EVALUATION OF THE SUBMANDIBULAR FOSSA AND ITS CORRELATION TO IMPLANT PLACEMENT USING CONE-BEAM COMPUTED TOMOGRAPHY

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ABSTRACT

Evaluation of the submandibular fossa and its correlation to implant placement using Cone-Beam Computed Tomography

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Background: The alveolar ridge morphology in the posterior mandibular region has many variations that may pose fatal complications if not assessed and addressed properly.

Aim: The aim of this study is to assess the different morphological variations in the posterior mandible and attempt to propose a new classification for the submandibular concavity.

Materials and Methods: Cone Beam Computed Tomography (CBCT) from 195 patients taken from the Dubai Dental Hospital (DDH) database after going through the inclusion/exclusion criteria and analyzed. The data collected included width of the alveolar bone at the crest (Wc), width of the alveolar bone at the base (Wb), alveolar ridge height (Vcb), alveolar bone height below the P point (Vb) and alveolar bone height above the P point (Vc). Furthermore, age, gender, presence or absence of the first molar and if the submandibular undercut is present or absent.

Results: The selected 195 CBCT scans included 46.2% males and 53.8% females with an age ranging from 20 years to over 70 years old. In those, U type ridge (ridge with undercut) was found to be the most prevalent type (54.4% left, 52.1% right) followed by P type (parallel ridge) (27.2% left, 33.5% right) and the least type was the C type (convergent type) (18.5% left, 14.4% right). Alveolar ridge height had correlation with age, gender, ridge type, presence or absence of the first molar and presence or absence of an undercut. Alveolar ridge width had a correlation with the width of the alveolar bone at the crest and ridge type. The concavity depth has a correlation with the presence of the first molar, presence of an undercut and the ridge type.

Conclusion: Proper understanding of the ridge morphology lead to a safe and predictable dental implant planning and treatment. The proposed new classification can help the dental practitioner to provide accurate assessment of the submandibular concavity when planning for dental implant insertion in the posterior mandible, this will lead to safe and predictable treatment outcome.

DEDICATION

First and foremost, I would like to praise and thank the all mighty Allah for giving me the help, strength and guidance that allowed me to reach this point in my journey and my life.

Secondly, I would like to dedicate this thesis to parents for their love and support throughout my life and their help and prayers that helped me reach this point in my life.

I would also like to dedicate this thesis to my wife and my son for their love, support and patience throughout the three-year journey in MBRU.

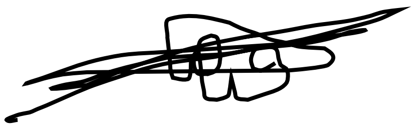
Finally, I would like to dedicate this thesis to my brothers and sisters for their help and motivations that helped me through the hard times.

DECLARATION

I declare that all the content of this thesis is my own work. There is no conflict of interest with any other entity or organization

Name: Faisal Alqaood

Signature:



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1. INTRODUCTION

Tooth loss can occur as a result of many conditions including but not limited to caries, periodontal disease, trauma, and non-restorable teeth. Dental implants are routinely used to restore missing teeth with a high success and survival rates that have been documented in the literature. The advancements in implantology allow for a streamlined methodology for dental implant placement with pleasing aesthetics and high patient acceptance. However, to ensure the success of dental implants, proper diagnosis and treatment planning is needed along with a thorough assessment of the region where the implant is to be placed. The assessment includes but is not limited to the height and width of the available ridge, bone density and quality, position of the dental prosthesis, presence of undercut and bone depth. Moreover, careful assessment of the related anatomical structures such as nasal floor, maxillary sinus, incisive nerve, mental foramen and inferior alveolar nerve are important to avoid any complications.

The posterior region of the mandible contains vital structures such as the inferior alveolar nerve and when damaged, the patient may develop paresthesia and loss of sensation of the lower lip and chin. Furthermore, the submental and sublingual arteries are also located in the area and could be damaged through the perforation of the lingual cortex of the mandible resulting in hemorrhage and formation of a hematoma. Post-surgical infection may also occur and can invade the submandibular space which can be life threatening as it can cause airway obstruction. Therefore, placing a dental implant in the posterior mandible requires careful planning in assessing the lingual undercut. The implant needs to be placed at appropriate angles to accommodate the mandibular body angulation with the aim of avoiding perforation of the lingual cortex. Periapical and/or panoramic radiographs have been widely used to assess the potential implant sites, however, due to their two-dimensional nature the bucco-lingual width of the mandible could not be assessed. To overcome such shortcomings, practitioners have used bone sounding/mapping, palpation of the region and dental casts to measure the buccolingual width of the bone.

Yet, these methods still lacked useful details of the anatomical variations and bone morphology. In addition, the accurate buccolingual relation of the inferior alveolar canal to the future dental implant position cannot be determined with the previously mentioned methods. Consequently, the use of the cone-beam computed tomography (CBCT) and computed tomography (CT) is very useful in evaluating the dental implant site. They offer a three-dimensional view of the area of interest. These views allow the clinician to assess the region and determine the position of the future dental implant in relation to the adjacent teeth, anatomical structures and the presence of any undercut. CT is a useful imaging modality for imaging dental implant sites but expose the patients to higher radiation dose. CBCT has many advantages over CT including lower radiation exposure and shorter scan time. CBCT is, therefore, a better imaging modality for pre-surgical assessment for dental implants.

2. REVIEW OF THE LITERATURE

2.1. Reasons for tooth loss:

Tooth loss can occur as a result of many causes with dental extraction being the most common cause. As dental extractions being used routinely by dental practitioners, the rate of the partially edentate mandible and/or maxilla increases. Schneider, et al. (2019), conducted a study in Switzerland involving 17784 patients with an age ranging between 15-74 years old and found that 5% of all dental treatments performed were extractions, Broers, et al. (2022). Del melo, et al. (2015), performed another study in Brazil and showed that 10% of all dental treatments performed between 1998-2012 were extractions of permanent teeth, Broers, et al. (2022). Dental extractions can be indicated by many conditions, dental caries was the most common condition, Broers, et al. (2022). Other conditions include periodontitis, endodontic problems, orthodontic considerations, failure of eruption, part of a prosthodontic treatment plan, Broers, et al. (2022), dental trauma, aesthetics, and other extractions justified by a medical condition such as dental treatment prior to radiotherapy or chemotherapy.

2.2. Sequala of tooth loss:

V.J. Kingsmil (1999), conducted a literature review describing post-extraction remodeling of the mandible. In which, it was reported that after dental extraction, the site undergoes an initial healing phase by which the blood clot fills the freshly created socket. Osteoblasts differentiate from Osteoprogenitor cells from the ruptured periodontal ligaments, invades the coagulum and form woven bone, Lin, et al. (1994). A course cancellous bone then replaces the woven bone while a new bone is formed deep surrounding the inferior dental canal, Boyne (1982), resulting in a reduced and narrow crest of the alveolar ridge, Atwood (1963). Following this, two mechanisms occur; continuous ridge resorption by the osteoclastic activity and endosteal apposition. However, the periosteal surface of the alveolar ridge has no new bone formation and as a result, it is porous without a complete cortical layer, Pudwill and Wentz (1975). The lamellar and the Haversian systems' arrangements are disrupted and the trabeculae are thin and poorly organized due to further internal remodeling, (Neufeld 1958; Seipel 1948).

2.3. Residual alveolar ridge classifications:

The residual alveolar ridge classification was introduced by Atwood (1963) and later reinforced by Cawood and Howell (1988). Both authors proposed six types and they are as follow; type Ⅰ was described as pre-extraction, type Ⅱ was described as post-extraction, type Ⅲ was described as high, well rounded residual ridge, type Ⅳ was described as knife-edge residual ridge, type Ⅴ was described as low, well rounded residual ridge and type Ⅵ was described as depressed residual ridge fig (1).

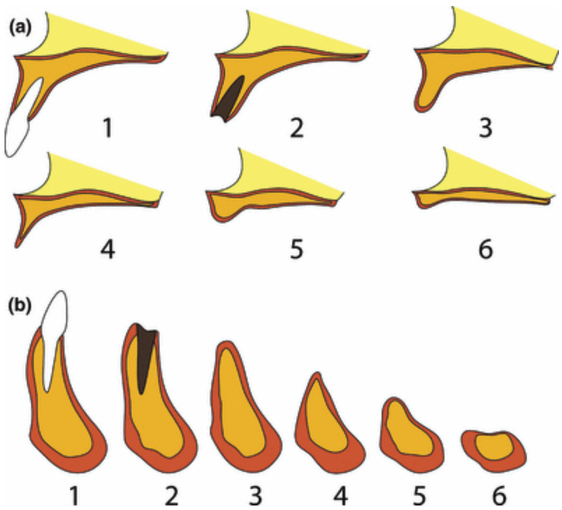

Figure (1) Cawood and Howell classification of alveolar ridge resorption pattern; (a) maxillary resorption pattern and (b) mandibular resorption pattern, Reich, et al. (2010).

Seibert et al. 1983 proposed another alveolar ridge classification which stated that class Ⅰ ridge had buccolingual alveolar ridge defect, class Ⅱ apicocoronal alveolar ridge defect and class Ⅲ had a combination of both, Seibert (1983) fig (2).

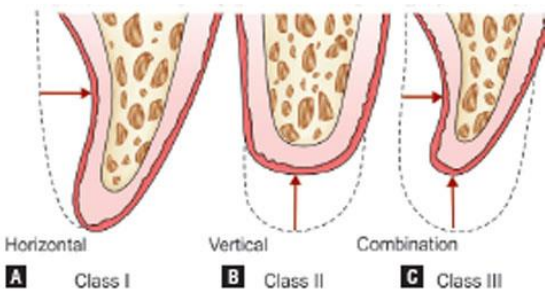

Figure (2) Seibert classification of alveolar ridge resorption (A) class Ⅰ (B) class Ⅱ (C) class Ⅲ, Bathala Shalu (2011)

2.4. Posterior mandibular morphology:

The anatomy of the posterior region of the lingual side of the mandible consist of the mylohyoid ridge which is a bony prominence where the mylohyoid muscle is attached. The body of the mandible posterior to the mylohyoid ridge can have an incline creating an undercut in the region called the submandibular fossa or retromylohyoid fossa. Chan et al. (2010), performed a study on one hundred and three subjects with a mean age of 51 years ranging from 23.7-70.4 years to determine the prevalence and degree of the lingual concavity in the mandible. Cone beam computed tomography (CBCT) of the mandibular first molar edentulous region was used analyzing the mandibular morphology 2mm above the inferior alveolar canal. Chan et al. classified the mandibular morphology into a convex (C), parallel (P) and undercut (U) fig (3) based on the presence of lingual concavity and the shape of the alveolar ridge.

