T test were calculated to find the correlation between the dimensional parameters (V, D, θ) and age, gender, dentate status, and tooth type. The impacts of the parameters to the lingual plate perforation were evaluated by using chi-square test and 2-sample T test. The significance level of P value was set at 0.05.

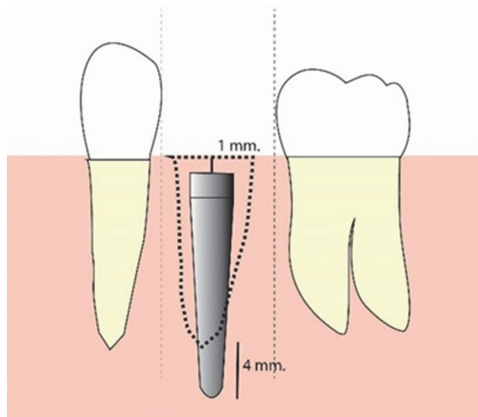

Figure 4 Demonstration of the implant position on dentate ridge.

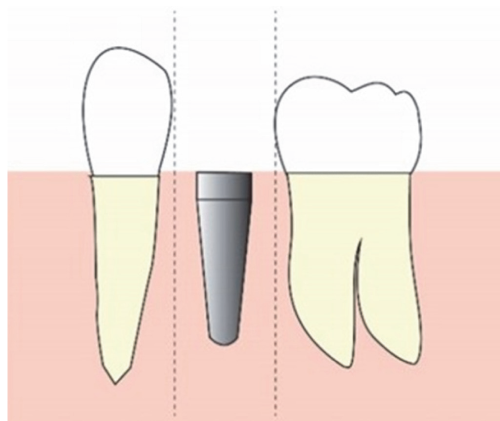

Figure 5 Demonstration of the implant position on edentulous ridge with single tooth loss.

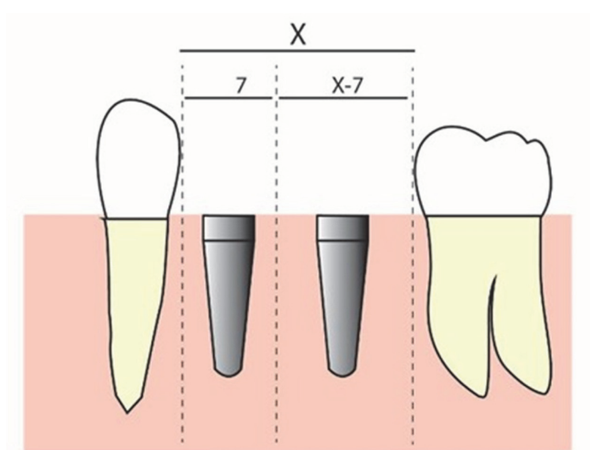

Figure 6 Demonstration of the implant position on edentulous ridge with two teeth loss.

Results

The classification of ridge morphology and measurements

The 208 CBCT images of 102 subjects that showed both the mandibular second premolar and first molar areas were included in this study (49 males and 53 females) with mean age of 51.99 years (range: 27-76 years). The prevalence of each ridge types on the mandibular second premolar area (Table 1) and the mandibular first molar area (Table 2) was presented. The most common ridge morphology of the mandibular second premolar and first molar area were C type ridge (39.4%) and U type ridge (42.3%) respectively. There were the significant differences in the distribution of ridge type between dentate and edentulous ridge in first molar area (P<0.05). The results showed that C type ridge (53.20%) was the most common ridge type for edentulous ridge, while U type (50.90%) was the most common ridge for dentate ridge (Table 2). The inter-examiner agreement was excellent (0.97).

Dimensional parameters of the area 2 mm above the IAC of the U type ridge (n = 79) were further evaluated. The mean V, D, and θ of each area and dentate status were presented (Table 3). The relationships between the parameters and other factors, including age, gender, dentate status, and tooth location, were studied. However, there were no significant differences among them (P>0.05). The intra-examiner agreement was excellent (0.97).

Table 1 Frequency distribution of ridge morphology on the mandibular second premolar area.

