REVIEW ARTICLE

A Narrative Review of Alveolar Bone Analysis and CBCT Classification related to Immediate Implant Placement in The Anterior Maxilla

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ABSTRACT

Immediate implant placement into fresh extraction sockets has gained a lot of attention in implant dentistry. Besides proper risk assessment, the evaluation of tooth anatomy aids the clinicians to select the finest treatment protocol. Cone Beam Computed Tomography (CBCT) imaging was frequently used for alveolar bone analysis prior to tooth extraction in immediate implant placement. As an ideal position is required to prevent a buccally tilted implant or too palatal implant placement, various authors have proposed the treatment guidelines for immediate implant placement in the anterior maxilla. Although insightful, the previous classification was lacking anatomic variant and key anatomical features of alveolar bone and tooth angulation. Furthermore, there is no standardization method of measuring the specific degree of tooth angulation in CBCT scans that could possibly be used in clinical setting for appropriate treatment protocol. Thus, it is essential for the clinician to have adequate knowledge on the role of facial alveolar bone, palatal alveolar bone and tooth angulation related to immediate implant before selecting the appropriate treatment guidelines based on the classification reviewed. In this review, the previous quantitative measurements were categorized, and the previous classification was listed for the sake of familiarity by the dental practitioner with the major updates on implant placement strategy, patient selection and to reduce the rate of surgical complications.
Malaysian Journal of Medicine and Health Sciences (2022) 18(6):311-323. doi:10.47836/mjmhs18.6.40

Keywords: Alveolar bone , Tooth angle, Palatal bone, Immediate Dental Implant loading , Cone Beam Computed Tomography

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INTRODUCTION

The evaluation of alveolar bone thickness and bone anatomy has gained significant attention in implantology, periodontology, oral surgery, and other branches of dentistry (1, 2). In general, the findings of facial, palatal and root position from the previous studies have influenced surgical planning, prosthetic implant rehabilitation outcomes, the choice of skeletal anchorage for orthodontic mechanics, and the identification of a possible drainage route for odontogenic infections (3). Many studies have documented that the thickness of facial alveolar bone is essential to support the soft tissue volumes for long-term stability of biological and aesthetic outcome in implant treatment guidelines (4, 5). Furthermore, the occurrence of vertical and horizontal reductions following tooth extraction has made the analysis of facial bone thickness essential, in order to avoid fenestrations, gingival recession, and to predict potential bone resorption in implant treatment (6-8). As a result, determining and evaluating the patient's facial and palatal alveolar bone thickness, as well as tooth-related factors such as tooth angulation, is critical in determining the best treatment approach in implant treatment.

In addition to facial alveolar bone thickness, the palatal alveolar bone thickness is important in the immediate implant treatment protocol to guide implant placement at the anterior region in the optimal location. A previous study found that the palatal alveolar bone aspect allows implant engagement to achieve primary stability without touching the buccal wall (9). This approach, however, is not applicable in all clinical situations because it is dependent on tooth root angulation in relation to the alveolar housing and residual socket. As a result, assessing tooth angulation is also required to predict the need for bone regeneration, selecting the appropriate implant with the desired dimension, and planning future prostheses.

Various classifications have been documented previously to guide clinicians to select appropriate treatment approach in implant placement related to facial, palatal bone and tooth inclination (10-14). Yet, there is a lack of knowledge about which classifications methods can be used in a clinical settings of immediate implant placement. Hence, the objective of the present work is to discuss briefly on the application of Cone Beam Computed Tomography (CBCT) for implants planning and to review the role of assessing the alveolar bone wall characteristics and tooth angulation related to immediate implant. Moreover, the previous classification related to immediate implant placement in the anterior maxilla was discussed aiming at highlighting the dental practitioner with recent updates about treatment guidelines, through the data reviewed in this article.

METHODOLOGY

The relevant literature was searched from Scopus, Google Scholar, PubMed, Springer Link and Web of Science (WOS) from January 2000 to December 2020. An additional manual search was also carried out from the reference list of all full text publications from the following journals: The Journal of Prosthetic Dentistry, Journal of Oral Implantology, European Journal of Oral Implantology, Journal of Osseointegration, International Journal of Oral and Maxillofacial Implants, International Journal of Prosthodontics, Clinical Implant Dentistry and Related Research and Clinical Oral Implant Research. The following keywords and terminology were used: ‘’immediate implant placement”, “buccal wall”, “palatal wall”, “tooth angulation”, “classification immediate”, “tooth inclination” and “Cone beam Computed Tomography (CBCT)”. Studies were included if the following information was reported:

Inclusion criteria
- English articles
- Articles related to CBCT classification for immediate implant placement
- Quantitative measurements of alveolar bone analysis

Exclusion criteria were
- animal studies
- in vitro study

HISTORY OF CBCT SCAN AND ITS APPLICATION IN IMPLANT PLANNING

CBCT was first introduced in 1982 for angiography procedure (15). In the late 1990s, the CBCT scan was then applied in the oral and maxillofacial region in Italy and in Japan (16, 17). CBCT is the preferred method for imaging due to its simplicity, high spatial image resolution at low cost and low radiation. Because of the anatomic proximity of radiosensitive organs in the head and neck areas, estimating the potential radiation risk to patients following CBCT scan exposure has been critical. Therefore, it is imperative to follow the fundamental principle for diagnostic radiology by ALARA (the acronym for as low as reasonably achievable) with the goal to control multiple related factors such as the field of view (FOV) (18). Following this principles, by reducing the FOV of CBCT examination in the region of interest, the dose reduction is achieved (19). In general, selecting a large FOV resulted in an effective radiation dose ranging between 46 and 916 μSv (20). According to Ludlow et al, the large FOV of 16cm X 22cm has radiation dose of 235 μSv as compared to the medium FOV of 16cm X 13cm that has radiation dose of 47 to 560 μSv (20). Therefore, it is possible for the clinician to control the radiation dose of CBCT by adjusting the field of view (21).

