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A New Classification of Anterior Mandible Edentulous Ridge Based on Cone Beam Computed Tomography

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ABSTRACT: *Purpose* – Dental implants in the anterior mandible have become increasingly common due to popular prosthetic treatments. The aim of this study was to evaluate cone beam computed tomography (CBCT) images of mandibles from edentulous patients in need of anterior dental implants to present qualitative descriptions in the mental interforaminal region and to present a new classification.

Material and Methods – A total of 180 (CBCT) scans of patients requiring implant installation in the anterior mandible for implant assisted overdenture treatment plan were evaluated regarding parameters such as ridge height, width, inclination, and undercuts. All assessments were performed on the cross-sectional images mesial to the mental foramen.

Results – The most common ridge morphology was cylindrical (74.1%) followed by atrophic (19.4%) and undercut (6.4%). The prevalence of atrophic ridge was significantly higher in females and ridge with undercut was significantly more detected in males ($P < 0.05$). D1 and D2 bone types was detected higher in males than in females ($P < 0.05$).

Conclusion – Cylindrical morphology was the most prevalent features of anterior mandible of edentulous patients. A CBCT scan is a useful diagnostic tool providing important information about anatomical structures and morphological variations in the sites of interest.

KEY WORDS: cone beam computed tomography, edentulous, anterior mandible, morphology

I. INTRODUCTION

Dental implants have become an important treatment modality in the esthetic, functional, and prosthetic rehabilitation of patients with partial and complete edentulism.[1] Dental implants have gained widespread popularity in prosthodontic rehabilitation including single tooth replacement, multiple teeth replacement, support for complete arch fixed dental prostheses, and retention for removable complete and partial overdentures.[2] Currently, dental implants in the anterior mandible have become increasingly common due to popular prosthetic treatments such as two-implant retained mandibular overdentures, mandibular fixed implant-supported prostheses, and implant-supported four-to-six-unit anterior fixed dental prostheses on partially edentulous patients. Each of these treatment modalities includes at least two implants in the anterior mandible, typically at the positions of the lateral incisors or canines. In fact, today, a mandibular two-implant overdenture therapy is considered a first-choice standard of care.[3] The mandibular anterior region has historically been considered a safe and predictable zone for implant surgery.[4,5] The predictability was attributed to the relatively thick cortices and dense bone; however, the safe zone concept was a misnomer, primarily due to the lack of knowledge and appreciation of anatomic structures in this region. The shape and morphology of anterior mandible can vary from cylindrical to thin knife edge.[6] Recent literature discuss a number of adverse events, after implant placement, ranging from neurosensory disturbances to life-threatening complications in this region, including formation of sublingual hematoma, upper airway obstruction, and profuse, pulsatile bleeding.[7,8] Therefore, profound knowledge of surgical anatomy of the anterior mandible is critical.

To insert implant fixtures into the anterior region of mandible, a thorough clinical examination and radiographic assessments are needed. These examinations help to assess the quality and quantity of mandibular bone. Conventional radiography such as panoramic, lateral cephalometric, and transphyseal views can present a general information of the jaw bone.[9] Cone beam computed tomography (CBCT) is a three dimensional radiography that can accurately define the shape, morphology, and quantity of mandibular bone.[10] This imaging modality presents cross-sectional views that can exactly indicate ridge height and width, the location of mental and incisive foramina, lingual concavity, and ridge angulation degree.[11,12]

The aim of this study is to evaluate a large series of available CBCT images of mandible from edentulous patients in need of anterior dental implants to present a qualitative description of morphological variations in the mental interforaminal region and to present a classification of anterior mandible ridge shape and morphology.

II. METHODS AND MATERIAL

This study was approved by research committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.DRC.REC. 1398.002).

A. Sample Size

This multicenter analytical study was performed on data from CBCT examinations of 180 patients referred to four private oral and maxillofacial radiology clinics in Tehran, Iran (two clinics in the city center, one center in the north, and one center in the west) from January 2018 to January 2019.

