The Alveolar Bone Thickness Evaluation of Variable Sagittal Root Position in Maxillary Central Incisors: A Cone-Beam Computed Tomography Study

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Abstract

Due to the challenging of esthetic outcome after tooth extraction. The information on the alveolar bone thickness of variable sagittal root position (SRP) in maxillary central incisors in the Thai population was still lacking. The objectives of this study are 1) To classify the degree of SRP in their alveolar bone housing and 2) To analyze the relationship of SRP with bone thickness, sex, and age in the Thai population. 120 CBCT scans of the maxillary central incisor area were selected and categorized into 3 age groups. The SRP was classified into 4 classes (I-IV). Bone thickness was measured at a mid-root level on the labial and palatal sides. The relationship between age and sex associated with SRP classification was analyzed using the Chi-square test. The difference of labial and palatal bone thickness among groups was analyzed by the Kruskal Wallis H test with Dunn's post hoc test. It is found that Class II SRP (retroclined) showed the highest frequency (40%). There were no significant differences in SRP between age groups and each sex. Majority of labial bone was ≤ 1mm (70%). Class I SRP showed the highest bone thickness (0.96±0.49 mm) with a significant difference when compared with Class II (0.70±0.37 mm) (p<0.05). 95.8% of subjects revealed palatal bone thickness ≥ 1 mm except for Class IV SRP (0.82±0.81 mm). Then, a majority of maxillary anterior teeth in the Thai population were retroclined with labial bone thickness <1 mm and palatal bone thickness >1 mm. Hence, clinicians may use the palatal bone wall as primary stability for implant placement.

Keywords: *Alveolar bone housing, Alveolar bone thickness, Cone-beam computed tomography, Immediate implant placement, Maxillary central incisor, Sagittal root position*

1. Introduction

Nowadays, dental implants are extensively used as an option for patients who have edentulous areas and are not satisfied with removable dentures because of their long-term predictability and high success rate (Beschnidt et al., 2018). One of the factors affecting the success rate of dental implants is the period of implant surgery including immediate, early, and delay placement. The successful of immediate implant placement depends upon case selection and tooth conditions along with suitable treatment planning and clinical procedures (Becker, 2006). Placing an implant immediately at the upper anterior area is the most challenging procedure due to highly esthetic expectations and bone morphology. The proper position of an implant is very important because it can affect the final prosthetic position. Therefore, cone-beam computed tomography (CBCT) is recommended as an imaging tool to assess bone quantity, bone quality, and surrounding anatomical structures in three-dimension (Jacobs et al., 2018).

In daily dental practice, radiography is one of the diagnostic tools that are frequently used to identify dental diseases and problems. A conventional radiograph is widely used due to its easy access, cost-effectiveness, and image quality but there are some limitations such as two-dimensional data and image distortion. For the panoramic radiograph, clinicians cannot avoid distorting in a horizontal plane and enlarging in a vertical plane (Özalp et al., 2018). The CBCT has become an important tool for dental implant procedures because of its accuracy compared to conventional ones (Jacobs et al., 2018). The measurement of CBCT can be also affected by several factors such as parameter setting (tube voltage, tube current, and voxel size), a field of view (FOV), image quality, and software (Fokas et al., 2018). Artifacts are one of the disadvantages points in using CBCT, which irritates the process of bone thickness measurement (Nagarajappa et al., 2015). Nevertheless, overcome by many strengths like reasonable radiation dose and three-dimensional data, CBCT still be admired in the implant working areas (Jacobs et al., 2018). Adequate bone volume tends to provide good primary stability after placing an implant immediately because surrounding hard and soft tissue can change in both vertical and horizontal dimensions after tooth extraction (Baniasadi & Evrard, 2017; Hansson & Halldin, 2012). Thus, CBCT is crucial to help evaluate all bone walls such as labial bone wall, palatal bone wall and bone beyond apex of the root to make sure that there is enough bone for implant placement (Javed et al., 2013). An early study proposed that resorption of bone could be reduced without bone augmentation (Rosenquist & Grenthe, 1996), in contrast with many recent studies showed that bone resorption still occurred even placing an implant immediately after extraction (Botticelli et al., 2004; Calvo-Guirado et al., 2015). The labial alveolar ridge is usually very thin in an anterior zone which may affect an esthetic outcome after implant placement (Vera et al., 2012). Thus, bone augmentation is recommended to reduce horizontal bone loss and proper angulation is also essential to avoid bony dehiscence (Chen et al., 2007; Clementini et al., 2019).