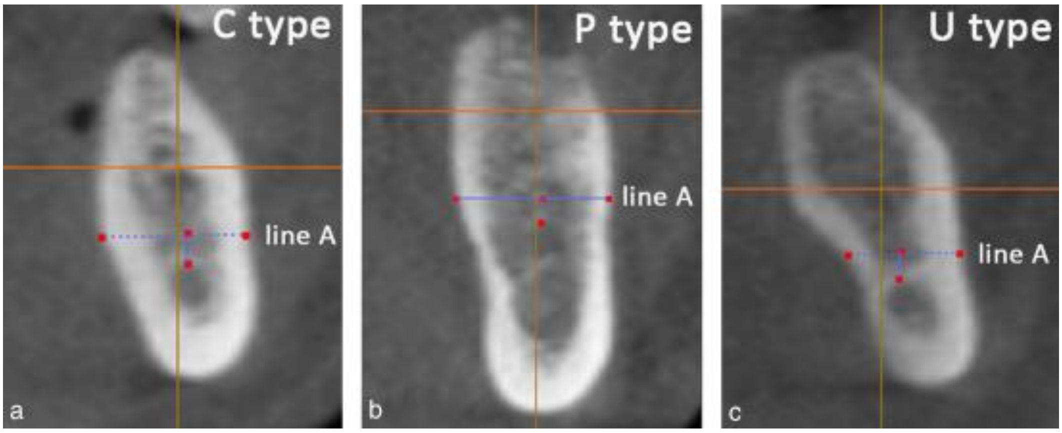

Figure (3) Illustration of Chan's classification of the alveolar ridge morphology; (a) C type, (b) P type and (c) U type, Chan, et al. 2010

Furthermore, the characteristics of the lingual concavity were determined using measurement of selected anatomical landmarks which included the depth, the angulation and the vertical location of the lingual concavity. U type was found to be the most prevalent type accounting for 66%, the mean undercut depth was 2.4mm, the mean angulation was 57.7 degree, the mean vertical distance from the most prominent point of the lingual concavity to the cementoenamel junction of the second premolar was 11.7mm and mean vertical distance from the most prominent point of the lingual concavity to the inferior border of the mandible was 14.9mm. Herranz-Aparicio, et al. (2016), evaluated CBCT scans from one hundred and fifty one subjects including sixty four males and eighty seven females. Type U was the most common type with 64.2%, the concavity angle was 66.6 degree in males and 71.6 in females and the concavity depth was 4.5mm in males and 3.1 in females. Salemi, et al. (2018), performed a cross-sectional analysis using cone beam computed tomography (CBCT) using the same methods and parameters as Chan, et al. (2010) One hundred and sixty-four CBCT scans collected from seventy-seven males and eighty-seven females with a mean age of 43.9 years. Type U was found to be the most common type with 50% followed by type C was 26.2% and type P was 23.8%. No significant difference was found between age and the depth of the undercut, type of ridge morphology or between the ridge morphology and gender. Males showed significantly greater ridge height and distance between the most prominent point and the ridge crest. Parnia, et al. (2010) and Rajput, et al. (2018), both analyzed CBCTs to assess the submandibular fossa using a different classification method than that used by Chan et al. The classification was proposed by Jung (2004) where the mandibular concavity morphology was classified into type Ⅰ with concavity depth less than 2mm, type Ⅱ with concavity between 2-3mm and type Ⅲ with concavity depth more than 3mm fig (4).

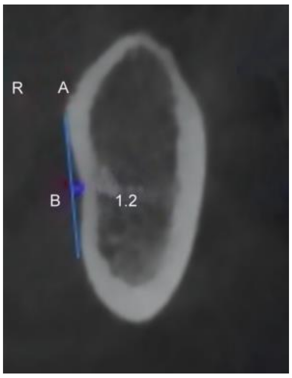

Figure (4) Illustration of Jung’s classification of the mandibular concavity morphology; Type Ⅰ, Rajput, et al. (2018)

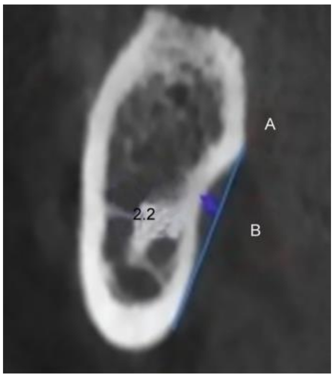

Figure (5) Illustration of Jung’s classification of the mandibular concavity morphology; Type Ⅱ, Rajput, et al. (2018)

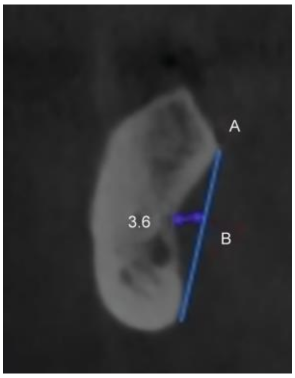

Figure (6) Illustration of Jung's classification of the mandibular concavity morphology; Type Ⅲ, Rajput, et al. (2018)

Both studies found type Ⅱ to be the most common type and no significant difference between age and gender.

2.5. Residual ridge resorption pattern:

The rate of residual alveolar ridge resorption is four times higher in the mandible when compared to the maxilla, Kingsmill (1999) and most of the resorption occurs in the anterior region, Tallgren (1957). The mylohyoid and external oblique ridges undergo very little changes and the bone around them resorbs, they become more prominent, and in some extreme cases it could form a deeper lingual concavity, Neufeld (1958). Ridge resorption occurs labially in the anterior region and lingually in the posterior region, Kingsmill (1999) and occurs most within the first year post-extraction with the highest rate being in the first few months, Tallgren (1966).

2.6. Factors affecting residual ridge resorption:

The rate of resorption can be affected by many factors which can be functional, anatomical, inflammatory or systemic, Kingsmill (1999).

2.6.1. Functional factors:

These factors include lack of mechanical stress, absence/presence of dentures, nature and magnitude of applied force, period of daily denture wear, number of sets and years of denture use, denture tooth selection, soft lining and muscle tone, Kingsmill (1999).

2.6.2. Anatomical factors:

These factors include facial form, original size of mandible, original depth of tooth socket, local bone quality, proportion of extrinsic fibers, age/availability of bone cells, quality of soft tissue, blood supply and muscle attachment, Kingsmill (1999).

2.6.3. Inflammatory factors:

These factors include trauma inflicted at extraction, pre-existing/residual Infection, periodontal disease, mucosal inflammation, local inflammatory mediators and denture hygiene.

2.6.4. Systemic factors:

These factors include age, gender, skeletal status, bone regulatory hormones and dietary calcium, Kingsmill (1999).

Furthermore, the effect of tooth loss does not stop at the mouth level but also extends further to include complications to the patients in terms of aesthetics and function which are the main reasons driving people to seek dental treatment.

2.7 Treatment options and planning:

Treatment options for the partially edentate mandible varies from considering a shortened dental arch, removable dental prosthesis and fixed dental prosthesis, which can be either tooth supported or implant supported. Dental implants are routinely used to restore missing teeth with a high success and survival rates that have been documented in the literature, Howe, et al. (2019). The advancements in implantology allow for a streamlined methodology for dental implant placement with pleasing aesthetics and high patient acceptance. However, to ensure the success of dental implants, proper diagnosis and treatment planning is needed along with a thorough assessment of the region where the implant is to be placed, Kalpidis and Setayesh

(2004). The assessment includes but is not limited to the height and width of the available ridge, bone density and quality, position of the dental prosthesis, presence of undercut and bone depth, (Froum et al. 2011; Watanabe, et al. 2010). Moreover, careful assessment of the related anatomical structures such as nasal floor, maxillary sinus, incisive nerve, mental foramen and inferior alveolar nerve are important to avoid any complications, Isaacson (2004).

2.8. Anatomical landmarks in the posterior mandible:

The posterior region of the mandible contains vital structures such as the inferior alveolar nerve and when damaged, the patient may develop paresthesia and loss of sensation of the lower lip and chin, (Chan, et al. 2011; Uchida, et al. 2012). Furthermore, the submental and sublingual arteries are also located in the area and could be damaged through the perforation of the lingual cortex of the mandible resulting in hemorrhage and formation of a hematoma which can have fatal consequences, (Greenstein, et al. 2008; Leong, et al. 2011; Rajput, et al. 2018). Post-surgical infection may also occur and can invade the submandibular space which can be life threatening as it can cause airway obstruction (Berberi, A., et al. 1993; Dubois, et al. 2010; Givol, et al. 2000). Therefore, placing a dental implant in the posterior mandible requires careful planning in assessing the lingual undercut. The implant needs to be placed at appropriate angles to accommodate the mandibular body angulation with the aim of avoiding perforation of the lingual cortex.

2.9. Assessment of the posterior mandibular region:

Periapical and/or panoramic radiographs have been widely used to assess the potential implant sites. Panoramic radiographs are commonly available, provide information on the mandible and the maxilla and are relatively inexpensive. Panoramic radiographs are useful in the initial diagnostic phase of implant planning, Tyndall, et al. (2012), however, due to their two-dimensional nature the bucco-lingual width of the mandible could not be assessed, (Chen et al. 2008; Tyndall, et al. 2012). To overcome such shortcomings, practitioners have used additional measures such as bone sounding/mapping, palpation of the region and dental casts to measure the buccolingual width of the bone.

Yet, these methods still lacked useful details of the anatomical variations and bone morphology. In addition, the accurate buccolingual relation of the inferior alveolar canal to the future dental implant position cannot be determined with the previously mentioned methods.

2.10. CBCT and CT:

The use of the cone-beam computed tomography (CBCT) and computed tomography (CT) is very useful in evaluating the dental implant site. They offer a three-dimensional view of the area of interest, Tyndall, et al. (2012). These views allow the clinician to assess the region and determine the position of the future dental implant in relation to the adjacent teeth, anatomical structures and the presence of any undercut, Magat (2020). CT is a useful imaging modality for imaging dental implant sites however, it has some disadvantages such as higher cost and only available in hospitals and medical imaging centers when compared to the CBCT, Chan, et al. (2011). CBCT differs from CT by the use of a single x-ray source producing a cone beam of radiation while the CT produces a fan beam of radiation, Tyndall, et al. (2012). CBCT uses a single flat-panel or image intensifier radiation detector that is less expensive and the imaging is performed by the use of a rotating platform where the x-ray source and detector are fixed, Tyndall, et al. (2012). Multiple, sequential and planar projection images can be acquired by the rotation of the x-ray source and detector around the object being scanned, Tyndall, et al. (2012). An arc of rotation of 180 or more is required and the images are then mathematically reconstructed into a volumetric data, Tyndall, et al. (2012). The entire field of view is irradiated simultaneously in only one rotational sequence allowing the collection of enough data for volumetric image reconstruction, Tyndall, et al. (2012). Many CBCT devices can provide panoramic and cephalometric imaging as they are multimodal, in addition, CBCT devices are technically operated with the same ease as panoramic devices, they are suitable for the dental office as they have a low footprint, they collimate the beam specifically to the region of interest and thereby reducing the radiation exposure to the patient and they can produce submillimeter resolution images of high quality, Tyndall, et al. (2012). Nevertheless, CBCT is still inferior to CT in soft tissue contrast as the data collected for creating the image contains considerable noise caused by the scattered radiation and therefore, CBCT are not the optimal choice for detection of small changes in radiodensity, Tyndall, et al. (2012). The volumetric datasets collected in CBCT and CT can be exported in DICOM (Digital Imaging and Communications in Medicine) format allowing good three-dimensional digital implant planning when imported in a third-party designing software, Tyndall, et al. (2012). The software can be used to create virtual image-displays and can simulate implant placements and can fabricate a computer-guided surgery, Tyndall, et al. (2012). CBCT has many advantages over CT including lower radiation exposure, shorter scan time, the equipment used is far less expensive and the software used for planning implants is much easier to use and more useful, (Ramaswamy, et al. 2020; Tyndall, et al. 2012). CBCT is, therefore, a better imaging modality for pre-surgical assessment for dental implants.

2.11. CBCT guidelines:

2.11.1. SEDENTEXCT guidelines:

SEDENTEXCT was a collaborative project that aimed to acquire key information necessary for sound and scientifically based clinical use of CBCT in dental and maxillofacial imaging. Basic guidelines were issued in 2012 for the use of CBCT and it stated that:

1- CBCT examinations must not be carried out unless a history and clinical examination have been performed.

2- CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.

3- CBCT examinations should potentially add new information to aid the patient's management.

4- CBCT should not be repeated "routinely" on a patient without a new risk/benefit assessment having been performed.