CBCT images accurately identify the relevant anatomical boundaries when clinical examination and conventional radiography fails to locate the important structures (16). The American Academy of Oral and Maxillofacial Radiology (AAOMR) was the first professional organization to recommend using cross sectional imaging to produce the anatomic precision required for basic preoperative implant planning (22). This was later in agreement with the European Association for Osseointegration (EAO) to use the cross-sectional imaging for implant cases (23). The widespread use of CBCT imaging was documented in a previous study by Bornstein et al, who discovered that 70% of all implants placed in the maxilla, regardless of anterior vs. posterior location, were planned on the basis of an adjunctive CBCT scan (24). Furthermore, for more complex procedures such as guided bone regeneration (GBR) or sinus floor elevation (SFE), it was discovered that more than 90% of the implants were inserted after adjunctive CBCT scans. In addition, 75% of older patients with extended edentulous spaces and distal extension cases indicated for implant placement require a CBCT scan. (25). Therefore, it may suffice to say that CBCT scan have become a normal routine diagnostic procedure in implant dentistry to maximize the potential success in implant therapy.

Many authors have documented an accuracy of CBCT images of bone analysis with less than 1 mm errors (25, 26). All of the CBCT measurements were found to be non-significantly different from the direct measurements on cadaver heads, and there was no pattern of underestimation or overestimation (19). Although possible errors of overestimation were recorded, it was recommended to maintain a safety margin of 2mm distance from the vital anatomical structure when planning with three-dimensional (3D) data in implant treatment (19, 27, 28). The distribution and frequency of CBCT scans for additional 3D analysis as adjunctive measures for implant site evaluation are influenced by indication (single tooth, extended edentulous gap, distal, edentulism), location (maxilla or mandible), and need for bone augmentation (horizontal and/or vertical bone deficiencies) (24). With the appropriate selection of FOV, the CBCT scan should provide adequate details to assess and examine the following; (1) alveolar ridge anatomical characteristics, including the bone volume and density at possible implant sites to guide in implant selection, (2) determine the residual ridge orientation to assess morphologic characteristics that compromise the dental implant's alignment with respect to the prosthetic treatment plan, (3) identify the local anatomical or pathologic boundaries within the residual alveolar ridge that may limit or alter the planned implant placement (19, 28).

To perform immediate implant placement, CBCT imaging of facial bone height and thickness has been investigated previously by many authors to simulate implant position (29,30). With CBCT images, the clinicians can measure the thickness of the facial alveolar bone which is the key anatomical factor for immediate implant. The thin facial alveolar bone especially at the crest may compromise the esthetical outcome of implant therapy, necessitating additional surgical techniques such as bone grafting alveolar ridge preservation after tooth extraction, or contour augmentation at the time of early implant placement (31). The thin facial bone at the midroot level may indicated on opening a flap for immediate implant (24). Meanwhile, the palatal wall of maxillary anterior teeth represents the anatomical landmark that could provide bone anchorage of implant placement (13). Nevertheless, the assessment in CBCT images should be interpreted cautiously when suggesting for immediate implant placement, as the variable of tooth angulation or tooth type may not represent an ideal scenario.

CLINICAL PARAMETERS OF PREOPERATIVE PATIENT ASSESSMENT

The Alveolar Bone Wall Dimension and Analysis

The alveolar bone of tooth socket is consisting of inner cancellous and outer layers of cortical bone plate (facial and palatal). The alveolar bone proper, also called the bundle bone plates is prone to resorption following teeth extraction (6, 30, 32). The majority of bone remodeling occurs after tooth extraction, according to radiographic measurements, with crestal height changes of approximately 1.59 mm (1.67 mm buccally and 2.03 mm lingually) (33). The architectural and morphological changes that occur during bone loss occur not only on the labial and palatal surfaces, but also in the interproximal areas, resulting in the unwanted loss of the inter-proximal papilla (34). Because various unfavorable changes in the bone occur even during healing, it has been suggested that if implant treatment is indicated, a vestibular plate thickness of 2 mm is required for soft tissue stability and to prevent avascular necrosis.(3, 35) In addition, the sufficient bone thickness is essential to ensure predictable esthetic and prosthetic outcome and prevent complications of gingival recession (7, 36).

Analyzing bone thickness were frequently recorded previously based on direct measurement and radiographic assessment (2, 10, 37-44). The vital information of the selection studies such as study design, the alveolar bone walls parameters, the methodology and measurements techniques are presented in Table I. In some studies, the bone wall is measured at five to three levels including the cementoenamel junction (CEJ), bone crest, mid root, and apical (29). Other studies, however, have only measured the bone at two points: the alveolar crest and the mid-root region, which is a critical region for preventing dehiscence and fenestrations (45). The previous author also has categorized the bone thickness into thin (<1mm) and thick (>1mm) and divide the junction of the crestal bone of 4 mm from CEJ, and the radicular zone from the base of the crestal to the root apex (46). Based on this varied assessment, having accurate ideas about the value of measuring the alveolar bone wall at different level has significant impact for clinician to determine the tooth that has a greater risk of bone resorption or to decide whether to perform immediate or delayed approach in implant treatment (10, 47).

The Role of Facial Alveolar Bone

The architecture of the facial bones is important in maintaining the overall shape of the alveolus (48). The thickness of the facial bone wall influences the facial convexity of the alveolar process at the crown's emergence profile, while the height of the facial bone wall influences the position of the mucosal margin on the facial aspect (31, 41, 49). Because this anatomical structure has been reported to be predominantly thin (1mm), various precautionary methods, such as atraumatic extraction or partial extraction therapy, can be used to preserve the facial bone crest (47, 50). Furthermore, additional surgical techniques, such as minimal or flapless surgical elevation, can be used to overcome the anatomical limitations of thin facial bone (51). Yet, special attention should be considered when evaluating the facial bone on certain types of teeth in the anterior maxillary region. They were conflicting report on the continuity of facial thickness from crestal to apical, whether it is gradual increase or not continuous in the thickness (29, 47, 52). Previous study has recorded that midroot of facial bone was thinner than crestal especially in lateral incisor (52). This decreased thickness could be related to the populations involved and the method of measurement taken from the CEJ (47). Thus, it was recommended to measure at least 4 mm from the crest for midroot measurement to allow more accurate identification of each level (47). In addition,