A proper angulation and inclination of dental implants in the alveolar bone can improve both function and esthetic outcome. Due to the various shapes of the alveolar ridge, clinicians are recommended to prepare an osteotomy site for immediate implant placement by inclining with the palatal bone wall (Gluckman et al., 2018). Different types of osseous housing can affect the results of immediate implant placement. Several previous studies have classified root position in the anterior maxillary region but still lack information about the thickness of bone in each type (Kan et al., 2011; Lau et al., 2011; Xu et al., 2016). Recently, there was a study that classified a radial tooth position and measured bone height and bone thickness in maxillary anterior teeth (Gluckman et al., 2018). However, the information on bone morphology in the Thai population is still very limited. This study was to present a classification of maxillary central incisor root position compared with bone thickness in different ages and sexes in Thai patients.

2. Objectives

The purposes of this study were including

1) To classify the degree of sagittal root position in maxillary central incisors
2) To analyze the relationship of sagittal root position with bone thickness, sex, and age in the Thai population

3. Materials and methods

Sample selection

The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2020-083).

All CBCT images were acquired using a CBCT scan (iCAT^{TM} Imaging Sciences International, Hatfield, PA, USA) with a 170x130 mm field of view (FOV) and 0.25 mm voxel size. The data of CBCT were transferred into the picture archiving and communication system (PACS) server. 120 CBCT scans with optimal image quality were selected from the hospital server at the Faculty of Dentistry, Chulalongkorn University between January 2019 and July 2020 with the presence of maxillary central incisor tooth and must be Thai nationality. Sixty CBCT scans of both males and females, age range between 20-80 years old, were included. The samples were divided into 3 age groups; 20-40, 40-60, and 60-80 years old. CBCT scans were excluded when present with the following features; apical lesion or infection, severe periodontitis, previously orthodontic, endodontic, and surgical treatment, history of systemic disease affecting bone, history of trauma at maxillary central incisors teeth, and the presence of contraindications for implant placement.

Examiner

CBCT was viewed on PACS software (Infinitt® software, Infinitt Healthcare Co. Ltd., Seoul, Korea). All the CBCT images were measured by one examiner who is a dentist with 4 years of experience. The examiner was calibrated with dentomaxillofacial radiologist by viewing a few cases together prior to the measurements.

Radiographic evaluation

Part I Sagittal root position (SRP) classification

The SRP was classified into 4 groups based on the labio-palatal orientation of the tooth in the alveolar ridge and bone wall thickness of the maxillary central incisors (Table 1, Figure 1).

Table 1 The sagittal root position classification

SRP	Labio-palatal inclination of tooth in alveolar ridge
Class I	The root is centrally positioned in the alveolar ridge
Class II	Retroclined tooth
Class III	Proclined tooth
Class IV	Thin labial and palatal bone walls