B. Evaluation of CT Scans

CBCT scans were taken with (1) HDX WILL (Dentri, Korea, maximum KVP of 100 and free field of view [FOV], Voxel size 200 μm, mAs = 8), (2) Scanora 3D (Sordex, Finland, KVP = 90, mAs = 8, FOV = 7.5 × 10, Voxel size 200 μm), (3) Newtom VGi (Verona, Italy, KVP = 110, automatic exposure control, FOV = 8 × 10, Voxel size 300 μm) and (4) Newtom Giano (Verona, Italy, KVP = 110, automatic exposure control, FOV = 8 × 10, Voxel size 300 μm). Images were evaluated using OnDemand3D application version 10.0.1 in a standardized position with interforaminal area perpendicular to horizontal axis. Demographic information including age and gender were recorded. All assessments taken from the CBCT scans were completed by one experienced oral and maxillofacial radiologist.

C. Inclusion Criteria

- CBCT scans must have been completely edentulous in the mandible.
- Patients with excessive posterior mandibular ridge atrophy and in need of anterior mandible implant assisted over denture were included.
- Scans must have been full volume.
- Images must have been of adequate resolution/diagnostic quality.

D. Exclusion Criteria

- Any scan that did not satisfy any of the requirements listed in the inclusion criteria.
- Any scan with radiographic noise or patient movements that did not allow assessments to be recorded in the planning software.
- Any scan that included maxillofacial trauma, orthognathic surgery, congenital anomalies, or pathology.
- Patients with previous anterior dental implant or bone graft.
- Patients with previous history of bisphosphonate drug consumption.

On the selected cross-sectional image, 7 mm mesial to anterior mental foramina loop situated left and right, ridge assessments such as height, width, angulation, undercut, corticocancellous proportion were performed in the interforaminal region according to Nickenig et al.[13] (Fig. 1).

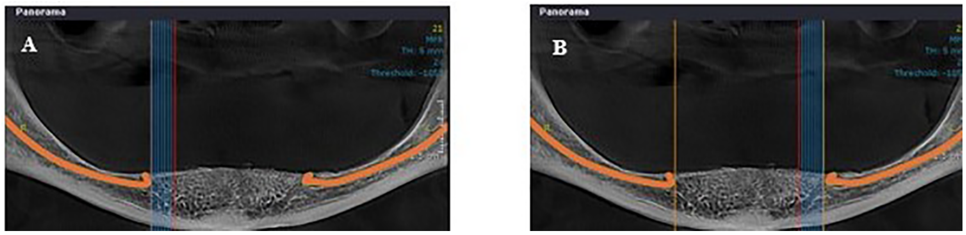


FIG. 1: Reconstructed panoramic image from CBCT scan. The most anterior hash line shows the site of assessment in (A) left side and (B) right side of mandibular edentulous ridge.

E. Categorization of Ridge Morphology

Cross-sectional views were evaluated with respect to the anatomical ridge morphology. Two investigators (a periodontist and an oral and maxillofacial radiologist) examined the scans. Ridge morphology was generally clear cut, and there was a general agreement on the classification of ridge morphology.

Following a pilot study assessing 60 mandibular edentulous ridges, three main categories were proposed: (1) cylindrical (ridge with no undercut, and sufficient height, more than 13 mm), (2) undercut (ridge with undercut either buccal, lingual, or both sides) and (3) atrophic (ridge with no undercut and excessive resorption, less than 13 mm height). Furthermore, each category was then divided into different subcategories (Table 1). In the cylindrical group, the ridge was defined as straight with angulation less than 25 degrees and angulated with angulation more than 25 degrees. If the ridge was wider in caudal portion compared with the crestal region, it was categorized as pedunculated. Table 1 demonstrates categories of ridge morphology.

In the undercut group, three categories were proposed: ridge with undercut on buccal side and smooth surface of lingual side was defined as the buccal group, ridge with concavity on the lingual side and smooth surface of buccal side was defined as the lingual group, and finally if there were undercuts both on lingual and buccal side, the term *dual* was applied.