Table I: Previous Studies Measuring the Alveolar Bone Thickness

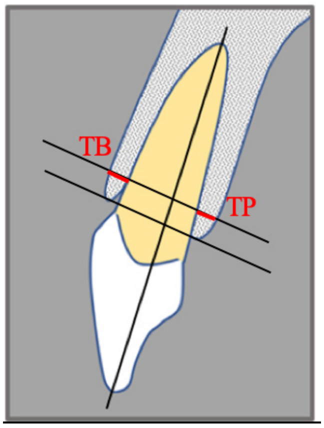
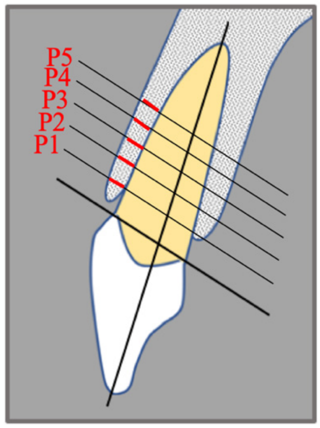
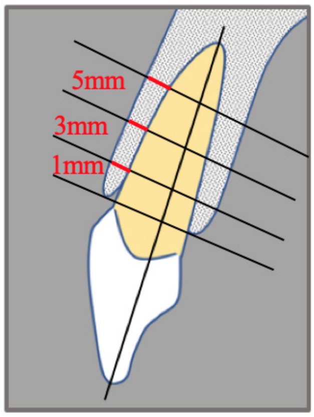
Author, year	Study design	Study Object	Method of evaluation	Measurement of figures and illustrations
(Huynh-Ba et al., 2010)	Prospective randomized-controlled multicenter clinical study	Buccal and palatal bone thickness of extraction socket in maxillary anterior (central incisor, lateral incisor, canine) and premolar.	On extraction socket applying calliper	 Figure 1 : 1mm apical to the alveolar crest (AC). TB(Thickness buccal), TP(Thickness Palatal)
(Nowzari, Molayem, Chiu, & Rich, 2012)	Retrospective study	Facial alveolar bone wall of maxillary anterior teeth (central incisor).	Cone-beam computed tomography (CBCT) scans	 Figure 2 : Measurement of buccal bone thickness (P1) 1mm from AC, (P2) 2mm from AC, (P3) 3mm from AC, (P4) 4mm from coronal margin from AC , (P5) 5mm from AC
(Januario et al., 2011)	Cross-sectional study	Facial bone wall thickness of all maxillary anterior teeth (central incisor, lateral incisor, canine)	Cone-beam computed tomography (CBCT) scans	 Figure 3 : Measurement of buccal bone thickness of 1 mm AC, 3 mm from AC and 5 mm from AC

Table I: Previous Studies Measuring the Alveolar Bone Thickness (continued)

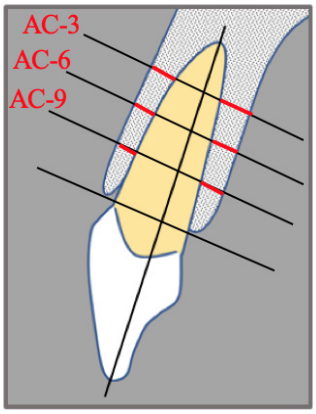
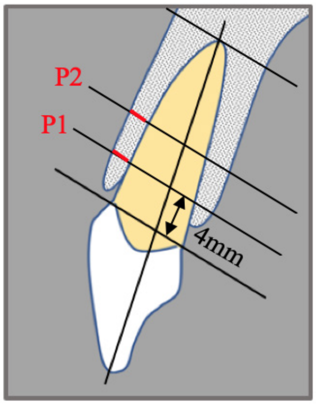
<table>
<tr><th>Author, year</th><th>Study design</th><th>Study Object</th><th>Method of evaluation</th><th>Measurement of figures and illustrations</th></tr>
<tr><td>(Han & Jung, 2011)</td><td>In-vitro study (Cadaver heads)</td><td>Buccal and lingual bone thickness in all anterior maxillary and mandibular teeth (central incisor, lateral incisor, canine)</td><td>On Cadaver heads measured using digital callipers</td><td>

Figure 4 : Measurement of buccal bone thickness of 3mm apical to the alveolar crest (AC-3), 6mm apical to the alveolar crest (AC-6) and 9mm apical to the alveolar crest (AC-9).</td></tr>
<tr><td>(Braut, Bornstein, Belser, & Buser, 2011)</td><td>Retrospective study</td><td>Facial bone wall of all maxillary anterior teeth (central incisor, lateral incisor, canine, and first premolar)</td><td>Cone-beam computed tomography (CBCT) scans</td><td>

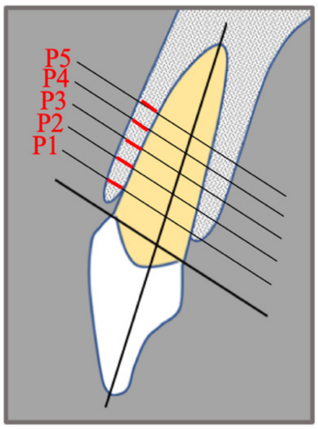
Figures 5 : Measurement of buccal bone thickness of at the crest level (4 mm apical to the CEJ) (P1), and at the middle of the root (P2).</td></tr>
<tr><td>(Ghassemian et al., 2012)</td><td>Retrospective study</td><td>Facial alveolar bone wall of all maxillary anterior teeth (central incisor, lateral incisor, canine)</td><td>Computerized tomographic (CT) scans</td><td>

Figure 6 : Measurement of buccal bone thickness
(P1) 1mm from AC, (P2) 2mm from AC, (P3) 3mm from AC, (P4) 4mm from coronal margin from AC , (P5) 5mm from AC</td></tr>
</table>

Table I: Previous Studies Measuring the Alveolar Bone Thickness (continued)