5- When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT practitioner to perform the justification process.

6- CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional radiographs.

7- CBCT images must undergo a thorough clinical evaluation (radiological report) of the entire database.

8- Where it is likely that evaluation of soft tissue will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MRI, rather than CBCT.

9- CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient.

10- Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used.

11- A quality assurance program must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures.

12- Aids to accurate positioning (light beam markers) must be used.

13- All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.

14- CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility uses and patients, has not significantly deteriorated.

15- For staff protection from CBCT equipment, the guidelines detailed in 6 of the European Commission documents “Radiation protection 136. European Guideline on Radiation Protection in Dental Radiology” should be followed.

16- All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection.

17- Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted.

18- Dentists responsible for CBCT facilities who have not previously received adequate theoretical and practical training should undergo a period of additional theoretical and practical training that has be validated by an academic institution (university or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programs should involve a DMF Radiologist.

19- For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and maxilla up to the floor of the nose (e.g. 8cm X 8cm or smaller fields of view). Clinical evaluation (radiological report) should be made by a specially trained DMF Radiologist or, where this is impracticable, an adequately trained general dental practitioner.

20- For non-dento-alveolar small fields of views (e.g. temporal bone) and all craniofacial CBCT images (fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ and the maxilla up to the floor of the nose), clinical evaluation (radiological report) should be made by a specially trained DMF Radiologist or by a clinical Radiologist (Medical Radiologist).

Furthermore, SEDENTEXCT issued specific guidelines for the use of CBCT in implant dentistry and they are indicated in the following scenarios:

- In single maxillary tooth:
  - When the incisive canal is involved.
  - When there is a descent in the maxillary sinus.
  - When there is a clinical doubt about the shape of the alveolar ridge.
- In partially dentate maxilla:
  - When there is a descent in the maxillary sinus.
  - When there is a clinical doubt about the shape of the alveolar ridge.
- In the edentulous maxilla:
  - When there is a descent in the maxillary sinus.
  - When there is a clinical doubt about the shape of the alveolar ridge.
- In single mandibular tooth:
  - When there is a clinical doubt about the position of the mandibular canal.
  - When there is a clinical doubt about the shape of the alveolar ridge.
- In the partially dentate mandible:
  - When there is a clinical doubt about the position of the mandibular canal or mental foramen.
  - When there is a clinical doubt about the shape of the alveolar ridge.
- In the edentulous mandible:
  - When there is a severe resorption
  - When there is a clinical doubt about the position of the mandibular canal if posterior implants are to be placed.

- When there is a clinical doubt about the shape of the alveolar ridge.

2.11.2. The American Academy of Periodontology guidelines:

The American Academy of Periodontology Best Evidence Consensus Statement on Selected Oral Application for Cone-Beam Computed Tomography, Mandelaris, et al. (2017) issued an expert opinion supporting the potential application of CBCT in the surgical management of patients requiring dental implants in the following scenarios:

- When there is a question regarding selection of implant sites, number, diameter, length or loading strategy.
- When the patient presents with a thin phenotype or there are aesthetic concerns (risk for bone or soft tissue deformities).

2.11.3. The American Academy of Oral and Maxillofacial Radiology guidelines:

The American Academy of Oral and Maxillofacial Radiology issued recommendations for the selection criteria for the use of radiology in dental implant, Tyndall, et al. (2012):

- Recommendation 1: Panoramic radiography should be used as the image modality of choice in the initial evaluation of the dental implant patient.
- Recommendation 2: Use intraoral periapical radiography to support the preliminary information from panoramic radiography.
- Recommendation 3: Do not use cross-sectional imaging, including CBCT, as initial diagnostic imaging examination.
- Recommendation 4: The radiographic examination of any potential implant site should include cross-sectional imaging orthogonal to the site of interest.
- Recommendation 5: CBCT should be considered as the imaging modality of choice for preoperative cross-sectional imaging of potential implant site.

- Recommendation 6: CBCT should be considered when clinical conditions indicate a need for augmentation procedures or site development before placement of dental implant.
- Recommendation 7: CBCT imaging should be considered if bone reconstruction and augmentation procedures (e.g. ridge preservation or bone grafting) have been performed to treat bone volume deficiencies before implant placement.
- Recommendation 8: In the absence of signs or symptoms, use intraoral periapical radiography for the postoperative assessment of implants. Panoramic radiographs may be indicated for more extensive implant therapy cases.
- Recommendation 9: Use cross-sectional imaging (particularly CBCT) immediately postoperatively only if the patient presents with implant mobility or altered sensation, especially if the fixture is in the posterior mandible.
- Recommendation 10: Do not use CBCT imaging for periodic review of clinically asymptomatic implants.
- Recommendation 11: Cross-sectional imaging, optimally CBCT, should be considered if implant retrieval is anticipated.

3. AIM

The aim of this study is to assess the submandibular fossa morphology prevalence and correlate its various characteristics with implant placement in posterior mandible.

3.1. Specific objectives:

- Analyze CBCT scans to identify various characteristics of submandibular gland fossa (SGF).
- Explore the relationship between various types of SGF and the inferior alveolar canal.
- Explore the clinical relevance of each type of SGF to the pre-surgical planning for dental implant.
- Attempt to propose a new classification system to describe the posterior alveolar ridge morphology.

4. MATERIALS AND METHODS

4.1. Sample and sample size:

The CBCT scans were obtained from the Dubai Dental Hospital (DDH). The scans were acquired for various indications.

A cross-sectional study was conducted to achieve the study's objectives. The CBCT scans were acquired with Sirona Galileos CBCT scanner and the following imaging protocol:

- kVp = 85
- mA = 28
- Exposure time = 14.21 seconds

Using size of 140 and found the prevalence of type I lingual concavity is 23%.

4.2. Sample size calculation:

The Cochrane sample size for simple random sampling is given by the formula:

$$n = z_{\alpha/2}^{2} \frac{p\,(1-p)}{d^{2}}$$

where p is the proportion of lingual concavity, d is the precision of the estimate and $z_{\alpha/2}^{2}$ is the quantile of the 95% confidence interval. Consider a relative precision of 25% for 'p'. Assuming a maximum permissible limit of 25% for p, and an estimated addiction proportion of lingual concavity to be 23%, then the calculated precision will be (25/100) *23= 0.25*23= 5.75. This means that we will be able to detect a 'p' (proportion) of 17.25% or more {half the value of relative precision on either side of 'p'–> +/- 5%: 35% to 28.75%}.

Suppose we want to estimate the proportion p of lingual concavity to within 5 percentage points with 95% probability. We ignore the stratification and two-stage design of the sample and assume the simple random sampling formula above. Suppose the maximum value of p is thought to be 23%. Then the formula gives the value for n as we use type III the sample will be: 1.96*1.96*0.15*(1-0.15)/ (0.05*0.05) = 195

These are possible values according to the paper published by Rajput et al. (2018).

4.3. Selection criteria:

4.3.1. Inclusion criteria:

- Patients with pre-operative CBCT scan.
- Patients over the age of 19 years old with no specifications in race or gender.
- Patients with at least one missing lower first molar.
- Availability of sufficient bone height to accommodate an 8 mm long dental implant.
- Availability of sufficient bone width of at least 3.5mm.

4.3.2. Exclusion criterial:

- Patients receiving bone graft with the dental implant placement.
- Presence of a bony lesion.
- Patients with congenital and/or developmental disorders.
- Presence of abnormal ridge morphology due to trauma.

4.4. Radiographic evaluation and data collection:

Firstly, a pilot study was undertaken and analyzed by the principle investigator using 10 CBCT scans. The 10 CBCT scans were then reviewed by the two supervisors and an agreement was reached between the principal investigator and the two supervisors on the time spent on analysis, the parameters used in the analysis and the practicability of performing the study.

Once an agreement is reached, the total number of the CBCT scans (195) were selected from the scans obtained from the DDH after obtaining DDH approval (appendix 1) according to the inclusion criteria. With the use of Microsoft Excel each patient's record number was assigned a random number and was added in a table. Afterwards, a master list was formulated including the assigned random numbers of the patients.

The CBCT scans taken were reviewed first by the principal investigator and the required number of scans were chosen according to the inclusion criteria. The final list of scans was exported in Digital Imaging and Communication in Medicine (DICOM) format from DDH's CBCT database. All patients' identifiers were removed and anonymized with the use of "Anonymize" tool of OsiriX image processing software by the principal investigator.

All CBCT scans were analyzed by the principal investigator using two daisy-chained Dell UP3017 monitors connected to MacBook Pro computer in controlled room lightening using OsiriX DICOM viewer. The SGF was analyzed with Dental3DPlugin image analysis tool.

Training and calibration of the principal investigator and one supervisor was done before the evaluation of the CBCT scans, starting with the training and calibration of the principal investigator in performing the pilot study using 10 scans. Once the pilot study is achieved, the principal investigator analyzed the region of interest in the required 195 CBCT scans. Furthermore, the principal investigator analyzed a randomly selected 30 CBCT scans from the 195 scans obtained two weeks after the first analysis was done and an intra-examiner agreement was analyzed using a Kappa test. An inter-examiner agreement analysis was done between the principal investigator and the supervisor using Kappa test after the supervisor analysed randomly selected 30 scans.

The region of interest includes the mandibular occlusal plane to the inferior border of the mandible. Depending on the presence of the first molar; if present, a cross-sectional image that crosses the midpoint of the edentulous ridge mesio-distally was chosen. If the first molar is absent; a cross-sectional image that is 5mm distal to cemento-enamel junction (CEJ) of the second premolar was chosen. If the second molar and the second premolar are missing or in the case of an edentulous ridge, a cross-sectional image that is 13mm distal to the distal border of the mental foramen (which is the sum of the average width of the second premolar (8mm) plus the 5mm previously chosen) was chosen. Once the cross-sectional image is obtained, the inferior alveolar nerve (IAN) was identified and a line was drawn 2mm coronal to the superior border of the IAN (line A). This is because the recommended distance between the implant and the IAN is at least 1.5mm. The intersection between line A and the lingual plate was identified (point A). The most prominent point on the lingual plate was identified (point P). The bucco-lingual width that is 2mm apical to the alveolar ridge crest (Wc) and at the level of line A (Wb) was measured for morphological characterization. Three lines were drawn and measured from the crest of the alveolar ridge to line A (Vcb), from point P to the inferior border of the mandible (Vb) and from the crest of the alveolar ridge to point P (Vc). The depth of the sublingual concavity was represented by the angle formed by the intersection of point P, point A and the horizontal line formed from point A and the intersection with line Vb (Fig 5). Additional information was collected including age, gender, ridge type, presence or absence of the first molar and presence or absence of a ridge undercut (concavity).

After the principal investigators and one supervisor analyses the scans, the data was reviewed by the three supervisors. Once the review is done, if a disagreement was found, the principal investigator and the three supervisors discussed the disagreements and agree on the final findings.