In the atrophic group, the ridges were categorized into two groups. If the ridge had inclination it was termed as inclined and if no inclination was detected, the term *straight* was applied.

To include all ridge morphology, another criterion was also assessed in each site. If the ridge had severe narrowing in the crestal portion, this criterion was marked in the assessed site with the term *horn* (Fig. 2).

In each evaluated site, bone type was also assessed using the bone density meter in the application of OnDemand3D version 10 and were categorized into D1, D2, D3, and D4. The presence or absence of a prominent incisive canal was also evaluated.

F. Statistical Analysis

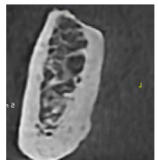
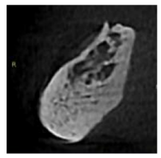
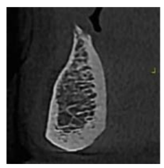
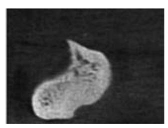
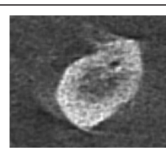
All data were entered into a database system and evaluated using SPSS® for Windows version 21 (SPSS Inc., Chicago, IL, USA, 2012). Patients' data were analyzed anonymously. Every case was assigned a registration number before evaluation to allow explicit and anonymous attribution of necessary information. For the categorical variable and cross-sectional shape of the anterior mandible, the distributions of each mandibular shape were compared using Fisher's exact test. An overall chi-square test was not used for mandibular shape. Instead, multiple Fisher's exact tests were used because of the rarity of some shapes. An alpha value of 0.05 was chosen to test for any statistical significance. Intraclass correlation coefficients (ICC) test was performed on 20 samples to assess the intraoperator reliability.

III. RESULTS

A. Intraoperator Reliability

Ridge assessments for the first and second replicates of 20 patients were recorded and intraclass

TABLE 1: The classification of ridge morphology into three main groups and further subgroups

Ridge morphology group	Ridge morphology subgroup	Cross-sectional image
Cylindrical	Straight	
	Angulated	
	Pedunculated	
Undercut	Buccal	
	Lingual	
	Dual	
Atrophic	Straight	
	Inclined	

correlation coefficients (ICC) were established for all measurements. Most measures demonstrated a high degree of reliability between the first and second replicates with ICC values exceeding from 0.73 to 0.99.

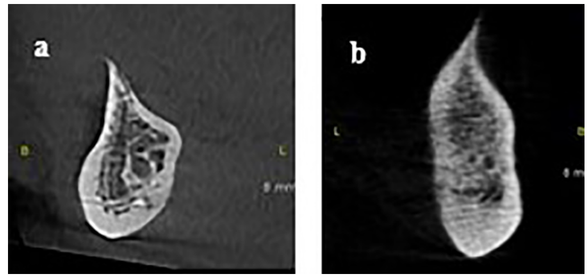


FIG. 2: (A) and (B) shows excessive narrowing in crestal portion of the ridge

B. Demographic Data

Within the 180 assessed CBCT scans, the gender distribution was 97 female (53%) and 83 male (46%). The age range of subjects in this study varied from 35 to 85 years old with mean of 64.33 ± 10.61 for females and 65.16 ± 10.88 for males.

C. Ridge Morphology Classification

In total 360 mandibular sites from 180 patients were assessed. The prevalence of ridge morphology in interforaminal region was 74.15% (N = 267) cylindrical, 19.4% (N = 70) atrophic, and 6.4% (N = 19.4) undercut. The prevalence of ridge morphology was 73.3% cylindrical, 19.4% atrophic, and 7.2% undercut type on the right side of interforaminal area and 75% cylindrical, 19.4% atrophic, and 5.6% undercut type on the left side of interforaminal area. No significant statistical difference was detected between right side and left side of interforaminal region ($P > 0.05$).