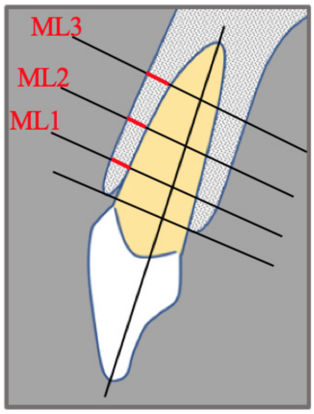
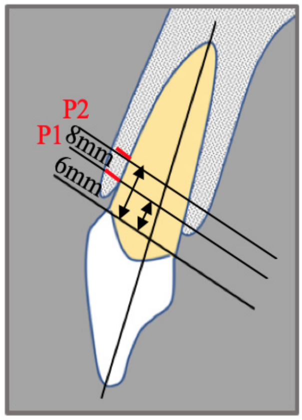
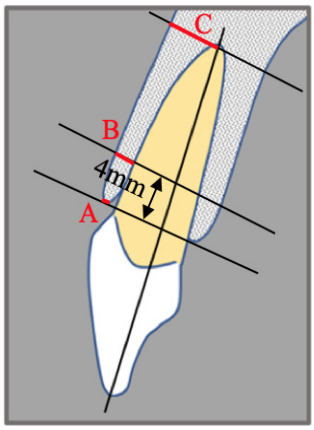
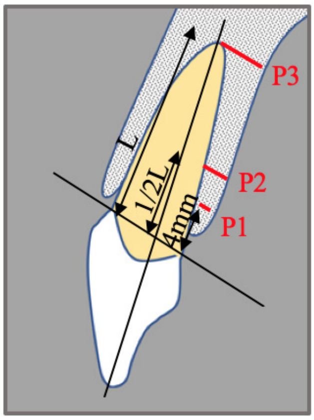
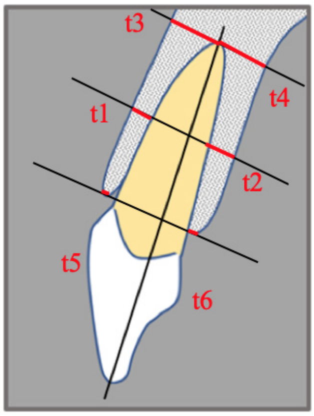
Author, year	Study design	Study Object	Method of evaluation	Measurement of figures and illustrations
(Zekry, Wang, Chau, & Lang, 2014)	Retrospective study	Facial alveolar bone of maxillary and mandibular teeth from central incisor to the first molar)	Computerized tomographic (CT) scans	 Figure 7 : At 3 predefined locations: (ML1) 1 mm apical to the alveolar crest of the facial alveolar bone wall , (ML2) 2.3 mm apical to the alveolar crest of the facial alveolar bone wall 3. 5 mm apical to the alveolar crest of the facial alveolar bone wall (ML3).
(Jaf et al., 2018)	Retrospective study	Buccal cortical bone thickness in maxillary and mandible teeth, from distal of canine to mesial of second molar	Cone-beam computed tomography (CBCT) scans	 Figure 8: At 2 different vertical levels: (P1): 6mm from the cemento-enamel junction (CEJ), (P2):8mm from the cemento-enamel junction (CEJ)
(Lopez-Jarana et al., 2018)	Descriptive retrospective study	Buccal bone of all maxillary and mandibular (central incisor, lateral incisor, canine, first and second premolars, first and second molar)	Cone-beam computed tomography (CBCT) scans	 Figure 9 : At 3 different location: (A) At the coronal part of the buccal crest (B) 4mm from the coronal buccal crest (B). (C) At the apex (from the apical constriction to the buccal wall

Table I: Previous Studies Measuring the Alveolar Bone Thickness (continued)

Author, year	Study design	Study Object	Method of evaluation	Measurement of figures and illustrations
(Do, Shen, Fuh, & Huang, 2019)	Retrospective study	Palatal alveolar bone of maxillary incisors	Cone-beam computed tomography (CBCT) scans	 Figure 10 : At 3 different locations: (PI) 4 mm apical to the Cemento-enamel junction (P2) Middle of the root (mid-point between P1 to P3) (1/2 L) (P3) Apex
(Zhang, 2020)	Retrospective study	Buccal and palatal bone thickness of all maxillary teeth (central incisor. Lateral incisor, canine)	Cone-beam computed tomography (CBCT) scans	 Figure 11: At 3 different locations: (t5, t6)1mm apical to alveolar crest (t1, t2) Mid-root (t3, t4) Apical level

as variation existed on the pattern of facial bone, the flapless approach might not be suitable to prevent fenestration in immediate implant placement (52). Based on the variation of measurement presented in Table I, it is recommended to have a standard approach when investigating the facial bone with specific FOV and resolution to allow uniformity of the result.

The Role of Palatal Alveolar Bone

The palatal alveolar bone is mostly made up of lamellar bone, so there is less vertical bone reduction after extraction (6). The thickness of the palatal alveolar bone is an important factor to consider when determining the diameter and length of the implant, as well as providing anatomic information to guide implant placement in the optimal position. Furthermore, in immediate implant placement, the palatal alveolar bone is critical for primary implant stability (9). To achieve initial stability, the immediate implant was recommended to place at least 3 mm apical to the extraction site and 2 mm beyond the midroot of palatal bone (10, 53). However, clinicians must be aware of the thinnest part of the palatal bone plate as well as severe maxillary incisor protrusion. This is done to avoid perforation of the palatal bone plate during immediate implant placement surgical procedures (10).

For the palatal bone thickness, a significant difference was recorded with facial bone was thicker than the palatal (37). In contrast, a previous cadaver study has recorded an opposite finding, with palatal bone was thicker than the facial bone. According to the tooth type, palatal crest was thickest on lateral incisor as compared to central incisor and canines (38). When compared with CBCT assessment, the finding is similar with human clinical study with palatal bone being greater thickness than buccal (3). These different findings could be due to measurement method, the type of sample and the influenced by slice selected for measurement. Based on the previous research, it is possible to conclude that the palatal plate of the maxillary anterior teeth serves as an anatomical landmark for implant bone anchorage (2, 3, 29). Nonetheless, the clinicians should not exploit the residual palatal bone to achieve the primary stability as placing the implant too palatal may cause buccally tilted implant (10). Therefore, the assessment of tooth angulation or root angulation is also essential to achieve a prosthetic driven implant location.