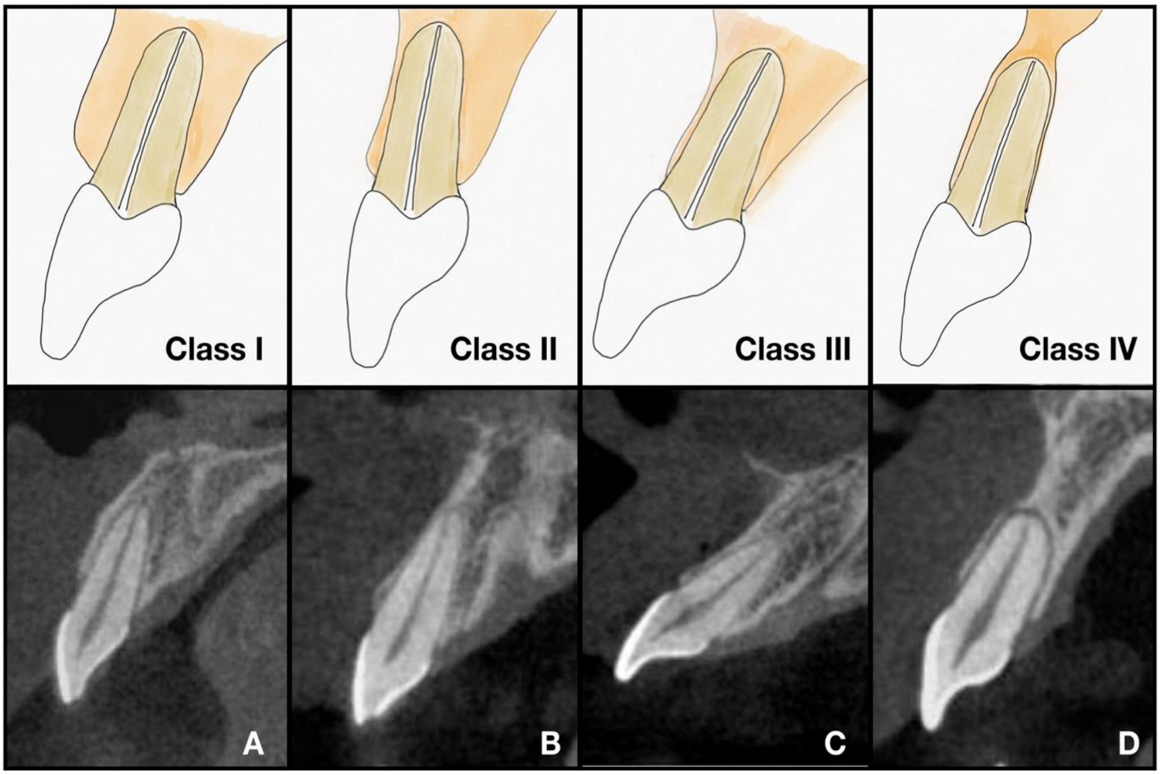

Figure 1 The sagittal root position classification. A Centrally positioned tooth. B Retroclined tooth. C Proclined tooth. D Thin labial and palatal bone walls tooth

Part II Bone thickness evaluation

Labial bone thickness was described as the distance from the labial side of the root to the outer surface of the labial bone wall and palatal bone thickness was also measured from the palatal side of the root to the outer surface of the palatal bone wall. The bone thickness was measured at the mid-root level (Line B) on both labial and palatal sides. The mid-root level was a half distance between the most crestal bone aspect level (Line A) and the apex of the root level (Line C) while all levels were drawn parallel to a cervical line (Line 1) (Figure 2).

The data were analyzed using IBM® SPSS® software for Windows version 27 (IBM, New York, USA). The distribution of data was tested by the Shapiro-Wilk test. Kruskal Wallis H test with Dunn's posthoc test was used to identify the difference between labial bone and palatal bone thickness among sagittal root position groups due to the data was non-normal distribution. The associations between classes of SRP and age and sex were analyzed using the Chi-square test. P-values less than 0.05 were considered statistical significance.