There was significant difference between male and female in ridge morphology, as atrophic ridge was significantly more seen in females (P = 0.00) and undercut ridge was significantly more detected in males (P = 0.00) (Table 2).

The most common form of cylindrical ridge was straight (75.6%), followed by pedunculated (16.4%) and angulated (8.0%) (P = 0.00). The most common form of ridge with undercut, was dual (56.5%), followed by buccal (34.8%) and lingual (8.7%) (P

TABLE 2: The prevalence of ridge morphology in total evaluated sites and in males and females

Ridge morphology	Male *N* (%)	Female *N* (%)	Total *N* (%)
Cylindrical	127 (35.3%)	140 (52.3%)	267 (74.15%)
Atrophic	23 (38.5%)	47 (65.6%)	70 (19.4%)
Undercut	16 (66.45%)	7 (30.4%)	23 (6.4%)
P value	—	0.006	—

= 0.01). The most common form of atrophic ridge was straight (77.9%) followed by inclined (22.1%) ($P = 0.00$).

No statistically significant difference was detected in subgroups between the two genders ($P > 0.05$) (Table 3).

D. Excessive Ridge Narrowing in the Crestal Portion (Horn)

Within the total assessed sites, the prevalence of ridge horn was 24.7% ($N = 89$). 16.3% ($N = 27$) of males and 32.0% ($n = 62$) of females had ridge horn and a statistically significant difference was detected between the two genders ($P = 0.01$) (Table 4).

E. Incisive Canal Prominence

Within the total assessed sites, the prevalence of prominent incisive canal was 5% ($N = 18$); 6.0% ($N = 10$) of males and 4.1% ($n = 8$) of females had prominent incisive canal although this difference was not statistically significant ($P > 0.05$) (Table 4).

F. Bone Type

The most frequent bone type was D3 with 49.7% ($N = 179$) prevalence, following D2 with 29.2% ($N = 105$), D1 with 9.2% ($N = 33$), D2–D3 with 8.3% ($N = 30$), D1–D2 with 3.1% ($N = 11$), and D4 with 0.6% ($N = 2$) prevalence respectively (Fig. 3).

Bone type D1 and D2 were significantly more seen in males ($P < 0.05$) while bone type D3 was significantly more detected in females ($P < 0.05$).

G. Relation between Age and Ridge Morphology

There was a significant decrease in concavity and height (bone loss) associated with age ($P = 0.00$). Atrophic ridge was significantly more detected in older patients ($P = 0.01$).

TABLE 3: The number and prevalence of ridge morphology subgroups in total evaluated sites and in each gender

Ridge morphology group	Ridge morphology subgroup	Male *N* (%)	Female *N* (%)	Total *N* (%)
Cylindrical	*Straight*	99 (29.2%)	99 (12.3%)	198 (75.6%)
	Angulated	9 (7.2%)	12 (8.8%)	21 (8%)
	Pedunculated	17 (13.6%)	26 (19%)	43 (16.4%)
P value	—	0.41		0.00
Undercut	*Buccal*	6 (37.5%)	2 (28.6%)	8 (34.8%)
	Lingual	0 (0%)	2 (28.6%)	2 (8.7%)
	Dual	10 (65.5%)	3 (42.9%)	13 (56.5%)
P value	—	0.08		0.01
Atrophic	*Straight*	18 (81.8%)	35 (76.1%)	53 (77.9%)
	Inclined	4 (18.2%)	11 (23.9%)	15 (22.1%)
P value	—	0.75		0.00

TABLE 4: The number and prevalence of ridge horn and prominent incisive canal in total evaluated sites and in each gender

Criteria	Male *N* (%)	Female *N* (%)	Total *N* (%)
Ridge horn	27 (16.3%)	62 (32.0%)	89 (24.7%)
P value	0.01		
Prominent incisive canal	10 (6.0%)	8 (4.1%)	18 (5%)
P value	0.41		