The Role Tooth Angulation

The angle formed between the long axis of the tooth and the long axis of its relative alveolar bone housing is referred to as tooth angulation (54). This measurement is critical for determining implant size and orientation. Previous authors classified this position as a sagittal view based on CBCT images, but it was suggested that it be changed to a radial view (12, 13). To simulate root anatomy in circle radius, the CBCT scan viewer scrolls through the ridge in a cross-section of sagittal slices. (Fig. 1). The insertion was suggested at the same angle as the original tooth relative to the alveolar housing in this position.(46) However, only 9.5% were able to follow these principles, highlighting the importance of evaluating an implant's angulation and position to avoid unpredictable outcomes (11).

Based on the previous study, the tooth angulation was found to be frequent in 10° to 20° (29,45). In this type of tooth angulation, it was recorded as predictable, suitable to follow the same orientation and ideal as

Figure 1: Sagittal view used for CBCT analysis for alveolar bone wall thickness.

screw-retained restoration (55-56). Nevertheless, special attention should be given in 1-10° group and more than >20° group as it will result in compromised situations (2, 56). Therefore, besides planning with immediate implant based on sagittal position, the quantitative method of tooth angulation was useful in clinical setting to emphasize the contraindication of immediate implant. Because there was a significant correlation between tooth angulation and bone thickness, clinicians may have the option of using a smaller diameter implant, either cemented or implant with angulated screw, or bone grafting with delayed implant placement (10). As standard method of tooth angulation measurement in CBCT is lacking, there is a clear need to combine the parameters of alveolar bone thickness and tooth angulation in quantitative method and establish a comprehensive classification related to immediate implant placement (47,55).

PREVIOUS CLASSIFICATION FOR POSITION OF TOOTH ROOT RELATED TO IMMEDIATE IMPLANT PLACEMENT IN THE ANTERIOR MAXILLA

Several classifications have previously been reported to provide clinicians with guidelines for immediate implant placement (12,55,58). The tooth angulation was not quantitatively specified for each group based on all these classifications. However, tooth position was generally determined by an inclination toward buccal or palatal inclination. The compilations of previous classification were recorded in Table II.

From the previous assessment, Lau et al. has included 300 images of the maxillary anterior teeth from CBCT. Measurements were performed to assess the facial and bone thickness at crestal level, midroot and apex. The sagittal root position was further divided into buccal, middle, and palatal through the alveolar bone long axis. (11) A descriptive classification and recommendation of indication or contraindication of immediate implant was further categorized .Nonetheless , the data only concern on maxillary central incisors and has limitation on other teeth.

Kan et al. developed an insightful classification and included more anatomic variants of all maxillary anterior teeth within the same year (central incisor, lateral incisor, canine). The respective study included 100 patients with 600 images, between 2006 and 2010, with the mean age of patients of 53.1. The sagittal root position was classified according to its relationship with its relative osseous housing into four classes. The classification included Class I the root was positioned against the labial cortical plate, Class II the root was centered in the middle of the alveolar housing and not engaging at the apical third of the root into either the labial or palatal cortical plates, Class III the root was positioned against the palatal cortical plate, Class IV at least two thirds of the root is engaged into both the labial and the palatal

Table 2: Previous Classifications of Root Position of Anterior Teeth Relative to Immediate Implant Placement

Author, year	Study design	Study Object	Method of evaluation	Classification formulated
Lau et al, 2011(?)	Prospective study	Maxillary Central Incisor	Cone-beam (CB) images	**Level I** (M1, P1) Implant placed at the same angulation as the extraction socket. **-Type M1:** 1. Tooth lies midway between the buccal and palatal alveolar surface. 2. Root apex angulated toward the buccal side with the long axis passing posterior **- Type P1:** 1. Tooth lies closer to the palatal alveolar surface. 2. Root apex angulated toward the palatal side or parallel to the alveolus **Level II** (B1, B2, M2, M3, P2, P3) Modify angulation of implant more palatally **-Type B1:** -Tooth lies closer to the buccal alveolar surface. -Root apex angulated toward the palatal side or parallel to the alveolus **-Type B2:** -Tooth lies closer to the buccal alveolar surface. - Root apex angulated toward the buccal side with the long axis passing posterior to point A. **-Type M2:** - Tooth lies midway between the buccal and palatal alveolar surface. - Root apex angulated toward the buccal side with the long axis passing posterior to point A. **-Type M3:** - Tooth lies midway between the buccal and palatal alveolar surface. - Root apex angulated toward the buccal side with the long axis passing anterior to point A. **-Type P2:** - Tooth lies closer to the palatal alveolar surface. - Root apex angulated toward the buccal side with the long axis passing posterior to point A. **-Type P3:** - Tooth lies closer to the palatal alveolar surface. - Root apex angulated toward the buccal side with the long axis passing anterior to point A. **Level II** (B3) Extreme angle/socket transformation **-Type B3** - Tooth lies closer to the buccal alveolar surface) - Root apex angulated toward the buccal side with the long axis passing anterior to point A.
Kan et al, 2011(?)	Retrospective study	All maxillary anterior teeth (central incisor, lateral incisor, canine)	Cone-beam computed tomography (CBCT) scans.	-**Class I**: The root is positioned against the labial cortical plate. -**Class II**: The root is centered in the middle of the alveolar housing without engaging either the labial or the palatal cortical plates at the apical third of the root. -**Class III**: The root is positioned against the palatal cortical plate. -**Class IV**: At least two thirds of the root is engaging both the labial and palatal cortical plates
Xu et al, 2016 (?)	Retrospective study	Maxillary Central Incisor	Cone-beam computed tomography (CBCT) scans.	**(B) Buccal type**: the apical point of the incisor is within the buccal first third of the alveolar bone, and the root is closer to the buccal bone wall. **BI**: Buccal type the incisor root is covered by the buccal bone wall 4 mm apical to the CEJ, midroot, and apex and the bone thickness increases toward the apex. **BII:** Buccal type the incisor root is covered by relatively thinner buccal bone wall in comparison with subtype I, bone thickness does not increase noticeably toward the apex which is covered by bone tissue in the long axis of the tooth. **BIII:** Buccal type and the apex is not covered by bone tissue in the long axis of the tooth, with or without buccal bone wall **(M) Middle type**: the apical point of the incisor is within the middle third of the alveolar bone, and the buccal and palatal bone walls are approximately equal in thickness, or are both very thin or even absent. **(P) Palatal type:** the apical point of the incisor is within the palatal first third of the alveolar bone, and the root is closer to the palatal bone wall
Gluckman et al, 2018 (?)	Observational, clinical study	All maxillary anterior teeth (central incisor, lateral incisor, canine)	Cone-beam computed tomography (CBCT) scans.	-**Class I**: Tooth centrally positioned within ridge Class IA: thick facial bone wall (1 mm) Class IB: thin facial bone wall (<1 mm) -**Class II**: Tooth retroclined Class IIA: thick crestal bone Class IIB: thin crestal bone -**Class III**: Tooth proclined: typically, thick palatal bone, thin facial crest, thick facial wall apically -**Class IV**: Tooth facially positioned outside of bone

cortical plate. Yet, the data has disagreement and was evaluated subjectively based on the examiner viewing the cross-sectional image at the midpoint of the tooth parallel to its long axis and its relation to the osseous housing (12).