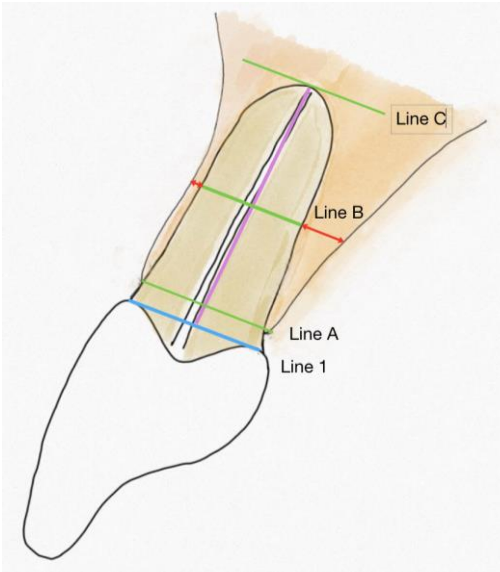

Figure 2 Labial and palatal bone thickness

4. Results

From 120 SRP images, no statistically significant difference was found in each SRP classification in-between age groups and sexes as shown in Table 2. Class II (retroclined tooth) showed the highest frequency in all groups.

Table 2 Frequency distribution of Class I, Class II, Class III, and Class IV SRP with each age group and each sex

Factors	Sagittal root position				*p*-value
	Class I	**Class II**	**Class III**	**Class IV**	
Sex					0.140
Male	21 (35.0%)	26 (43.3%)	13 (21.7%)	0 (0.0%)	
Female	19 (31.7%)	22 (36.7%)	14 (23.3%)	5 (8.3%)	
Age group					0.984
20-40	13 (32.5%)	15 (37.5%)	10 (25.0%)	2 (5.0%)	
40-60	14 (35.0%)	15 (37.5%)	9 (22.5%)	2 (5.0%)	
60-80	13 (32.5%)	18 (45.0%)	8 (20.0%)	1 (2.5%)	

The majority of the SRP was Class II (retroclined tooth), accounting for 40% of the samples. Class I (centrally position) was 33.3%, followed by Class III (proclined tooth) and Class IV (thin labial and palatal bone walls), accounting for 22.5% and 4.2%, respectively. The average bone thickness of the labial and palatal bone wall in different types of SRP is presented in Table 3. CBCT revealed that 70% of all teeth had labial bone thickness < 1 mm at mid-root. On the other hand, 95.8% of samples showed palatal bone wall thickness ≥ 1 mm. Up to 98.3% of samples had palatal bone walls thicker than the labial bone wall. A statistically significant difference was found only between Class I (0.96 ± 0.49 mm) and Class II (0.70 ± 0.37 mm) ($p < 0.05$) at the labial bone wall. For the palatal bone wall, the lowest value was Class IV (0.82 ± 0.81 mm), which was significantly different when compared with values from other groups ($p < 0.05$).

Table 3 Median (interquartile range) of bone thickness (mm) according to sagittal root position (SRP)

Position	Sagittal root position classification				*p*-value
	Class I	**Class II**	**Class III**	**Class IV**	
Labial bone wall	0.96 (0.49)	0.70 (0.37)	0.77 (0.42)	0.74 (0.36)	0.010
Palatal bone wall	3.19 (2.07)	2.85 (1.70)	3.76 (1.89)	0.82 (0.81)	0.002

5. Discussion

The anatomical of osteotomy site and root position before tooth extraction can be used to evaluate a proper treatment plan for immediate implant placement using CBCT (Gluckman et al., 2018). The ITI Consensus Conference recommended immediate implant placement with an intact labial bone wall of at least 1mm(Morton et al., 2014) in accordance with other studies that showed the recession of bone after surgery especially when the labial bone thickness was less than 0.5 mm (Farronato et al., 2020). After tooth removal, the thickness of residual bone combined with adequate soft tissue is resulting in an esthetic outcome.