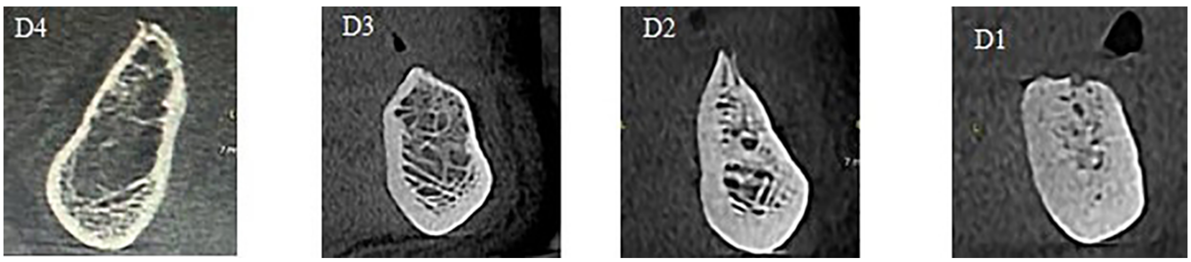


FIG. 3: Various bone types in anterior mandible

H. Discussion

The purpose of this study was to evaluate CBCT images of mandibles from edentulous patients with severe alveolar resorption and in need of anterior dental implants to present qualitative descriptions and morphological classification in the mental interforaminal region.

As dental implants have gained widespread popularity in prosthodontic rehabilitation, the number of reports citing adverse events has increased as well.[14,15] CBCT allows a complete visualization of the morphology of the surgical site and therefore enables interactive treatment planning.[16]

Various studies have evaluated the morphology of posterior mandible,[17–23] however, the mandibular morphology in the anterior region has not been extensively researched. To our knowledge, there are few studies that evaluate this region in particular for implant placement or attempt to classify the morphology.[11,13,16]

The results of this study suggested three main morphology groups in interforaminal area: cylindrical, undercut, and atrophic with prevalence of 74.15%, 19.4%, and 6.4%, respectively. This result is in consensus with previous studies conducted by Quirynen et al.,[11] and Nickenig et al.,[13] and Yoon et al.[16] In the study of Quirynen the most frequent morphology of the interforaminal region was with no undercut in buccal or lingual side (69.5%) followed by lingual slope of the ridge (28.1%) and lingual concavity (2.4%). In the study of Nickenig et al., the ridge morphology in the premolar-canine region was 60.9% parallel, 24.7% convex, and 14.4% with undercut.

In 2017, Yoon et al.[16] conducted a study to evaluate variations in and the prevalence of mandibular lingual concavity. CBCT scans of 104 edentulous patients were assessed in anterior mandibular region. The scans were classified into one of three categories, parallel, concave, or convex, based on the measurements of the level of concavity degree, as well as the mandibular morphology observed. Of the three different morphological classifications used, the vast majority were identified as parallel with the prevalence of 51% in the anterior mandibular region.[16]

In the study of Watanabe[24] the most frequent ridge morphology in interforaminal region was with buccal concavity (74%) followed by round ridge (17%) and ridge with lingual concavity (8%). In the study of Bulut et al.,[25] ridge with buccal concavity and round lingual side were more frequent (45%) followed by ridge with lingual concavity and round buccal side (30%) and ridge with both round lingual and buccal sides (25%). The difference between studies might be due to racial differences and various sample sizes. The other probability is due to evaluation of dentate and edentulous ridge ensemble and not separately in these studies.

Bone type is an important factor in implant stability. In the present study, a majority of bone types were D3, followed by D2 and D1. Isoda et al. evaluated the bone quality by CBCT and showed a high correlation with the primary stability of the implants, in which in patients with extremely low bone density, the primary stability of the implant immediately after placement was usually low.[26] However, Roze et al. indicated the dominant role of cortical bone thickness in primary implant stability.[27]

To prevent buccal or lingual cortical bone perforation during drilling, the implant should be inserted according to the shape of the mandible. To include various morphology, this study further divided each morphology group to various subgroups. Each morphology is unique and has its own individual treatment plan before implant insertion, as outlined in the following sections.