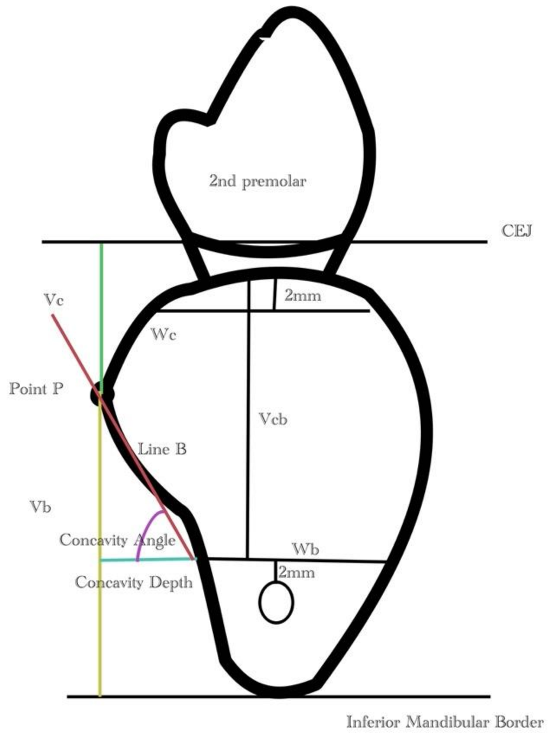

Figure (7) Illustration of the points collected from the CBCT for data analysis

4.5. Statistical analysis:

Data was entered into the computer using IBM-SPSS for windows version 28.0.0.0 (190) IBM (SPSS Inc., Chicago, IL). Frequency and percentage, measures of tendency and measures dispersion were performed as descriptive statistics for categorical and continuous data respectively. Kolmogorov-Smirnov was used to test the normality of continuous variables. The Mann-Whitney test and t-test were used for comparing means between two groups depending on the normality of the data. When comparing the means between more than two groups the Kruskal-Willi's test was used if the continuous data was not normally distributed, if the data was normal ANOVA test was used. Wilcoxon Signed Ranks test was used to test between pair measurements between left and right for different variables. A P-value of less than 0.05 was considered significant in all statistical analysis.

5. RESULTS

5.1. Characteristics of the sample:

Table 1: Characteristics of the sample under study

Items	No (%)
Gender	
Male	90 (46.2)
Female	105 (53.8)
Age	
20 - 29	40 (20.5)
30 - 39	68 (34.9)
40 - 49	38 (19.5)
50 - 59	31 (15.9)
60 - 69	15 (7.7)
70±	3 (1.5)

5.1.1. Gender:

The number of males included in the study was 90(46.2%), whereas the number of females included was 105(53.8%), (table 1).

5.1.2. Age:

Age was divided into six groups; group 1 was from the age of 20 till the age of 29 which included 40(20.5%) people, group 2 was from the age of 30 till the age of 39 which included 68(34.9%) people, group 3 was from the age of 40 till the age of 49 which included 38(19.5%) people, group 4 was from the age of 50 till the age of 59 which included 31(15.9%) people, group 5 was from the age of 60 till the age of 69 which included 15(7.7%) people and group 6 was anyone above the age of 70 years old which included 3(1.5%) people, (table 1).

5.2. Dental characteristics of the sample:

Table 2: Dental characteristics of sample under study

Items	No (%)
Left: first molar present	122 (62.6)
Right: first molar present	120 (61.5)
Left: ridge type	
C	36 (18.5)
P	53 (27.2)
U	106 (54.4)
Right: ridge type	
C	28 (14.4)
P	65 (33.5)
U	101 (52.1)

5.2.1. Presence of the first molar:

The first molar was present in the left side in 122(62.6%) cases and 120(61.5%) cases had their first molar present in the right side.

5.2.2. Ridge type:

The left side included 36(18.5%) cases with a convergent ridge type, 53(27.2%) cases had a parallel ridge type and 106(54.4%) cases had an undercut ridge type.

The right side included 28(14.4%) cases with a convergent ridge type, 65(33.5%) cases had a parallel ridge type and 101(52.1%) cases had an undercut ridge type.

5.3. Test of normality by Kolmogorov-Smirnova:

The data was normally distributed in the following parameters: width of the alveolar bone at the base on the right side, width of the alveolar bone at the base on the left side, ridge height above the P point on the right side, width of the alveolar bone at the crest on the left side, alveolar ridge height on the left side and ridge height above the P point on the left side and width of the alveolar bone at the crest on the left side.

The data was not normally distributed in the following parameters: width of the alveolar bone at the crest on the right side, alveolar ridge height on the right side, ridge height below the P point on the left side, ridge height below the P point on the right side, concavity depth on the left side, concavity depth on the right side, concavity angle on the left side and concavity angle on the right side.

Table 3: Test of normality by Kolmogorov-Smirnova

	Statistic	df	P-value
Left: width of the alveolar bone at the crest	0.062	192	0.066*
Right: width of the alveolar bone at the crest	0.077	192	0.008
Left: width of the alveolar bone at the base	0.063	192	0.063*
Right: width of the alveolar bone at the base	0.044	192	.200*
Left: alveolar ridge height	0.058	192	.200*
Right: alveolar ridge height	0.083	192	0.003
Left: ridge height above the P point	0.049	192	.200*
Right: ridge height above the P point	0.064	192	0.051*
Left: ridge height below the P point	0.092	192	<.001
Right: ridge height below the P point	0.074	192	0.012
Left: concavity depth	0.121	192	<.001
Right: concavity depth	0.118	192	<.001
Left: concavity angle	0.233	192	<.001
Right: concavity angle	0.203	192	<.001

5.4. Comparison of the measurements:

5.4.1. The left side analysis:

5.4.1.1. Gender:

Table 4: Comparison the measurements by gender

	Left			Right		
Items	Male	Female	P-value	Male	Female	P-value
width of the alveolar bone at the crest	9.28 (2.87)	8.57 (2.45)	0.068#	9.16 (2.49)	8.6 (32)	0.095##
width of the alveolar bone at the base	11.22 (2.08)	10.69 (2.21)	0.092#	11.13 (1.76)	10.67(1.98)	0.091#
alveolar ridge height	15.23 (3.73)	13.4 (3.46)	<0.001#	15.49 (3.94)	13.66(3.33)	0.047#
ridge height above the P point	18.47 (4.62)	16.02 (4.6)	<0.001#	17.98 (4.32)	16.77(4.98)	<0.001#
ridge height below the P point	10.16 (5.01)	9.76 (5.52)	0.370##	10.19 (4.62)	9.2 (5.59)	0.044##
concavity depth	1.72 (1.46)	1.56 (1.32)	0.521##	1.93 (1.56)	1.7 (1.48)	0.436##
concavity angle	57.35(28.72)	55.24 (28.65)	0.259##	57.38(27.67)	52.75(31.45)	0.636##

5.4.1.1.A. Width of the alveolar bone at the crest:

The P-value was 0.068 which was insignificant and the mean value for males was 9.28 (2.87), while for females it was 8.57(2.45).

5.4.1.1.B. Width of the alveolar bone at the base:

The P-value was 0.092 which was insignificant and the mean value for males was 11.22(2.08), while for females it was 10.69(2.21).

5.4.1.1.C. Alveolar ridge height:

The P-value was less than 0.001 which was significant and the mean value for males was 15.23(3.73), while for females it was 13.4(3.46).

5.4.1.1.D. Ridge height above the P point:

The P-value was less than 0.001 which was significant and the mean value for males was 18.47(4.62), while for females it was 16.02(4.6).

5.4.1.1.E. Ridge height below the P point:

The P-value was 0.370 which was insignificant and the mean value for males was 10.16(5.01), while for females it was 9.76(5.52).

5.4.1.1.F. Concavity depth:

The P-value was 0.521 which was insignificant and the mean value for males was 1.72(1.46), while for females it was 1.56(1.32).

5.4.1.1.G. Concavity angle:

The P-value was 0.259 which was insignificant and the mean value for males was 57.35(28.72), while for females it was 55.24(28.65).

5.4.1.2. Age group:

Table 5: Comparison measurements by age groups

	Left			Right		
Items	< 40 years	≥ 40 years	P-value	< 40 years	≥ 40 years	P-value
width of the alveolar bone at the crest	9.29 (2.53)	8.41 (2.77)	0.023#	9.35 (2.24)	8.25 (2.48)	<0.001##
width of the alveolar bone at the base	11.13 (1.9)	10.69 (2.44)	0.154#	10.95 (1.95)	10.8 (1.83)	0.566#
alveolar ridge height	14.79 (3.28)	13.57 (4.06)	0.025#	15.16 (3.18)	13.69 (4.19)	0.008#
ridge height above the P point	17.06 (4.71)	17.26 (4.84)	0.774#	17.29 (4.84)	17.39 (4.48)	0.887#
ridge height below the P point	10.01 (5.04)	9.86 (5.59)	0.610##	9.87 (5.17)	9.4 (5.21)	0.433##
concavity depth	1.64 (1.36)	1.62 (1.41)	0.889##	1.85 (1.65)	1.76 (1.34)	0.853##
concavity angle	57.09(28.41)	55.13 (29.02)	0.508##	54.18(30.89)	55.77(28.28)	0.985##

5.4.1.2.A. Width of the alveolar bone at the crest:

The P-value was 0.023 which was significant and the mean value for those below 40 years old was 9.29(2.77), while, the mean value for those who are 40 years old or above was 8.41(2.77).

5.4.1.2.B. Width of the alveolar bone at the base:

The P-value was 0.154 which was insignificant and the mean value for those below 40 years old was 11.13(1.9), while, the mean value for those who are 40 years old or above was 10.69(2.44).

5.4.1.2.C. Alveolar ridge height:

The P-value was 0.025 which was significant and the mean value for those below 40 years old was 14.79(3.28), while, the mean value for those who are 40 years old or above was 13.57(4.06).

5.4.1.2.D. Ridge height above the P point:

The P-value was 0.774 which was insignificant and the mean value for those below 40 years old was 17.06(4.71), while, the mean value for those who are 40 years old or above was 17.26(4.84).

5.4.1.2.E. Ridge height below the P point:

The P-value was 0.610 which was insignificant and the mean value for those below 40 years old was 10.01(5.04), while, the mean value for those who are 40 years old or above was 9.86(5.59).

5.4.1.2.F. Concavity depth:

The P-value was 0.889 which was insignificant and the mean value for those below 40 years old was 1.64(1.36), while, the mean value for those who are 40 years old or above was 1.62(1.41).

5.4.1.2.G. Concavity angle:

The P-value was 0.508 which was insignificant and the mean value for those below 40 years old was 57.09(28.41), while, the mean value for those who are 40 years old or above was 55.13(29.02).

5.4.1.3. Presence of first molar:

Table 6: Comparison of different measurements by the present of first molar

	Left			Right		
Items	Yes	No	P-value	Yes	No	P-value
width of the alveolar bone at the crest	10.04 (1.92)	6.99 (2.66)	<0.001#	10.14 (1.65)	6.81 (1.99)	<0.001##
width of the alveolar bone at the base	11.07 (2.06)	10.71 (2.32)	0.134#	10.9 (2.04)	10.84(1.64)	0.834#
alveolar ridge height	15.72 (2.94)	11.78 (3.51)	<0.001#	15.64 (3.28)	12.69(3.71)	<0.001#
ridge height above the P point	18.11 (4.79)	15.55 (4.30)	<0.001#	18.73 (4.82)	15.14(3.45)	<0.001#
ridge height below the P point	10.53 (5.49)	8.97 (4.79)	0.043##	9.48 (5.48)	9.95 (4.68)	<0.001##
concavity depth	1.75 (1.44)	1.44 (1.27)	0.087##	2.11 (1.61)	1.33 (1.22)	<0.001##
concavity angle	56.92 (29.3)	55.04 (27.62)	0.157##	58.64(28.33)	48.89(31.2)	0.005##

5.4.1.3.A. Width of the alveolar bone at the crest:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 10.04(1.92), while, the mean value for those with their first molar absent was 6.99(2.66).

5.4.1.3.B. Width of the alveolar bone at the base:

The P-value was 0.134 which was significant and the mean value for those with their first molar present was 11.07(2.06), while, the mean value for those with their first molar absent was 10.71(2.32).

5.4.1.3.C. Alveolar ridge height:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 15.72(2.94), while, the mean value for those with their first molar absent was 11.78(3.51).

