Original Article

Relationship between Facial Alveolar Bone Thickness and Root Position of Maxillary Anterior Teeth Using Cone Beam Computed Tomography

Papatpong Sirikururat[1] and Supranee Benjasupattananan[1]

[1]School of Dental Medicine, Faculty of dental medicine, Rangsit University, Pathumthani

Abstract

This study purposed to assess the average of the facial alveolar bone thickness at the facial root surface of the maxillary anterior teeth, along with its relationship to the root position by using cone-beam computed tomography (CBCT) in a group of Thai population. Seventy CBCT scans (420 teeth) were randomly selected from the CBCT database at School of Dental Medicine, Rangsit University. The exclusion criteria were the subjects with extensive dental caries, fixed coronal restoration, severe root resorption, and destructive periodontal disease in maxillary anterior region. After recruitment, 406 teeth were used to measure facial alveolar bone thickness and sagittal root position (SRP). The data of the facial alveolar bone thickness was collected in cross-sectional dimensions. The measurements were performed at three reference points, which were 4 mm apical to CEJ (R1), midpoint between 4 mm to CEJ and mid-root (R2), and mid-root (R3). The results revealed that the facial alveolar bone thickness seemingly decreased apically in every type of tooth. The mean facial bone thickness of maxillary teeth was between 0.67±0.75 to 1.04±0.67 mm. The majority of examined teeth in this study exhibited Class I SRP (overall 92.87 %; central incisor 93.87 %, lateral incisor 89.85 %, and canine 95.56 %). Class II SRP was found to be 5.4 %, 5.22 % and 2.27 % in lateral incisor, central incisor and canine respectively. Class IV SRP was found only 1.73 % (lateral incisor 1.45 %, central incisor 1.50 % and canine 2.22 %). But Class III SRP did not present in this study. Simple correlation test showed no statistically significance between the facial alveolar bone thickness and root position. In conclusion, the anterior maxillary teeth have a high prevalence of thin facial alveolar bone wall. These findings may consider risking of facial alveolar bone dehiscence, fenestration or soft tissue recession after immediate implant placement. The majority of the root position is SRP class I which is favorable for the implant – alveolar bone engagement of immediate implant placement.

Keyword: Facial alveolar bone thickness, Root position, Dental cone beam computed tomography, Anterior maxilla

Received Date: **Accepted Date:**

doi:

Correspondence to:

Supranee Benjasupattananan. Rangsit University, 52/347 Muang-Ake, Phaholyothin Road, Lak-Hok, Muang, Pathumthani 12000 Thailand

Tel: 085-1092515 Fax: 02-7916000 Email: supranee.b@rsu.ac.th

Introduction

Immediate implant placement and provisionalization has been claimed to be the treatment of choice when it comes to replacing failing teeth in esthetic zone due to its stability of soft tissue shape over time.[1,2,3] To achieve an esthetically successful outcome, the bone surrounding root apex at palatal side should be 4-5 mm, and at buccal aspect of the root surface should be 2 mm in thickness to provide stable post-implant placement environment and prevent soft tissue recession, fenestration, and dehiscence.[4,5,6] Sagittal root position (SRP) represents the relationship of root to its osseous housing which is important in determining the feasibility of immediate implant placement. The amount of palatal alveolar bone is considered for implant engagement to attain primary stability during immediate implant placement. The other anatomical factor that should be considered for dental implant in esthetic zone is the marginal bone thickness at mesial and distal to the implants, and the facio-lingual dimension of the papillary base that correlates to papillary fill and gingival recession after the treatment.[2,7] To assess and determine the factors concerned, the information of the underlying structures that involved in implants treatment should be carefully and precisely measured by means of gathering the data to construct a proper treatment plan that is best suited case by case. Not only a clinical and non-invasive data-collecting examination, but also radiographic examinations are required, which is mandatory for observing hard tissue and bony structure prior to the treatment plan for implantation established.[2,8]

Cone beam computed tomography (CBCT) has been considered to be a useful radiographic assessment prior to implant placement since it offers a 3D imaging of the bony structure while providing a less radiation dose compare to that medical CT or other types of radiograph with equal information.[9,10] Anyhow, the study about facial alveolar bone thickness using CBCT in Thai population is still very limited. The available information shown the low prevalence of labial plate thicker than 1 mm.[11] The facial alveolar bone wall should be ideally at least 2 mm after implant bed preparation.[12] Hence, sufficient information is required for the prediction of implant treatment outcome in Thai population. The aims of this study were to assess average bone thickness at three reference points along the facial root surface of anterior teeth, and along with its relationship to the root position, by assessing the radiographic images from the CBCT.