Condition	Ridge morphology			Total	p-value
	C	P	U		
Dentate ridge	26 (41.30%)	15 (23.80%)	22 (34.90%)	63 (100%)	0.674
Edentulous ridge	15 (36.60%)	13 (31.70%)	13 (31.70%)	41 (100%)	
Total	41 (39.40%)	28 (26.90%)	35 (33.70%)	104 (100%)	

Data are presented as number of alveolar ridges (%), C = concave type, P = parallel type, U = undercut type

Table 2 Frequency distribution of ridge morphology on the mandibular first molar area.

Condition	Ridge morphology			Total	p-value
	C	P	U		
Dentate ridge	6 (14.30%)	15 (35.70%)	21 (50.90%)	42 (100%)	< 0.001
Edentulous ridge	33 (53.20%)	6 (9.70%)	23 (37.10%)	62 (100%)	
Total	39 (37.50%)	21 (20.20%)	44 (42.30%)	104 (100%)	

Data are presented as number of alveolar ridges (%), C = concave type, P = parallel type, U = undercut type

Table 3 Dimensional parameters of lingual concavity in U type ridge

Tooth type	Second premolar		First molar	
Condition	Dentate ridge	Edentulous ridge	Dentate ridge	Edentulous ridge
V (mm)	16.815 ± 2.601	15.046 ± 2.309	17.029 ± 2.681	15.177 ± 3.146
D (mm)	3.126 ± 1.673	3.276 ± 2.058	3.541 ± 2.101	3.277 ± 1.280
θ (degrees)	79.389 ± 5.975	79.823 ± 3.730	78.549 ± 5.883	77.539 ± 5.692

Data are presented as mean ± standard deviation, V = vertical distance between the top of the crest to the most concave area, D = concavity depth, θ = concavity angle

The risk of lingual plate perforation by virtual implant placement

The 71 cross-sectional images of U type ridge were evaluated. 8 subjects (3 dentate second premolar sites and 5 dentate first molar sites) were excluded from the study due to the limited distance between the tips of the root to superior border of IAC (<6mm). 7% of implants were found to be ≤ 1mm from the lingual plate and no implants was found to be placed out of the lingual cortical bone outline. All the perforation incidences were found in the mandibular first molar area. Thus, the tooth location showed statistically significant relationship with the lingual plate perforation (P<0.05). Other factors, such as dentate status or dimensional parameters (V, D, θ) did not affect the incidence of the lingual plate perforation significantly (Table 4).

Discussion

The U type is the most highly concerned among all ridge types when performing the implant surgery in the posterior mandibular area due to its high risk of lingual plate perforation. The morphology of the ridge made the placed implant to be in close proximity to the lingual plate [22]. The present study evaluated the prevalence of each ridge types at the mandibular second premolar and first molar area. The prevalence was also evaluated in each dentate status. The dentate and edentulous alveolar ridge can represent the immediate and conventional implant placement situation in the assessment of the lingual plate perforation, respectively.

In the present study, even the C type is the most common ridge type, the U type ridges were found more than 30% in every tooth location (31.70 – 50.90%). The U type ridges were found in the mandibular first molar area more than the mandibular second premolar area in both dentate and edentulous conditions. For the mandibular second premolar area, the prevalence of U type in this study (33.70%) was higher than in the previous studies which ranged from 14.4% to 25.8% [17, 23, 24]. For the mandibular first molar area, the result (42.30%) was quite similar to the previous studies which showed that about 50% of alveolar ridges were U type [17, 23, 24]. Therefore, the clinicians should be aware when performing the implant surgery in the posterior mandibular area, which the lingual concavity can be found at least one-third of cases. In addition, the dentate mandibular first molar area was found to have the most prevalence of U type (50.90%). The higher prevalence of lingual concavity of dentate ridge than edentulous ridge could be due to the process of the ridge resorption after the extraction that reducing the dimensions of the ridge and the lingual concavity [25]. Therefore, when performs the immediate implant placement on the mandibular first molar area, the lingual concavity perforation should be concerned.

To evaluate the concavity's dimensional parameters (V, D, θ) were measured from the cross-sectional images. According to our literature reviews, no study had examined the vertical distance

Table 4 Prevalence of lingual plate perforation of U type ridge in each tooth types by dentate status and dimensional parameters.