5.4.1.3.D. Ridge height above the P point:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 18.11(4.79), while, the mean value for those with their first molar absent was 15.55(4.30).

5.4.1.3.E. Ridge height below the P point:

The P-value was 0.043 which was significant and the mean value for those with their first molar present was 10.53(5.49), while, the mean value for those with their first molar absent was 8.97(4.79).

5.4.1.3.F. Concavity depth:

The P-value was 0.087 which was insignificant and the mean value for those with their first molar present was 1.75(1.44), while, the mean value for those with their first molar absent was 1.44(1.27).

5.4.1.3.G. Concavity angle:

The P-value was 0.157 which was insignificant and the mean value for those with their first molar present was 56.92(29.3), while, the mean value for those with their first molar absent was 55.04(27.62).

5.4.1.4. Presence of undercut:

Table 7: Comparison of different measurements by the present of undercut

	Left			Right		
Items	Yes	No	P-value	Yes	No	P-value
width of the alveolar bone at the crest	8.90 (2.74)	8.84 (2.05)	0.465*	8.92 (2.43)	8.82 (2.13)	0.615**
width of the alveolar bone at the base	10.98 (2.17)	10.33 (1.98)	0.121*	8.92 (2.43)	10.58(1.83)	0.366*
alveolar ridge height	14.16 (3.75)	15.31 (2.85)	0.123*	14.32 (3.68)	16.35(3.27)	<0.001**
ridge height above the P point	17.53 (4.39)	12.59 (6.56)	0.006*	17.78 (3.68)	15.17(5.5)	0.006*
ridge height below the P point	9.46 (4.72)	15.78 (7.87)	0.002**	9.08 (4.74)	13.55(6.37)	0.026*
concavity depth	1.72 (1.4)	0.61 (0.64)	0.001**	2.01 (1.55)	0.71(0.69)	<0.001**
concavity angle	57.67(27.24)	38.82(39.95)	0.152**	56.60(27.49)	46 (39.71)	0.902**

5.4.1.4.A. Width of the alveolar bone at the crest:

The P-value was 0.465 which was insignificant and the mean value for those with an undercut was 8.90(2.74), while, the mean value for those without an undercut was 8.84(2.05).

5.4.1.4.B. Width of the alveolar bone at the base:

The P-value was 0.121 which was insignificant and the mean value for those with an undercut was 10.98(2.17), while, the mean value for those without an undercut was 10.33(1.98).

5.4.1.4.C. Alveolar ridge height:

The P-value was 0.123 which was insignificant and the mean value for those with an undercut was 14.16(3.75), while, the mean value for those without an undercut was 15.31(2.85).

5.4.1.4.D. Ridge height above the P point:

The P-value was 0.006 which was significant and the mean value for those with an undercut was 17.53(4.39), while, the mean value for those without an undercut was 12.59(6.56).

5.4.1.4.E. Ridge height below the P point:

The P-value was 0.002 which was significant and the mean value for those with an undercut was 9.46(4.72), while, the mean value for those without an undercut was 15.78(7.87).

5.4.1.4.F. Concavity depth:

The P-value was 0.001 which was significant and the mean value for those with an undercut was 1.72(1.4), while, the mean value for those without an undercut was 0.61(0.64).

5.4.1.4.G. Concavity angle:

The P-value was 0.152 which was insignificant and the mean value for those with an undercut was 57.67(27.24), while, the mean value for those without an undercut was 38.82(39.95).

5.4.1.5. Ridge type:

Table 8: Comparison of different measurements by the type of ridge

	Left		Right	
Measurements	Mean (SD)	P-value	Mean (SD)	P-value
Width of the alveolar bone at the crest				
C	6.75 (3.19)		6.66 (2.21)	
P	9.44 (2.24)	<0.001$^{\#\#}$	8.95 (2.17)	<0.001$^{\#}$
U	9.35 (2.32)		9.4 (2.29)	
Width of the alveolar bone at the base				
C	10.69 (1.99)		10.87 (1.15)	
P	10.42 (1.98)	0.046$^{\#\#}$	10.60 (1.85)	0.328$^{\#\#}$
U	11.28 (2.26)		11.05 (2.07)	
Alveolar ridge height	10.93 (2.16)			
C	12.59 (3.12)		12.64 (3.82)	
P	15.43 (3.01)	0.001$^{\#\#}$	15.54 (3.61)	0.002$^{\#}$
U	14.22 (3.98)		14.3 (3.56)	
Ridge height above the P point				
	14.81 (3.92)		14.8 (3.53)	
	17.04 (5.51)	0.002$^{\#\#}$	17.49 (5.15)	0.007$^{\#\#}$
	18.0 (4.36)		17.91 (4.44)	
Ridge height below the P point				
C	10.38 (5.42)		10.39 (5.16)	
P	11.23 (6.49)	0.173$^{\#}$	10.5 (5.75)	0.141$^{\#}$
U	9.15 (4.40)		8.96 (4.73)	
Concavity depth				
C	1.19 (0.96)		1.16 (1.09)	
P	1.42 (1.22)		1.37 (1.03)	
U	1.89 (1.53)	0.021$^{\#}$	2.27 (1.74)	<0.001$^{\#}$
Concavity angle				
C	52.68 (29.99)	0.207$^{\#}$	43.42 (31.63)	<0.001$^{\#}$

P	57.42 (31.45)		59 (32.33)		
U	56.8226.82)		55.97 (26.5)		

5.4.1.5.A. Width of the alveolar bone at the crest:

The P-value was less than 0.001 which was significant and the mean value for those with a convergent ridge was 6.75(3.19), the mean value for those with a parallel ridge was 9.44(2.24) and the mean value for those with an undercut ridge was 9.35(2.32).

5.4.1.5.B. Width of the alveolar bone at the base:

The P-value was 0.046 which was significant and the mean value for those with a convergent ridge was 10.69(1.99), the mean value for those with a parallel ridge was 10.42(1.98) and the mean value for those with an undercut ridge was 11.28(2.26).

5.4.1.5.C. Alveolar ridge height:

The P-value was less than 0.001 which was significant and the mean value for those with a convergent ridge was 12.59(3.12), the mean value for those with a parallel ridge was 15.43(3.01) and the mean value for those with an undercut ridge was 14.22(3.98).

5.4.1.5.D. Ridge height above the P point:

The P-value was 0.002 which was significant and the mean value for those with a convergent ridge was 14.81(3.92), the mean value for those with a parallel ridge was 17.04(5.51) and the mean value for those with an undercut ridge was 18(4.36).

5.4.1.5.E. Ridge height below the P point:

The P-value was 0.173 which was insignificant and the mean value for those with a convergent ridge was 10.38(5.42), the mean value for those with a parallel ridge was 11.23(6.49) and the mean value for those with an undercut ridge was 9.15(4.40).

5.4.1.5.F. Concavity depth:

The P-value was 0.021 which was significant and the mean value for those with a convergent ridge was 1.19(0.96), the mean value for those with a parallel ridge was 1.42(1.22) and the mean value for those with an undercut ridge was 1.89(1.53).

5.4.1.5.G. Concavity angle:

The P-value was 0.207 which was insignificant and the mean value for those with a convergent ridge was 52.68(29.99), the mean value for those with a parallel ridge was 57.42(31.45) and the mean value for those with an undercut ridge was 56.82(26.82).

5.4.2. Right side analysis:

5.4.2.1. Gender:

5.4.2.1.A. Width of the alveolar bone at the crest:

The P-value was 0.095 which was insignificant and the mean value for males was 9.16(2.49), on the other hand, the mean value for females was 8.6(3.2).

5.4.2.1.B. Width of the alveolar bone at the base:

The P-value was 0.091 which was insignificant and the mean value for males was 11.13(1.76), on the other hand, the mean value for females was 10.67(1.98).

5.4.2.1.C. Alveolar ridge height:

The P-value was 0.047 which was significant and the mean value for males was 15.49(3.94), on the other hand, the mean value for females was 13.66(3.33).

5.4.2.1.D. Ridge height above the P point:

The P-value was less than 0.001 which was significant and the mean value for males was 17.98(4.32), on the other hand, the mean value for females was 16.77(4.98).

5.4.2.1.E. Ridge height below the P point:

The P-value was 0.044 which was significant and the mean value for males was 10.19(4.62), on the other hand, the mean value for females was 9.2(5.59).

5.4.2.1.F. Concavity depth:

The P-value was 0.436 which was insignificant and the mean value for males was 1.93(1.56), on the other hand, the mean value for females was 1.7(1.48).

5.4.2.1.G. Concavity angle:

The P-value was 0.636 which was insignificant and the mean value for males was 57.38(27.67), on the other hand, the mean value for females was 52.75(31.45).

5.4.2.2. Age group:

5.4.2.2.A. Width of the alveolar bone at the crest:

The P-value was less than 0.001 which was significant and the mean value for those below 40 years old was 9.35(2.24), while, the mean value for those who are 40 years old or above was 8.25(2.48).

5.4.2.2.B. Width of the alveolar bone at the base:

The P-value was 0.566 which was insignificant and the mean value for those below 40 years old was 10.95(1.95), while, the mean value for those who are 40 years old or above was 10.8(1.83).

5.4.2.2.C. Alveolar ridge height:

The P-value was 0.008 which was significant and the mean value for those below 40 years old was 15.16(3.18), while, the mean value for those who are 40 years old or above was 13.69(4.19).

5.4.2.2.D. Ridge height above the P point:

The P-value was 0.887 which was insignificant and the mean value for those below 40 years old was 17.29(4.84), while, the mean value for those who are 40 years old or above was 17.39(4.19).

5.4.2.2.E. Ridge height below the P point:

The P-value was 0.443 which was insignificant and the mean value for those below 40 years old was 9.87(5.17), while, the mean value for those who are 40 years old or above was 9.4(5.21).

5.4.2.2.F. Concavity depth:

The P-value was 0.853 which was insignificant and the mean value for those below 40 years old was 1.85(1.65), while, the mean value for those who are 40 years old or above was 1.76(1.34).

5.4.2.2.G. Concavity angle:

The P-value was 0.985 which was insignificant and the mean value for those below 40 years old was 54.18(30.89), while, the mean value for those who are 40 years old or above was 55.77(28.28).

5.4.2.3. Presence of first molar:

5.4.2.3.A. Width of the alveolar bone at the crest:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 10.14(1.65), on the other hand, the mean value for those with their first molar absent was 6.81(1.99).

5.4.2.3.B. Width of the alveolar bone at the base:

The P-value was 0.834 which was insignificant and the mean value for those with their first molar present was 10.9(2.04), on the other hand, the mean value for those with their first molar absent was 10.84(1.64).

5.4.2.3.C. Alveolar ridge height:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 15.64(3.28), on the other hand, the mean value for those with their first molar absent was 12.69(3.71).

5.4.2.3.D. Ridge height above the P point:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 18.73(4.82), on the other hand, the mean value for those with their first molar absent was 15.14(3.45).

5.4.2.3.E. Ridge height below the P point:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 9.48(5.48), on the other hand, the mean value for those with their first molar absent was 9.95(4.68).

5.4.2.3.F. Concavity depth:

The P-value was less than 0.001 which was significant and the mean value for those with their first molar present was 2.11(1.61), on the other hand, the mean value for those with their first molar absent was 1.33(1.22).

5.4.2.3.G. Concavity angle:

The P-value was 0.005 which was significant and the mean value for those with their first molar present was 58.64(28.33), on the other hand, the mean value for those with their first molar absent was 48.89(31.2).