In 2016, Xu et al has formulated another classification based on root position of maxillary incisors. The study has included 934 images of maxillary incisors and was divided into buccal (B), middle (M) and palatal (P) based on the root position. The buccal type was then divided into three parts into subtype I, II and III. However, the double classification appears to be complex and does not include specific measurement on facial crest, midroot and palatal apex that identifies the important parameters for immediate implant (58).

Finally, Gluckman et al. has established the most recent classification, in 2018. The author has included 150 patients with 591 teeth with the mean age of 49.4. The methodology has added tooth type, tooth inclination, buccal and palatal bone measurement on crest, midroot and palatal. In this study, radial plane positions were used instead of sagittal to assist technician with optimal osteotomy positioning. The study has improved the previous groundwork proposed by previous study to improve the classification in immediate implant. Although an extensive clinical guideline was recommended including the prospective restoration in implant treatment, the classification has limited information on quantitave measurement of tooth angulation in specific degree (59). Therefore, further research may add specific quantitative values of degrees in tooth angulation to apply in clinical settings. In addition, rather than a descriptive analysis, future research in implant dentistry could formulate a prediction model based on the treatment outcome in immediate implant and be able to estimate the reliability of the classifications produced.

CONCLUSION

CBCT planning for immediate implant placement should incorporate facial, palatal alveolar bone thickens as well as tooth angulation to allow immediate implant placement in a restorative driven position. As various variables could influence immediate implant placement, the reliability of previous classification should be further investigated and used as reference to develop a predictive modelling or risk assessment analysis.

REFERENCES

1. Jung YH, Cho BH, Hwang JJ. Analysis of the root position of the maxillary incisors in the alveolar bone using cone-beam computed tomography. Imaging Science in Dentistry. 2017;47(3):181-7. doi: 10.5624/isd.2017.47.3.181
2. Lopez-Jarana P, Diaz-Castro CM, Falcao A, Falcao C, Rios-Santos JV, Herrero-Climent M. Thickness of the buccal bone wall and root angulation in the maxilla and mandible: an approach to cone beam computed tomography. BMC Oral Health. 2018;18(1):194. doi: 10.1186/s12903-018-0652-x.
3. Porto OCL, Silva BSF, Silva JA, Estrela CRA, Alencar AHG, Bueno MDR, et al. CBCT assessment of bone thickness in maxillary and mandibular teeth: an anatomic study. J Appl Oral Sci. 2020;28:e20190148. doi: 10.1590/1678-7757-2019-0148
4. Fu JH, Yeh CY, Chan HL, Tatarakis N, Leong DJ, Wang HL. Tissue biotype and its relation to the underlying bone morphology. J Periodontol. 2010;81(4):569-74. doi: 10.1902/jop.2009.090591.
5. Zweers J, Thomas RZ, Slot DE, Weisgold AS, Van der Weijden FG. Characteristics of periodontal biotype, its dimensions, associations and prevalence: a systematic review. J Clin Periodontol. 2014;41(10):958-71. doi: 10.1111/jcpe.12275
6. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. Journal of clinical periodontology. 2005;32(2):212-8. doi: 10.1111/j.1600-051X.2005.00642.x.
7. Sanz M, Cecchinato D, Ferrus J, Pjetursson EB, Lang NP, Lindhe J. A prospective, randomized-controlled clinical trial to evaluate bone preservation using implants with different geometry placed into extraction sockets in the maxilla. Clin Oral Implants Res. 2010;21(1):13-21. doi: 10.1111/j.1600-0501.2009.01824.x
8. ARDEC AO. A cone beam tomographic evaluation of hard tissue alterations at immediate implants: a clinical prospective study. Int J Periodontics Restorative Dent. 2013;33:815-23. doi: 10.11607/prd.1442.
9. Kan JYK, Rungcharassaeng K, Deflorian M, Weinstein T, Wang HL, Testori T. Immediate implant placement and provisionalization of maxillary anterior single implants. Periodontol 2000. 2018;77(1):197-212. doi: 10.1111/prd.12212.
10. Do TA, Shen YW, Fuh LJ, Huang HL. Clinical assessment of the palatal alveolar bone thickness and its correlation with the buccolingual angulation of maxillary incisors for immediate implant placement. Clin Implant Dent Relat Res. 2019;21(5):1080-6. doi: 10.1111/cid.12835.
11. Lau SL, Chow J, Li W, Chow LK. Classification of maxillary central incisors-implications for immediate implant in the esthetic zone. J Oral Maxillofac Surg. 2011;69(1):142-53. doi: 10.1016/j.joms.2010.07.074.
12. Kan JY, Roe P, Rungcharassaeng K, Patel RD, Waki T, Lozada JL, et al. Classification of sagittal root position in relation to the anterior maxillary