Tooth type	Total (n)	Perforation	Dentate ridge (n)	Edentulous ridge (n)	V (mm)	D (mm)	θ (degrees)
Second premolar	32 (100%)	Y	0 (0.00%)[a]	0 (0.00%)[a]	N/A	N/A	N/A
		N	19 (59.38%)	13 (40.62%)	16.096 ± 2.602	3.187 ± 1.808	79.565 ± 5.115
First molar	39 (100%)	Y	4 (10.26%)[a]	1 (2.56%)[a]	15.820 ± 1.485	4.280 ± 2.763	78.458 ± 5.217
		N	13 (33.33%)	21(53.85%)	15.931 ± 3.226	3.231 ± 1.453	78.458 ± 5.217

Data are presented as mean ± standard deviation, n = number of alveolar ridges, Y = yes, N = no, N/A = Non-applicable, [a] P-value = 0.036, V = vertical distance between the top of the crest to the most concave area, D = concavity depth, θ = concavity angle between the top of the crest to the deepest point of the concavity before. This distance is critical because it was used for considering the implant length and planning the implant axis. In both mandibular second premolar and first molar areas, V on dentate ridge is fractionally higher than on edentulous ridge but the difference is so small that it does not have any statistical significance. Moreover, the value of V in all conditions was at least 15mm which exceeded the length of standard implant (10mm), It could be resulted from the inclusion criteria of this study that recruited only the alveolar ridge with at least 12 mm height from the inferior alveolar canal. The D in the mandibular first molar area was deeper than that in the mandibular second premolar area in both dentate and edentulous condition but not statistically significant. Combining with the prevalence data of U type ridge, the area of mandibular first molar tends to have both higher prevalence and deeper lingual undercut. Accordingly, the risk of lingual plate perforation may be higher in the mandibular first molar area.

The virtual implant placement is a useful method to determine the risk of the lingual plate perforation. Due to the different protocol of conventional and immediate implant placement, the risk of lingual plate perforation in both techniques were analyzed separately. It was remarkable that there was no implant placed out of the bone housing in this study. According to the previous study, the distance less than 1 mm from lingual cortical bone might be the perforation in real clinical situation when considering the linear measurement deviation from the computer guided surgery software [26]. Hence, this situation in our study could be defined as the lingual plate perforation. For the conventional implant placement, the implant with lingual cortical bone less than 1 mm were founded in the mandibular first molar area (2.56%). This result was consistent with the study of de Souza, which reported that the risk was greater in more posterior area than in more anterior area [16]. For the immediate implant placement, the 4mm apical bone anchorage is needed for the primary stability [19, 27-29]. The 10.26% of analyzed first molar area showed less than 1mm distance between implant surface and lingual cortical bone while none of the perforation incident was found in the mandibular second premolar area. The result was comparable to the previous studies which also reported the higher risk of perforation in first molar area than in the second premolar area [19, 23]. Summarily, the lingual plate perforation in both implant placement techniques was found only in the mandibular first molar area in the present study.

In the case of the adequate width and height of posterior mandible ridge, a previous study showed that the clinician have changed the treatment plan only 3.9% of all cases after receiving the cross-sectional image in addition to the clinical examination and panoramic radiograph [30]. The importance of CBCT image in the adequate ridge dimension seems to be low. However, it highly depends on the clinician's experience in evaluating the ridge morphology through the muscle attachments in posterior mandible area. Furthermore, this area is highly vascularized so even a small perforation can create various levels of complication from bleeding and infection to upper airway obstruction and mediastinitis [8, 9, 31, 32]. According to the present study, the lingual plate perforation can be occurred even on the alveolar ridge with adequate dimension. Hence, it is advisable for the clinician to take the CBCT prior to the dental implant treatment in the posterior mandibular area especially on the first molar area. The CBCT images can be beneficial in planning the implant axis or changing the shape of fixture in the case that the lingual concavity prevented the placement of implant in the designated position.

Conclusion

The lingual concavity is commonly found on posterior mandibular area which resulted in 33.7% for the second premolar area and 42.3% for the first molar area. The risk of lingual plate perforation incidence was remarkable in the mandibular first molar area. Therefore, it is advisable for the clinician to take the CBCT prior to the dental implant treatment in the posterior mandibular area especially on the first molar area, even in the case with the adequate alveolar ridge dimension for standard implant placement.

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