5.4.2.4. Presence of undercut:

5.4.2.4.A. Width of the alveolar bone at the crest:

The P-value was 0.615 which was insignificant and the mean value for those with an undercut was 8.92(2.43), while, the mean value for those without an undercut was 8.82(2.13).

5.4.2.4.B. Width of the alveolar bone at the base:

The P-value was 0.366 which was insignificant and the mean value for those with an undercut was 8.92(2.43), while, the mean value for those without an undercut was 10.58(1.83).

5.4.2.4.C. Alveolar ridge height:

The P-value was less than 0.001 which was significant and the mean value for those with an undercut was 14.32(3.68), while, the mean value for those without an undercut was 16.35(3.27).

5.4.2.4.D. Ridge height above the P point:

The P-value was 0.006 which was significant and the mean value for those with an undercut was 17.78(3.68), while, the mean value for those without an undercut was 15.17(5.5).

5.4.2.4.E. Ridge height below the P point:

The P-value was 0.026 which was significant and the mean value for those with an undercut was 9.08(4.74), while, the mean value for those without an undercut was 13.55(6.37).

5.4.2.4.F. Concavity depth:

The P-value was less than 0.001 which was significant and the mean value for those with an undercut was 2.01(1.55), while, the mean value for those without an undercut was 0.71(0.69).

5.4.2.4.G. Concavity angle:

The P-value was 0.902 which was insignificant and the mean value for those with an undercut was 56.60(27.49), while, the mean value for those without an undercut was 46(39.71).

5.4.2.5. Ridge type:

5.4.2.5.A. Width of the alveolar bone at the crest:

The P-value was less than 0.001 which was significant and the mean value for those with a convergent ridge was 6.66(2.21), the mean value for those with a parallel ridge was 8.95(2.17) and the mean value for those with an undercut ridge was 9.4(2.29).

5.4.2.5.B. Width of the alveolar bone at the base:

The P-value was 0.328 which was insignificant and the mean value for those with a convergent ridge was 10.87(1.15), the mean value for those with a parallel ridge was 10.60(1.85) and the mean value for those with an undercut ridge was 11.05(2.07).

5.4.2.5.C. Alveolar ridge height:

The P-value was 0.002 which was significant and the mean value for those with a convergent ridge was 12.64(3.82), the mean value for those with a parallel ridge was 15.54(3.61) and the mean value for those with an undercut ridge was 14.3(3.56).

5.4.2.5.D. Ridge height above the P point:

The P-value was 0.007 which was significant and the mean value for those with a convergent ridge was 14.8(3.53), the mean value for those with a parallel ridge was 17.49(5.15) and the mean value for those with an undercut ridge was 17.91(4.44).

5.4.2.5.E. Ridge height below the P point:

The P-value was 0.141 which was insignificant and the mean value for those with a convergent ridge was 10.39(5.16), the mean value for those with a parallel ridge was 10.5(5.75) and the mean value for those with an undercut ridge was 8.96(4.73).

5.4.2.5.F. Concavity depth:

The P-value was less than 0.001 which was significant and the mean value for those with a convergent ridge was 1.16(1.09), the mean value for those with a parallel ridge was 1.37(1.03) and the mean value for those with an undercut ridge was 2.27(1.74).

5.4.2.5.G. Concavity angle:

The P-value was less than 0.001 which was significant and the mean value for those with a convergent ridge was 43.42(31.63), the mean value for those with a parallel ridge was 59(32.33) and the mean value for those with an undercut ridge was 55.97(26.5).

5.4.3. Left and right sides analysis:

5.4.3.1. Gender:

Table 9: Pair comparison between left and right of the measurements by gender

	Males		Females	
	Pairs different		Pairs different	
	Mean (SD)	p-value	Mean (SD)	p-value
Width of the alveolar bone at the crest	0.11 (2.81)	0.894	-0.03 (2.45)	0.347
Width of the alveolar bone at the base	0.09 (1.52)	0.300	0.02 (1.2)	0.759
Alveolar ridge height	-0.25 (2.87)	0.400	-0.26 (2.67)	0.360
Ridge height above the P point	0.48 (4.30)	0.606	-0.95 (4.3)	0.104
Ridge height below the P point	-0.04 (4.31)	0.880	0.56 (4.2)	0.266
Concavity depth	-0.20 (1.13)	0.177	-0.15 (1.2)	0.097
Concavity angle	-0.03 (29.49)	0.551	2.49 (29.25)	0.681

5.4.3.1.A. Width of the alveolar bone at the crest:

The P-value for males was 0.894 which was insignificant with a mean value of 0.11(2.81), while the P-value for females was 0.347 which was insignificant and a mean value of -0.03(2.45).

5.4.3.1.B. Width of the alveolar bone at the base:

The P-value for males was 0.300 which was insignificant with a mean value of 0.09(1.52), while the P-value for females was 0.759 which was insignificant and a mean value of 0.02(1.2).

5.4.3.2.C. Alveolar ridge height:

The P-value for males was 0.400 which was insignificant with a mean value of -0.25(2.87), while the P-value for females was 0.360 which was insignificant and a mean value of -0.26(2.67).

5.4.3.1.D. Ridge height above the P point:

The P-value for males was 0.606 which was insignificant with a mean value of 0.48(4.30), while the P-value for females was 0.104 which was insignificant and a mean value of -0.95(4.3).

5.4.3.1.E. Ridge height below the P point:

The P-value for males was 0.880 which was insignificant with a mean value of -0.04(4.31), while the P-value for females was 0.266 which was insignificant and a mean value of 0.56(4.2).

5.4.3.1.F. Concavity depth:

The P-value for males was 0.177 which was insignificant with a mean value of -0.20(1.13), while the P-value for females was 0.097 which was insignificant and a mean value of -0.15(1.2).

5.4.3.1.G. Concavity angle:

The P-value for males was 0.551 which was insignificant with a mean value of -0.03(29.49), while the P-value for females was 0.681 which was insignificant and a mean value of 2.49(29.25).

5.4.3.2. Age group:

Table 10: Pair comparison between left and right of the measurements by age groups

	< 10 years		≥ 40 years	
	Pairs different		Pairs different	
	Mean (SD)	p-value	Mean (SD)	p-value
Width of the alveolar bone at the crest	-0.06 (2.38)	0.527	0.16 (2.9)	0.816
Width of the alveolar bone at the base	0.18 (1.1)	0.127	-0.11 (1.61)	0.882
Alveolar ridge height	-0.37 (2.65)	0.291	-0.12 (2.89)	0.636
Ridge height above the P point	-0.32 (4.39)	0.398	-0.24 (4.32)	0.686
Ridge height below the P point	0.14 (4.36)	0.557	0.45 (4.13)	0.452
Concavity depth	-0.20 (1.27)	0.071	-0.14 (1.02)	0.211
Concavity angle	2.91 (28.28)	0.484	-0.64 (30.6)	0.829

5.4.3.2.A. Width of the alveolar bone at the crest:

The P-value for those below 40 years old was 0.527 which was insignificant with a mean value of -0.06(2.38), while the P-value for those who are 40 years old or above was 0.816 which was insignificant and a mean value of 0.16(2.9).

5.4.3.2.B. Width of the alveolar bone at the base:

The P-value for those below 40 years old was 0.127 which was insignificant with a mean value of 0.18(1.1), while the P-value for those who are 40 years old or above was 0.882 which was insignificant and a mean value of 0.11(1.61).

5.4.3.2.C. Alveolar ridge height:

The P-value for those below 40 years old was 0.291 which was insignificant with a mean value of -0.37(2.65), while the P-value for those who are 40 years old or above was 0.636 which was insignificant and a mean value of -0.12(2.89).

5.4.3.2.D. Ridge height above the P point:

The P-value for those below 40 years old was 0.398 which was insignificant with a mean value of -0.32(4.39), while the P-value for those who are 40 years old or above was 0.686 which was insignificant and a mean value of -0.24(4.32).

5.4.3.2.E. Ridge height below the P point:

The P-value for those below 40 years old was 0.557 which was insignificant with a mean value of 0.14(4.36), while the P-value for those who are 40 years old or above was 0.452 which was insignificant and a mean value of 0.45(4.13).

5.4.3.2.F. Concavity depth:

The P-value for those below 40 years old was 0.071 which was insignificant with a mean value of 0.20(1.27), while the P-value for those who are 40 years old or above was 0.211 which was insignificant and a mean value of -0.14(1.0).

5.4.3.2.G. Concavity angle:

The P-value for those below 40 years old was 0.484 which was insignificant with a mean value of 2.91(28.28), while the P-value for those who are 40 years old or above was 0.829 which was insignificant and a mean value of -0.64(30.6).

5.4.3.3. Presence of the first molar:

Table 11: Pair comparison between left and right of the measurements by the present of first molar

	Present		Absent	
	Pairs different		Pairs different	
	Mean (SD)	p-value	Mean (SD)	p-value
Width of the alveolar bone at the crest	0.52 (2.39)	0.042	-0.77 (2.79)	2.79
Width of the alveolar bone at the base	0.21 (1.23)	0.076	-0.21 (1.51)	1.51
Alveolar ridge height	0.07 (2.49)	0.814	-0.81 (3.1)	3.10
Ridge height above the P point	-0.09 (4.22)	0.458	-0.60 (4.56)	4.56
Ridge height below the P point	0.46 (4.29)	0.229	-0.01 (4.2)	4.20
Concavity depth	-0.26 (1.14)	0.011	-0.02 (1.19)	1.19
Concavity angle	0.36 (28.29)	0.713	2.94 (31.08)	31.08

5.4.3.3.A. Width of the alveolar bone at the crest:

The P-value for those with their first molar present was 0.042 which was insignificant with a mean value of 0.52(2.39), while the P-value for those with their first molar absent was 2.79 which was insignificant and a mean value of -0.77(2.79).

5.4.3.3.B. Width of the alveolar bone at the base:

The P-value for those with their first molar present was 0.076 which was insignificant with a mean value of 0.21(1.23), while the P-value for those with their first molar absent was 1.51 which was insignificant and a mean value of -0.21(1.51).

5.4.3.3.C. Alveolar ridge height:

The P-value for those with their first molar present was 0.814 which was insignificant with a mean value of 0.07(2.49), while the P-value for those with their first molar absent was 3.10 which was insignificant and a mean value of -0.81(3.1).

5.4.3.3.D. Ridge height above the P point:

The P-value for those with their first molar present was 0.458 which was insignificant with a mean value of -0.09(4.22), while the P-value for those with their first molar absent was 4.56 which was insignificant and a mean value of -0.60(4.56).

5.4.3.3.E. Ridge height below the P point:

The P-value for those with their first molar present was 0.229 which was insignificant with a mean value of 0.46(4.29), while the P-value for those with their first molar absent was 4.2 which was insignificant and a mean value of -0.01(4.2).

5.4.3.3.F. Concavity depth:

The P-value for those with their first molar present was 0.011 which was significant with a mean value of 0.46(4.29), while the P-value for those with their first molar absent was 1.19 which was insignificant and a mean value of -0.02(1.19).

5.4.3.3.G. Concavity angle:

The P-value for those with their first molar present was 0.713 which was insignificant with a mean value of 0.36(28.29), while the P-value for those with their first molar absent was 31.08 which was insignificant and a mean value of 2.94(31.08).