1. Cylindrical Straight Ridge (Fig. 4)

In this type of ridge, the available ridge height and width is sufficient. The implant can be easily placed. Some cases, such as Fig. 4C, needs osteoplasty to achieve sufficient bone width. This would be helpful because the discrepancy between the anterior and posterior segments of ridge will be reduced. The use of hybrid prosthesis and stud attachment is further suggested in the implant assisted overdenture treatment plan.[28]

2. Cylindrical Angulated Ridge (Fig. 5)

In this type of ridge the available ridge height and width are sufficient, however, in severe angulated samples, the length of the implant should be reduced to prevent from perforation. Lingual concavities must be detected and considered into initial treatment plan.

3. Cylindrical Pedunculated Ridge (Fig. 6)

Due to decrease in bone width in the crestal portion compared with the caudal portion, slight bone reduction, at the 2–4 mm crestal area, is suggested prior to implant placement.

4. Atrophic Straight Ridge (Fig. 7)

In this type of ridge, the amount of available bone height and width is moderately sufficient, however we face basal bone rather than the alveolar process.

FIG. 4: Cylindrical straight ridge: (A and C) cross-sectional and (B) panoramic view

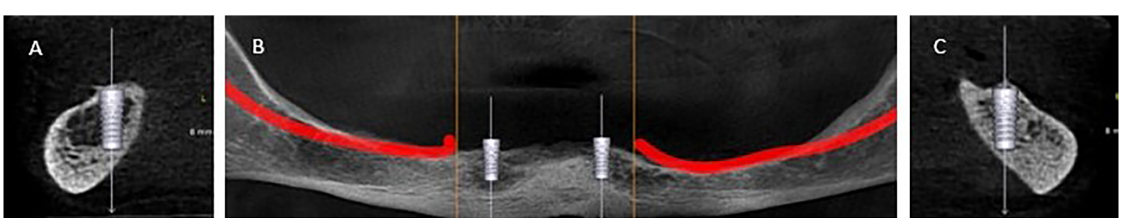


FIG. 5: Cylindrical angulated ridge: (A and C) cross-sectional and (B) panoramic view

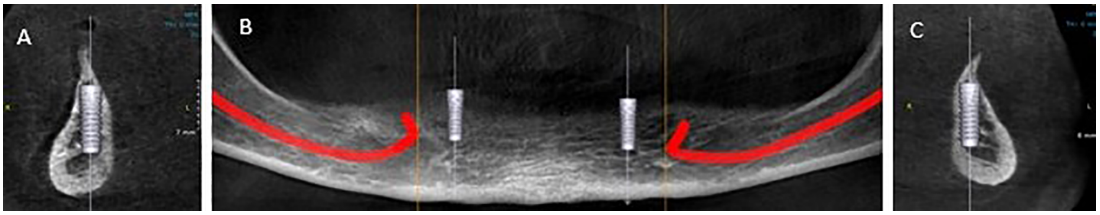


FIG. 6: Cylindrical pedunculated ridge: (A and C) cross-sectional and (B) panoramic view

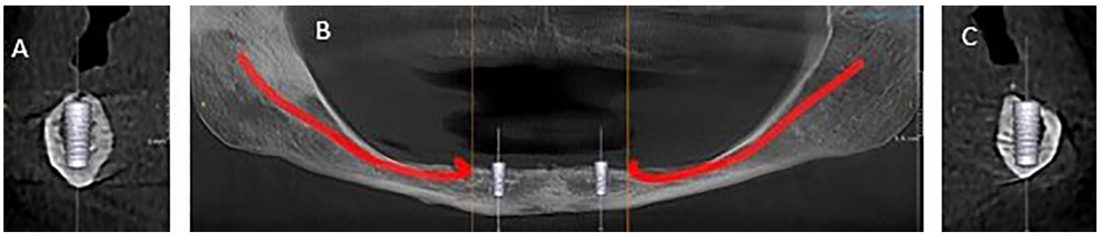


FIG. 7: Atrophic straight ridge: (A and C) cross-sectional and (B) panoramic view