osseous housing for immediate implant placement: a cone beam computed tomography study. International Journal of Oral & Maxillofacial Implants. 2011;26(4).
13. Gluckman H, Pontes CC, Du Toit J. Radial plane tooth position and bone wall dimensions in the anterior maxilla: A CBCT classification for immediate implant placement. J Prosthet Dent. 2018;120(1):50-6. doi: 10.1016/j.prosdent.2017.09.005
14. Moghaddas O, Behravan I. A new classification of the sagittal root positioning of the mandibular anterior teeth in relation to their anterior buccal bone using cone-beam computed tomography (CBCT). Journal of Advanced Periodontology & Implant Dentistry. 2020;12(2):65-71. doi: 10.34172/japid.2020.014.
15. Moudi E, Haghanifar S, Johari M, Gholinia H, Ghanbarabadi MK. Evaluation of the cone-beam computed tomography accuracy in measuring soft tissue thickness in different areas of the jaws. J Indian Soc Periodontol. 2019;23(4):334-8. doi: 10.4103/jisp.jisp_675_18.
16. Mozzo P PC, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8(9):1558-64. doi: 10.1007/s003300050586.
17. Arai Y TE, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol. Dento maxillo facial radiology. 1999;28(4):245-8. doi: 10.1038/sj/dmfr/4600448.
18. Uffmann M, Schaefer-Prokop C. Digital radiography: the balance between image quality and required radiation dose. European journal of radiology. 2009;72(2):202-8. doi: 10.1016/j.ejrad.2009.05.060
19. Fokas G, Vaughn VM, Scarfe WC, Bornstein MM. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: A systematic review. Clinical oral implants research. 2018;29:393-415. doi: 10.1111/clr.13142.
20. Ludlow JB TR, Walker C, Hunter R, Benavides E, Samuelson DB, et al. Effective dose of dental CBCT - A meta analysis of published data and additional data for nine CBCT units. Dentomaxillofac Radiol. 2015;44. doi: 10.1259/dmfr.20140197.
21. Harris D, Buser D, Dula K, Grondahl K, Haris D, Jacobs R, et al. E.A.O. guidelines fo the use of diagnostic imaging in implant dentistry. A consensus workshop organized by the European Association for Osseointegration in Trinity College Dublin. Clin Oral Implants Res. 2002;13(5):566-70. doi: 10.1034/j.1600-0501.2002.130518.x.
22. Tyndall DA, Brooks SL. Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial radiology. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2000;89(5):630-7. doi: 10.1067/moe.2000.106336.
23. Harris D, Horner K, Grondahl K, Jacobs R, Helmrot E, Benic GI, et al. E.A.O. guidelines for the use of diagnostic imaging in implant dentistry 2011. A consensus workshop organized by the European Association for Osseointegration at the Medical University of Warsaw. Clin Oral Implants Res. 2012;23(11):1243-53. doi: 10.1111/j.1600-0501.2012.02441.x
24. Bornstein MM, Brugger OE, Janner SF, Kuchler U, Chappuis V, Jacobs R, et al. Indications and Frequency for the Use of Cone Beam Computed Tomography for Implant Treatment Planning in a Specialty Clinic. Int J Oral Maxillofac Implants. 2015;30(5):1076-83. doi: 10.11607/jomi.4081.
25. Torres MG, Campos PS, Segundo NP, Navarro M, Crusoe-Rebello I. Accuracy of linear measurements in cone beam computed tomography with different voxel sizes. Implant Dent. 2012;21(2):150-5. doi: 10.1097/ID.0b013e31824bf93c.
26. Yusof NAM, Noor E, Yusof MYPM. The accuracy of linear measurements in cone beam computed tomography for assessing intrabony and furcation defects: A systematic review and meta-analysis. Journal of Oral Research. 2020;8(6):527-39. doi: 10.17126/joralres.2019.077
27. Luangchana P, Pornprasertsuk-Damrongsri S, Kiattavorncharoen S, Jirajariyavej B. Accuracy of linear measurements using cone beam computed tomography and panoramic radiography in dental implant treatment planning. International Journal of Oral & Maxillofacial Implants. 2015;30(6). doi: 10.11607/jomi.4073.
28. Gerlach NL, Ghaeminia H, Bronkhorst EM, Bergй SJ, Meijer GJ, Maal TJJ. Accuracy of assessing the mandibular canal on cone-beam computed tomography: a validation study. Journal of Oral and Maxillofacial Surgery. 2014;72(4):666-71. doi: 10.1016/j.joms.2013.09.030.
29. Dos Santos JG, Oliveira Reis Durao AP, de Campos Felino AC, Casaleiro Lobo de Faria de Almeida RM. Analysis of the Buccal Bone Plate, Root Inclination and Alveolar Bone Dimensions in the Jawbone. A Descriptive Study Using Cone-Beam Computed Tomography. J Oral Maxillofac Res. 2019;10(2):e4. doi: 10.5037/jomr.2019.10204
30. Esfahanizadeh N, Daneshparvar N, Askarpour F, Akhoundi N, Panjnoush M. Correlation Between Bone and Soft Tissue Thickness in Maxillary Anterior Teeth. J Dent (Tehran). 2016;13(5):302-8.
31. Buser D, Chappuis V, Belser UC, Chen S. Implant placement post extraction in esthetic single tooth sites: when immediate, when early, when late? Periodontol 2000. 2017;73(1):84-102. doi: 10.1111/prd.12170.
32. Araujo MG, da Silva JCC, de Mendonca AF, Lindhe J. Ridge alterations following grafting of fresh