5.4.3.4. Presence of an undercut:

Table 12: Pair comparison between left and right of the measurements by the present of undercut

	Present		Absent	
	Pairs different		Pairs different	
	Mean (SD)	p-value	Mean (SD)	p-value
Width of the alveolar bone at the crest	0.02 (2.69)	0.438	0.27 (1.47)	0.211
Width of the alveolar bone at the base	0.08 (1.38)	0.222	-0.30 (0.95)	0.394
Alveolar ridge height	-0.29 (2.8)	0.196	0.09 (2.26)	0.609
Ridge height above the P point	-0.12 (4.16)	0.643	-2.22 (6.04)	0.201
Ridge height below the P point	0.10 (3.87)	0.509	2.48 (7.29)	0.307
Concavity depth	-0.17 (1.19)	0.049	-0.23 (0.84)	0.262
Concavity angle	1.86 (28.74)	0.370	-5.12 (36.01)	0.515

5.4.3.4.A. Width of the alveolar bone at the crest:

The P-value for those with an undercut was 0.438 which was insignificant with a mean value of 0.02(2.69), while the P-value for those without an undercut was 0.211 which was insignificant and a mean value of 0.27(1.47).

5.4.3.4.B. Width of the alveolar bone at the base:

The P-value for those with an undercut was 0.222 which was insignificant with a mean value of 0.08(1.38), while the P-value for those without an undercut was 0.394 which was insignificant and a mean value of -0.30(0.95).

5.4.3.4.C. Alveolar ridge height:

The P-value for those with an undercut was 0.196 which was insignificant with a mean value of -0.29(2.8), while the P-value for those without an undercut was 0.609 which was insignificant and a mean value of 0.09(2.26).

5.4.3.4.D. Ridge height above the P point:

The P-value for those with an undercut was 0.643 which was insignificant with a mean value of -0.12(4.16), while the P-value for those without an undercut was 0.201 which was insignificant and a mean value of -2.22(6.04).

5.4.3.4.E. Ridge height below the P point:

The P-value for those with an undercut was 0.509 which was insignificant with a mean value of 0.10(3.87), while the P-value for those without an undercut was 0.307 which was insignificant and a mean value of 2.48(7.29).

5.4.3.4.F. Concavity depth:

The P-value for those with an undercut was 0.049 which was significant with a mean value of -0.17(1.19), while the P-value for those without an undercut was 0.262 which was insignificant and a mean value of -0.23(0.84).

5.4.3.4.G. Concavity angle:

The P-value for those with an undercut was 0.370 which was insignificant with a mean value of 1.86(28.74), while the P-value for those without an undercut was 0.515 which was insignificant and a mean value of -5.12(36.01).

5.4.4. Correlation between ridge type and presence of undercut:

5.4.4.1. Left side analysis:

Table 13: Ridge type (L), Presence of an undercut (L) Crosstabulation

			Presence of an undercut (L) No	Presence of an undercut (L) Yes	Total
Rdige type (L)	C	Count	5	31	36
		% within Rdige type (L)	13.9%	86.1%	100.0%
		% within Presence of an undercut (L)	33.3%	17.2%	18.5%
	P	Count	10	43	53
		% within Rdige type (L)	18.9%	81.1%	100.0%
		% within Presence of an undercut (L)	66.7%	23.9%	27.2%
	U	Count	0	106	106
		% within Rdige type (L)	0.0%	100.0%	100.0%
		% within Presence of an undercut (L)	0.0%	58.9%	54.4%
Total		Count	15	180	195
		% within Rdige type (L)	7.7%	92.3%	100.0%
		% within Presence of an undercut (L)	100.0%	100.0%	100.0%

5.4.4.2.A. Convergent ridge type:

A significant correlation was found with a P-value of less than 0.001 where 31(86.1%) cases had an undercut present.

5.4.4.1.B. Parallel ridge type:

A significant correlation was found with a P-value of less than 0.001 where 43(81.1%) cases had an undercut present.

5.4.4.1.C. Undercut ridge type:

A significant correlation was found with a P-value of less than 0.001 where 106(100%) cases had an undercut present.

5.4.4.2. Right side analysis:

Table 14: Ridge type (RT), Presence of an undercut (RT) Crosstabulation

			Presence of an undercut (RT)		
			No	Yes	Total
Rdige type (RT)	C	Count	4	22	26
		% within Rdige type (RT)	15.4%	84.6%	100.0%
		% within Presence of an undercut (RT)	14.8%	13.8%	13.9%
	P	Count	22	41	63
		% within Rdige type (RT)	34.9%	65.1%	100.0%
		% within Presence of an undercut (RT)	81.5%	25.6%	33.7%
	U	Count	1	97	98
		% within Rdige type (RT)	1.0%	99.0%	100.0%
		% within Presence of an undercut (RT)	3.7%	60.6%	52.4%
Total		Count	27	160	187
		% within Rdige type (RT)	14.4%	85.6%	100.0%
		% within Presence of an undercut (RT)	100.0%	100.0%	100.0%

5.4.4.2.A. Convergent ridge type:

A significant correlation was found with a P-value of less than 0.001 where 22(84.6%) cases had an undercut present.

5.4.4.2.B. Parallel ridge type:

A significant correlation was found with a P-value of less than 0.001 where 41(65.1%) cases had an undercut present.

5.4.4.2.C. Undercut ridge type:

A significant correlation was found with a P-value of less than 0.001 where 97(99%) cases had an undercut present.

5.5. Intra-examiner agreement:

The data was analyzed for normality of distribution using the Kolmogorov-Smirnova test and was found to be normally distributed. Therefore, t-test was performed between the first data analysis and the analysis done for the randomly selected 30 cases after two weeks to look for any reading inconsistencies. The t-test showed insignificant differences between the readings with P-value being more than 0.05, which means that the data analysis was consistent within the same examiner.

6. DISCUSSION

The floor of the mouth contains vital structures such as the submental and sublingual arteries in the anterior region which if injured, perfused bleeding may occur leading to fatal consequences, Dubois, et al. 2010. The posterior region contains the inferior alveolar nerve, lingual nerve, submandibular gland and lymph nodes. Injury to any of these vital structures e.g. by a lingual plate perforation from dental implant placement may lead a variety of complications which can be fatal sometimes (Chan, et al. 2010, 2011). Carful assessment of these anatomical structures and proper treatment planning prior to implant placement can reduce and/or eliminate such complications. Furthermore, proper knowledge on the variation of the morphology of the posterior region of the mandible can help in formulating the best treatment plan possible. The morphology of the posterior region of the mandible and its variations were analyzed in the present study to help in better understanding, assessing and treatment planning dental implant placement.

6.1. Alveolar ridge type:

In the present study, U type ridge was found to be the most prevalent type in the left and the right mandibular side (54.4% and 52.1% respectively) followed by the P type ridge (27.2% left and 33.5% right) and the least prevalent type was the C type ridge (18.5% left and 14.4% right). This agrees with studies performed by Chan et al. (2010), Herranz-Aparicio et al. (2016) and Yoon et al. (2017) which used similar methods, classifications and land marks for the ridge type determination. On the other hand, Salemi et al. (2018) found that C type ridge was more prevalent than P type ridge while U type ridge was still the most prevalent type. Even though the study used similar classification method, the data was only collected from patients with their first molar absent which could be the reason for the difference in the findings. Watanabe et al. 2010 found that type C ridge (round ridge) to be the most prevalent ridge type followed by type A (lingual concavity) and the least prevalent type was type B (buccal concavity). These findings are different from the present study's finding which could be due to the fact that a different classification method was used along with the ethnicity of the patients included in the study which was mainly Japanese, whereas, the present study had no ethnical restrictions and it included a variety of ethnicity.

6.2. Alveolar ridge height and width:

6.2.1. Gender:

Correlation was found between gender and the height of the alveolar ridge, the height of the alveolar ridge above the P point, in both left and right sides with males showing higher values, whereas the height of the alveolar ridge below the P point showed correlation only on the right side. The significance in the finding is that males might have higher and wider alveolar ridge which suggests a relatively safer implant placement procedure. These findings agree with the results found in studies by Sameli et al. (2018) and Watanabe et al. (2010). Chan et al. (2010) found a correlation only in the height of the alveolar ridge below the P point, while, Kamburoglu et al. (2015) and Herranz-Aparicio et al. (2016) found no correlation between the height of the alveolar ridge and gender.

The present study found no correlation between gender and the width of the alveolar bone at the crest nor at the base. Chan et al. (2010) found similar finding to the present study in the width of the alveolar bone at the base, however, a correlation was found between the width of the alveolar bone at the crest and gender. On the other hand, Herranz-Aparicio et al. (2016) did not find a correlation between the width of the alveolar bone at the crest and gender while a correlation was found between the width at the base and gender. Furthermore, Salemi et al. (2018) found a correlation between the width for both at the crest, at the base and gender. The disagreement in the findings could be due to the inclusion criteria which only included patients with an absent first molar.

6.2.2. Age:

The present study found a correlation between the height of the alveolar bone, the width of the alveolar bone at the crest and age with those below 40 years old showing higher values. The significance in the finding is that people below 40 years old might have higher and wider alveolar ridge at the crest which suggests a relatively safer implant placement procedure. This agrees with findings in a study by De Souza et al. (2016), however, Herranz-Aparicio et al. (2016) found a negative correlation between the width at the crest and age but found no correlation between the height of the ridge and age. To the knowledge of the author, no other studies found comparing these parameters.

6.2.3. Presence of the first molar:

The present study found a correlation between the height of the alveolar bone, height above and below the P point, width of the alveolar bone at the crest and age in those with their first molar present showing higher values. The significance in the finding is that people with their first molar present might have higher and wider alveolar ridge at the crest which suggests a relatively safer implant placement procedure. To the knowledge of the author, no studies found comparing these parameters.

6.2.4. Presence of an undercut:

The present study found a correlation between the height of the alveolar bone both below and above the P point, the concavity depth and the presence of an undercut with those having an undercut showing higher alveolar ridge above the P point and deeper concavity depth. On the other hand, the height of the ridge below the P point showed lower values in those with an undercut present. The significant of these findings is that those with an undercut present may present higher risk in lingual perforation while placing an implant due to the deeper concavity. To the knowledge of the author, no studies found comparing these parameters.

6.2.5. Ridge type:

The present study found a correlation between the height of the alveolar bone, the height below and above the P point, the width of the bone at the crest, width at the base and ridge type both in left and right sides. However, no correlation was found between the width at base and ridge type in the right side. The findings varied between the types showing the C type with the least values and the P and U types being close to each other with the P type showing higher values only in the height of the alveolar bone. The significance of these findings is that knowing the ridge type might indicate the need for further procedures and assessment e.g. C type might have a relatively higher chance in the need for bone augmentation due to it having the least width at the crest. To the knowledge of the author, no studies found comparing these parameters.

6.3. Concavity depth and angulation:

6.3.1. Gender:

The present study found no correlation between the depth, angulation of the concavity and gender. This agrees with findings by Rajput et al. (2018), Herranz-Aparicio et al. (2016), Yoon et al. (2017), Salemi et al. (2018), Chan et al. (2010) and Parnia et al. (2010). However, Ramaswamy et al. (2020) was the only study that showed a correlation between gender and concavity depth with males showing greater depth. This could be due to the difference in measurement methods.

6.3.2. Age:

The present study found no correlation between the depth, angulation of the concavity and age. This agrees with findings by Salemi et al. (2018), Chan et al. (2010) and Parnia (2010). Herranz-Aparicio et al. (2016), Kamburoglu et al. (2015) found a negative correlation between the concavity depth and age, while, Yoon et al. (2017) found a negative correlation between age and concavity height.

6.3.3. Presence of the first molar:

The present study found a correlation between the concavity depth and presence of the first molar with the concavity being deeper in those with their first molar present. This agrees with findings by Uchida et al. 2012 and Kamburoglu et al. (2015).

6.3.4. Presence of an undercut:

The present study found a correlation between the concavity depth and presence of an undercut with the concavity being deeper in those with an undercut. To the knowledge of the author, no studies found comparing these parameters. However, Braut et al. (2014) classified the undercut as being influential or non-influential if present and was found to be more influential in the molar region.