Drilling process will be more difficult and risk of bone fracture, especially during implant installation with high torque, should be mentioned.[26]

5. Atrophic Angulated Ridge (Fig. 8)

In this type of ridge, attention should be made both to the insufficient height and lingual inclination of the ridge. The use of shorter implants and drilling in proper direction prevents from lingual plate perforation.

6. Undercut in Buccal Side of the Ridge (Fig. 9)

In this type of ridge attention should be made to the undercut on buccal side, if the undercut does not reach the implant, no measure is needed. If the undercut is in the crestal portion, bone graft may be suggested.

7. Undercut in Lingual Side of the Ridge (Fig. 10)

In this type of ridge attention should be made to the undercut on lingual side, if the undercut does not reach the implant, no measure is needed. If the undercut is in the crestal portion, bone graft may be suggested.

8. Undercut in Lingual and Buccal Side of the Ridge (Dual) (Fig. 11)

Implant-based rehabilitation in the interforaminal region can be compromised in cases of severe alveolar constriction or the so-called hourglass

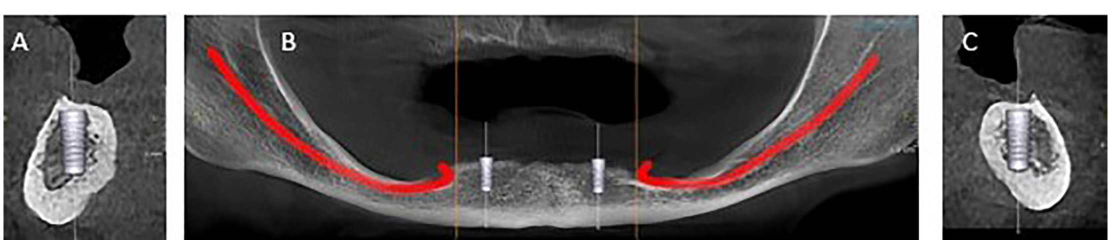


FIG. 8: Atrophic angulated ridge: (A and C) cross-sectional and (B) panoramic view

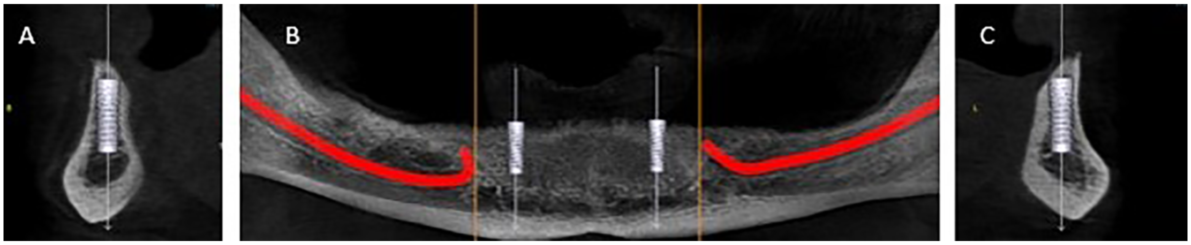


FIG. 9: Undercut in buccal side of the ridge: (A and C) cross-sectional and (B) panoramic view