This study investigated the classification of roots in their osseous housing and considered bone thickness on both labial and palatal sides. The results showed that 98.3% of all teeth had a palatal bone wall thicker than the labial bone wall at the mid-root level. The palatal wall side is usually thicker than 1 mm in the middle of the root (95.8%) similar to other studies that up to 98% and 60.2% of patients in the esthetic area were greater than1 mm (Gluckman et al., 2018; Huynh-Ba et al., 2010). This anatomical socket site may enhance a favorable place for implant placement by engaging the palatal bone wall and leaving a gap for bone augmentation between the implant and labial bone side (Kan et al., 2011). The current study showed that only 30% of all teeth had a labial bone thickness more than 1 mm in accordance with previous studies which demonstrated 80% of maxillary anterior teeth had thin facial bone (Wang et al., 2014), 83% of maxillary central incisor had labial bone wall less than 1 mm (El Nahass & S, 2015).

No significant difference when comparing the classification of SRP with Sex and with age. These findings were similar to the previous (Gluckman et al., 2018). However, another study demonstrated that facial bone had a statistically significant higher in female patients and negative relationship with age (Demircan & Demircan, 2015). The frequency of Class II (retroclined tooth) was 40% and be a majority for all groups of age and sex in accordance with another study that the retroclined tooth was the highest one up to 76.5% (Gluckman et al., 2018).

The relationship between tooth angulation and alveolar bone is essential in immediate implant planning, particularly in the maxillary anterior region. After placing an implant, the inclination of it can affect the prosthetic part such as the decision to choose types of abutments (angle or anatomical) and screw-retained or cement-retained. The predictable esthetic outcome can be occurred from both screw- and cemented-retained when the implant is placed in the proper position (Shadid & Sadaqa, 2012). In this study, accounted for 33.3% was Class I which the root located centrally in the alveolar ridge. It is an ideal outline for treatment planning of immediate implant placement. Class II showed the highest frequency (40%) which the labial bone thickness was rather unpredictable and the previous study suggested that delayed placement would be better (Gluckman et al., 2018). In Class III, which included 22.5% of this study's sample, the delayed procedure was also recommended due to a risk of labial bone resorption. However, in both Class II and Class III, a large volume of palatal bone was an advantage point and may enhance primary stability after placement. Only 4.2% of the sample population were Class IV that the root had a thin bone wall at the labial and palatal sides, the immediate implant placement is not suggested in this condition.

A few limitations were encountered during the conduct of this research. A CBCT image quality in this study was hardly interpreted on a millimeter scale for measuring bone thickness and some images were difficult to separate bone from surrounding structures. All images had large FOV because they were chosen from the database for the reason of implant placement. However, large FOV did not interfere with the resolution of the images for measuring methods. The images were classified and measured by only one observer that may have a risk of bias and chance of having imprecise results. Another observer should be added in future studies for inter-observer agreement analysis.

This study demonstrated the importance of CBCT which allow clinicians to assess the conditions of the tooth before surgery due to the limitations of the alveolus. The precise of measurement is very crucial especially in the maxillary anterior part as seen in this current study that the labial bone wall is usually very thin in contrast with the palatal bone wall that mostly thicker than 1 mm. The palatal side would be a good indication for placing an implant immediately in a situation that does not have enough osseous housing at the labial part to create primary stability and enhance the long-term success of the implant. Therefore, clinicians must carefully evaluate the quality of the working area using CBCT before doing immediate implant placement for the best outcome of patients. The CBCT image must have good quality and proper parameters such as FOV which should be the smallest size as possible to limit radiation exposure. In Thai patients, this study showed the recommendation to determine root position in the sagittal plane and demonstrated the bone thickness in each sagittal root position classification that can be used to be an information for proper treatment planning of immediate implant placement.

6. Conclusions

This study revealed that in the Thai population, a majority of maxillary anterior teeth were retroclined tooth position that may not be the proper condition for immediate implant placement. The labial bone is usually less than 1 mm and the palatal bone is generally more than 1 mm. Hence, clinicians may use the palatal bone wall as primary stability for implant placement.

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