extraction sockets in man. A randomized clinical trial. Clin Oral Implants Res. 2015;26(4):407-12. doi: 10.1111/clr.12366.
33. Javed F RG. The role of primary stability for successful immediate loading of dental implants. A literature review. Journal of dentistry. 2010;38(8):612-20. doi: 10.1016/j.jdent.2010.05.013
34. Kan JY, Rungcharassaeng K. Proximal socket shield for interimplant papilla preservation in the esthetic zone. International Journal of Periodontics & Restorative Dentistry. 2013;33(1). doi: 10.11607/prd.1346.
35. Grunder U, Gracis S, Capelli M. Influence of the 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent. 2005;25(2):113-9.
36. AO. A. A cone beam tomographic evaluation of hard tissue alterations at immediate implants: a clinical prospective study. Int J Periodontics Restorative Dent. 2013;33:815-23. doi: 10.11607/prd.1442.
37. Huynh-Ba G, Pjetursson BE, Sanz M, Cecchinato D, Ferrus J, Lindhe J, et al. Analysis of the socket bone wall dimensions in the upper maxilla in relation to immediate implant placement. Clin Oral Implants Res. 2010;21(1):37-42. doi: 10.1111/j.1600-0501.2009.01870.x.
38. Han JY, Jung GU. Labial and lingual/palatal bone thickness of maxillary and mandibular anteriors in human cadavers in Koreans. J Periodontal Implant Sci. 2011;41(2):60-6. doi: 10.5051/jpis.2011.41.2.60.
39. Nowzari H, Molayem S, Chiu CH, Rich SK. Cone beam computed tomographic measurement of maxillary central incisors to determine prevalence of facial alveolar bone width >/=2 mm. Clin Implant Dent Relat Res. 2012;14(4):595-602. doi: 10.1111/j.1708-8208.2010.00287.x.
40. Januario AL, Duarte WR, Barriviera M, Mesti JC, Araujo MG, Lindhe J. Dimension of the facial bone wall in the anterior maxilla: a cone-beam computed tomography study. Clin Oral Implants Res. 2011;22(10):1168-71. doi: 10.1111/j.1600-0501.2010.02086.x.
41. Braut V, Bornstein MM, Belser U, Buser D. Thickness of the anterior maxillary facial bone wall-a retrospective radiographic study using cone beam computed tomography. Int J Periodontics Restorative Dent. 2011;31(2):125-31.
42. Ghassemian M, Nowzari H, Lajolo C, Verdugo F, Pirronti T, D'Addona A. The thickness of facial alveolar bone overlying healthy maxillary anterior teeth. J Periodontol. 2012;83(2):187-97. doi: 10.1902/jop.2011.110172
43. Zekry A, Wang R, Chau AC, Lang NP. Facial alveolar bone wall width - a cone-beam computed tomography study in Asians. Clin Oral Implants Res. 2014;25(2):194-206. doi: 10.1111/clr.12096.
44. Zhang X LY, Ge Z, Zhao H, Miao L, Pan Y. The dimension and morphology of alveolar bone at maxillary anterior teeth in periodontitis: a retrospective analysis—using CBCT. Int J Oral Sci. 2020;12:4-. doi: 10.1038/s41368-019-0071-0.
45. Wang HM, Shen JW, Yu MF, Chen XY, Jiang QH, He FM. Analysis of facial bone wall dimensions and sagittal root position in the maxillary esthetic zone: a retrospective study using cone beam computed tomography. Int J Oral Maxillofac Implants. 2014;29(5):1123-9. doi: 10.11607/jomi.3348.
46. Mandelaris GA, Vence BS, Rosenfeld AL, Forbes DP. A classification system for crestal and radicular dentoalveolar bone phenotypes. Int J Periodontics Restorative Dent. 2013;33(3):289-96. doi: 10.11607/prd.1787.
47. Tsigarida A, Toscano J, de Brito Bezerra B, Geminiani A, Barmak AB, Caton J, et al. Buccal bone thickness of maxillary anterior teeth: A systematic review and meta-analysis. J Clin Periodontol. 2020;47(11):1326-43. doi: 10.1111/jcpe.13347.
48. Bamusa B AaA, Binjubair M, Badahdah O, Bakhadher W. Buccal alveolar bone thickness: A review of studies. Medicine and Medical Sciences. 2019;7(3):018-23.doi: 10.15413/mms.2019.0103
49. Buser D, von Arx T. Surgical procedures in partially edentulous patients with ITI implants. Clin Oral Implants Res. 2000;11 Suppl 1:83-100. doi: 10.1034/j.1600-0501.2000.011s1083.x.
50. Gluckman H, Salama M, Du Toit J. Partial Extraction Therapies (PET) Part 1: Maintaining Alveolar Ridge Contour at Pontic and Immediate Implant Sites. Int J Periodontics Restorative Dent. 2016;36(5):681-7. doi: 10.11607/prd.2783.
51. Chen ST, Darby IB, Reynolds EC, Clement JG. Immediate implant placement postextraction without flap elevation. J Periodontol. 2009;80(1):163-72. doi: 10.1902/jop.2009.080243.
52. Lin CY, Pan WL, Wang HL. Facial Fenestration and Dehiscence Defects Associated With Immediate Implant Placement Without Flap Elevation in Anterior Maxillary Ridge: A Preliminary Cone Beam Computed Tomography Study. Int J Oral Maxillofac Implants. 2018;33(5):1112-8. doi: 10.11607/jomi.6575.
53. 55. Ebenezer V BK, Vigil Dev Asir R , Sragunar B. Immediate placement of endosseous implants into the extraction sockets. J Pharm Bioallied Sci. 2015;7:S234-7. doi: 10.4103/0975-7406.155926.
54. Baysal A, Ucar FI, Buyuk SK, Ozer T, Uysal T. Alveolar bone thickness and lower incisor position in skeletal Class I and Class II malocclusions assessed with cone-beam computed tomography. Korean J Orthod. 2013;43(3):134-40. doi: 10.4041/kjod.2013.43.3.134
55. Gluckman H, Pontes CC, Du Toit J. Radial plane tooth position and bone wall dimensions in the anterior maxilla: A CBCT classification for immediate implant placement. The Journal of prosthetic dentistry. 2018;120(1):50-6. doi:

10.1016/j.prosdent.2017.09.005
56. Poletto-Neto V, Tretto PHW, Zen BM, Bacchi A, Dos Santos MBF. Influence of Implant Inclination and Prosthetic Abutment Type on the Biomechanics of Implant-Supported Fixed Partial Dentures. J Oral Implantol. 2019;45(5):343-50. doi: 10.1563/aaid-joi-D-18-00305.
57. Juodzbalys G, Sakavicius D, Wang HL. Classification of extraction sockets based upon soft and hard tissue components. J Periodontol. 2008;79(3):413-24. doi: 10.1902/jop.2008.070397.
58. Xu D, Wang Z, Sun L, Lin Z, Wan L, Li Y, et al. Classification of the root position of the maxillary central incisors and its clinical significance in immediate implant placement. Implant dentistry. 2016;25(4):520-4.
59. Hammerle CH, Araujo MG, Simion M, Osteology Consensus G. Evidence-based knowledge on the biology and treatment of extraction sockets. Clin Oral Implants Res. 2012;23 Suppl 5:80-2. doi: 10.1111/j.1600-0501.2011.02370.x.