6.4. Current alveolar ridge classifications and their shortcomings:

6.4.1. Chan's classification (2010):

Chan classified the mandibular morphology into a convex (C), parallel (P) and undercut (U) based on the presence of lingual concavity and the shape of the alveolar ridge. A ridge with a narrow base expanding to a wider crest in the bucco-lingual direction with a prominent P point lingually creating an undercut is classified as a U type ridge. In the absence of an undercut, a ridge with a base wider than the crest is classified as C type ridge and a ridge with a parallel ridge form is classified as a P type ridge. Most of the studies reviewed for the present study used this classification as it can provide good information about the ridge shape and form along with the presence of an undercut. However, this classification does not provide information about the depth of the concavity or whether if the concavity has an influence on implant placement or not. Furthermore, the classification is based on the presence of an undercut i.e. if it is present then the ridge is classified as a U type ridge. The limitation of this is that U type ridge only represent presence of an undercut but does not provide information about the shape and form of the ridge. Findings in the present study showed that an undercut can be present in all types of alveolar ridges and therefore, this type of classification does not take that under consideration.

6.4.2. Jung's classification (2004):

The mandibular morphology is classified into type Ⅰ with a concavity depth less than 2mm, type Ⅱ with a concavity between 2-3mm and type Ⅲ with a concavity depth more than 3mm. This classification was the second widely used type and although it provides sufficient information about the depth and in turn the angulation of the concavity, it provides no information about the ridge shape and form. This limits its use in the dental practice as the information provided is still lacking the sufficient information needed such as height and width of the ridge.

6.4.3. Watanabe's classification (2010):

Watanabe classified the alveolar ridge into Type A which is a round ridge buccally and a concave lingually, Type B which is a round ridge lingually and concave buccally and Type C ridge which is round on both sides. This classification provides good information about the ridge shape; however, it provides no information about the depth of the concavity. Moreover, the study's methodology did not account for the width of the alveolar ridge at the crest which might be a useful indication in the need for bone augmentation prior to implant placement.

6.4.4. Braut's undercut classification (2014):

Braut classified the undercut as absent, present and influential, i.e. located in the path of an implant insertion, and present non-influential, i.e. present without interfering with the path of an implant placement. This is a useful classification to minimize the risk of lingual plate perforation, however, it does not provide information about the ridge shape/form.

6.5. Proposed new classification:

The aim of this new classification is to combine the positives of the existing classification while at the same time decreasing/eliminating their shortcomings. The new classification will attempt to describe both the alveolar ridge shape/form along with the concavity's description which will help in providing as much clinical information to the dental practitioner to understand, assess and formulate a proper treatment plan.

6.5.1. Main classification:

The first step is to classify the alveolar ridge type which is divided into three types; C type (Convergent type) which is a ridge that is wide at the base and narrow at the crest, P type (Parallel type) which is a ridge that has roughly the same width at the crest and at the base and D type (Divergent type) which is a ridge that is narrow at the base and wide at the crest.

6.5.2. First subdivision:

The second step involves the determination whether the alveolar ridge includes an undercut (U) or not. This step only involves the addition of the letter U to the main classification if the undercut is present. If the undercut is absent then the main classification should suffice as a final classification.

6.5.3. Second subdivision:

The third and final step involves the determination whether the undercut (if present) is an influential (I), i.e. it is present above the inferior alveolar nerve with a depth and angulation that may pose a significant risk in lingual plate perforation, or not influential undercut (N). Once more this step is only used if the undercut is present.

6.5.4. Classification examples:

If a patient has a parallel ridge with a non-influential undercut then the final classification will be (P type/U/N) (fig 9), while, if a patient has a divergent ridge with an influential undercut then the final classification will be (D type/U/I) (fig 10). However, if a patient has a convergent ridge without an undercut then the final classification will be (C type).

Figure (8) U Type/U/I ridge

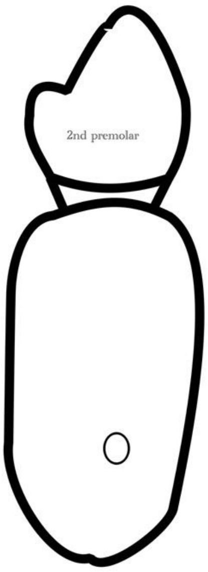

Figure (9) P type ridge

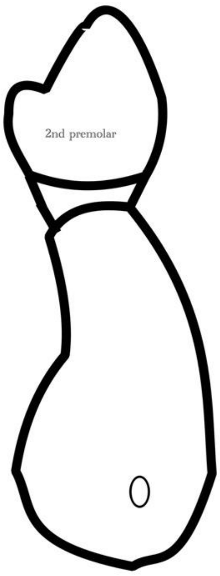

Figure (10) D type ridge

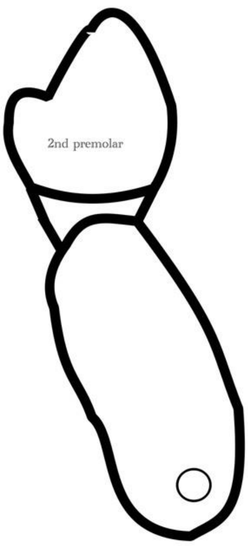

Figure (11) P type/U/I ridge

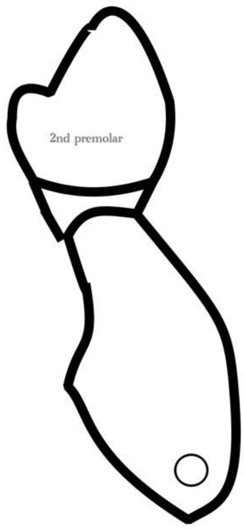

Figure (12) D type/U/I ridge

6.6. Significance of the new classification:

The new classification helps in providing as much clinical information as possible about the alveolar ridge morphology to the dental practitioner to help in understanding, assessing and formulating a proper treatment plan and helps with the communication between practitioners by allowing the visualization of the alveolar ridge morphology just by mentioning the classification. An example for this is a ridge that is classified as (U type/U/I) allows the practitioner to know that the ridge is narrow at the base and wide at the crest with the presence of an undercut that is above the inferior alveolar nerve with a depth and angulation that may pose a significant risk in lingual plate perforation. Therefore, the practitioner should place the dental implant with the proper angulation to avoid such complication. On the other hand, if a ridge is classified as (C type/U/N) allows the practitioner to know that the ridge is narrow at the crest and wide at the base with an undercut that is located below the inferior alveolar nerve or in a location/state that is not involved in the path of the implant position. This means that the implant placement is relatively safer and a risk of lingual plate perforation is reduced or eliminated.

7. CONCLUSION

Implant placement is a viable, safe and predictable treatment modality when there is a proper understanding of the alveolar ridge morphology variations and the anatomical landmarks that may influence such treatment. Dental practitioners should possess the knowledge and skills needed to perform such treatment safely and predictably. Alveolar ridge classifications have an important role in providing the proper clinical information to help the dental practitioners to understand the morphology along with allowing proper and easy communication between each other. Present classifications have their merits in achieving such task, however, they possess some limitations and therefore cannot provide all the clinical information necessary to formulate a proper treatment plan. The proposed new classification has the potential to be used as a reliable and highly informative classification system that can help in providing as much clinical information as possible to allow better understanding and communications by combining the merits of the existing classifications and at the same time reducing/eliminating their shortcomings.

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9. APPENDICES

9.1 APPENDIX: DDH no objection report

مستشفى دبي للأسنان
Dubai Dental
HOSPITAL

Ref: DDH –2021-062
Date: September 16, 2021

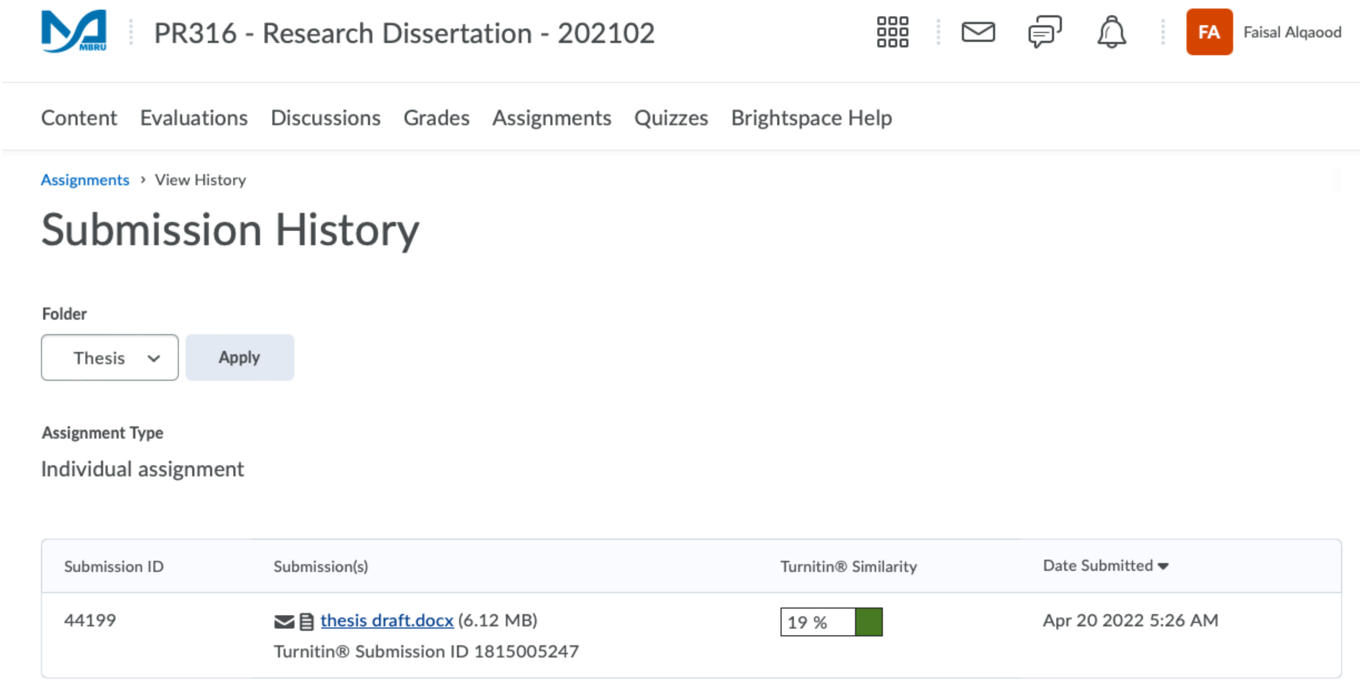
No Objection Certificate

This is to confirm that Dubai Dental Hospital has no objection in Dr Faisal Alqaood conducting his research on CBCT analysis collected from the hospital using patients' data.
The release of data will be permitted upon Ethical Approval and completing a Human Subject Research course.

Yours sincerely,

Dr. Khawla Belhoul
Director - Dubai Dental Hospital.

9.2 APPENDIX: Turnitin similarity report



Turnitin similarity report showing 19% similarity

9.3 APPENDEX: MBRU-IRB ethical approval

Date: 5-19-2022

IRB #: MBRU IRB-2021-52
Title: EVALUATION OF THE SUBMANDIBULAR FOSSA AND ITS CORRELATION TO IMPLANT PLACEMENT USING CONE-BEAM COMPUTED TOMOGRAPHY
Creation Date: 4-24-2021
End Date:
Status: Approved
Principal Investigator: Faisal Alqaood
Review Board: MBRU IRB 1
Sponsor:

Study History

Submission Type	Review Type	Decision
Initial	Expedited	Approved

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