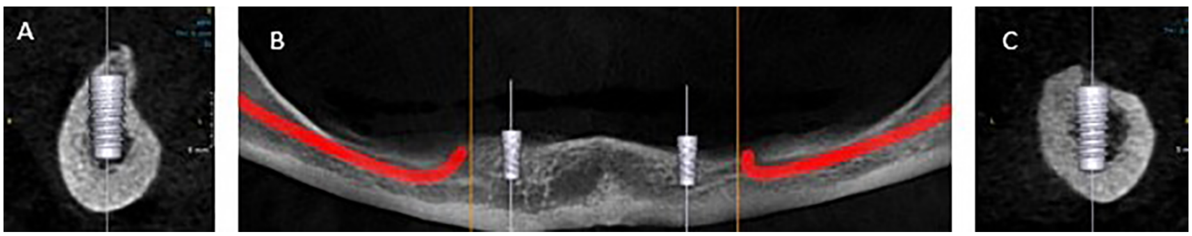


FIG. 10: Undercut in lingual side of the ridge: (A and C) cross-sectional and (B) panoramic view

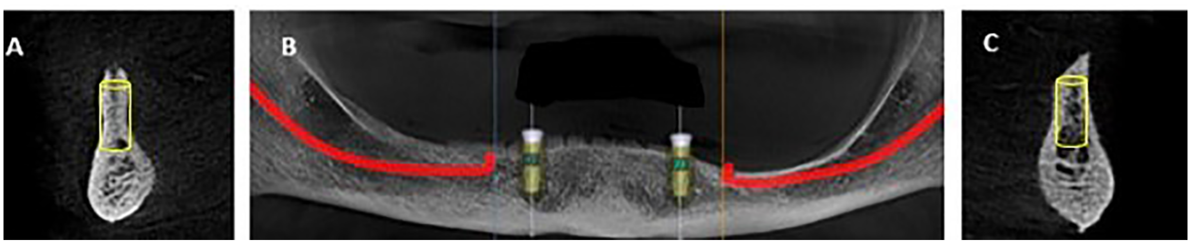


FIG. 11: Undercut in lingual and buccal side of the ridge (dual): (A and C) cross-sectional and (B) panoramic view (schematic cylinder placed to better show the concavities)

mandible variant. This type of ridge has osseous constriction at the alveolar–basal bone junction. Butura et al. suggested that the incidence of the hourglass variant is about 3.98%.[29] This extreme narrowing of bone makes dental implant placement challenging and often requires bone grafting procedures.[30]

An alternative treatment approach to dental implant placement in ridge with both buccal and lingual concavities is complete ostectomy past the bony constriction to an optimal width; although, reduction of the alveolar bone potentially brings crestal bone nearer to vital structures such as the sublingual and submental arteries.[31] Therefore, it is beneficial to further examine cross-sectional patterns of bone to not only identify the incidence of the hourglass variant, but also other potentially remarkable bony variations as well.

IV. STUDY LIMITATION AND RECOMMENDATIONS

All observations were made by one observer, which may introduce bias in data gathering. However, this may also be viewed as a strength, as it eliminates heterogeneity; additionally, the intraoperator reliability testing for the pilot study of 20 samples showed high consistency in measurements.

While the jaw shapes described were remarkably constant, some variations occur within each group. These variations were further categorized into compound morphology and were not included in this study due to the low prevalence. Future studies can expand the variations of ridge morphology and include the rarities.

The use of three-dimensional cross-sectional imaging using CBCT has resulted in better visualization of alveolar ridge topography and proximity of vital anatomic structures. However, current guidelines continue to only recommend the use of CBCT on an individual needs basis as an alternative to conventional imaging.[32] Not all cases warrant full CBCT analysis, which potentially increases the cost of treatment as well as radiation exposure to the patient. It is most advisable to apply the smallest suitable field of view when capturing a CBCT scan from patients eligible for assessments.[33,34]

Further studies can explore potential anatomic changes with systemic diseases and drug consumption. Furthermore, correlations can be made exploring possible relationships between mandibular cross-sectional morphology and race, skeletal classification, or length of time that the subject has been edentulous. Finally, future studies could be conducted in a similar manner concerning the posterior mandible.

V. CONCLUSION

Considering all limitations within this study, cylindrical morphology and D3 bone type were the most prevalent features of anterior mandible of edentulous patients. The results of the current study offer some clinical guidelines for practitioners who perform any surgical or prosthetic intervention in the anterior mandible.

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