Materials and Methods

Seventy CT scans (420 teeth) were randomly selected from the CBCT database at school of Dental Medicine, Rangsit University. The inclusion criteria were applied to all of participants' age between 20-70 years old that presented of all maxillary anterior teeth (central incisors, lateral incisors, canines). The exclusion criteria included the participants with extensive dental caries, fixed coronal restorations, severe root resorption, and destructive periodontal disease in maxillary anterior region. Finally, 406 teeth were used for measuring the facial alveolar bone thickness and classifying types of root position according to Kan's Sagittal Root Position (SRP) classification.

CBCT machine used in this study was i-CAT (i-CAT 17–19, Imaging Sciences International LLC, Hatfield, PA USA). The x-ray machined was set at 120 kVp, 5 mA and 14.7 s (voxel size: 0.25 mm, 14 bit, FOV: 16 x 13 cm). The software that was used for measuring was CS 3D Imaging Software (slice thickness: 250 μm).

From CBCT scan images, the data of facial alveolar bone thickness were collected in cross-sectional 1x1 dimensions. The reformatted panoramic curve was standardized by drawing the line from points of the center of the pulp at mid-root location from left to right of first premolar teeth. Due to the reasons above, long axis was drawn in each tooth and measured the facial alveolar bone thickness following the line which was perpendicular to imaginary line, from outer cortical bone to the external root surface. The facial bone was measured at three reference points as following: 4 mm apically to CEJ, represented with R1. The midpoint between 4 mm apically to CEJ and middle of root, represented with R2 and the middle of anatomical root, represented with R3 (Fig. 1). The cross-sectional images were scan-captures and independently evaluated for facial alveolar bone thickness measurement and root position by two examiners. The inter-examiner agreement was calibrated using 14 randomly selected images. An assessment of the reproducibility of measurements between two examiners measuring the same quantity was calculated at interclass correlation of 0.87 for 14 images.

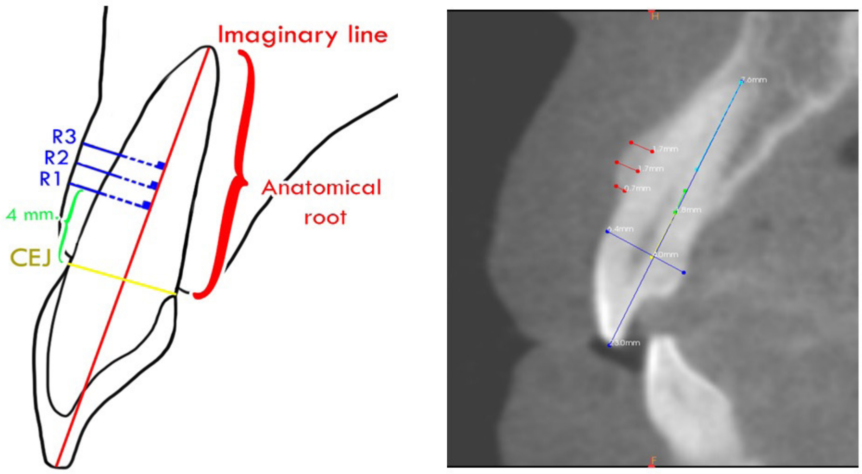

Figure 1 *Three reference points to assess the average facial alveolar bone thickness.*

In this study, SRP classification by Kan *et al* [2] was used to classify the position of root related to surrounding bone. The SRP in relationship to the osseous housing was evaluated by viewing the cross-sectional image made at the midpoint of the tooth parallel to its long axis, were divided into 4 classes (Fig. 2). 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 and class IV: at least two thirds of the root is engaging both the labial and palatal cortical plates. The root position of each anterior tooth was classified by using the same scans as using in facial alveolar bone thickness measurement and classified by one examiner (Fig. 3).

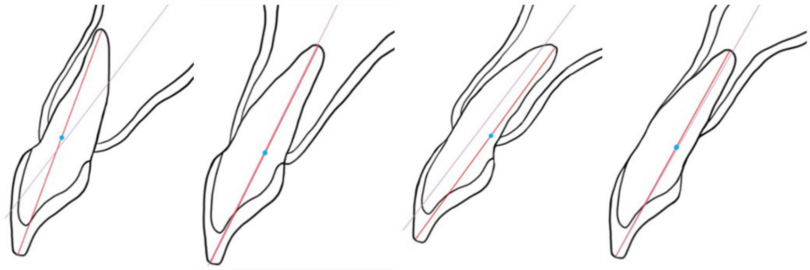

Figure 2 *SRP classification according to Kan et al.2 From left to right; class I, II, III and IV.*

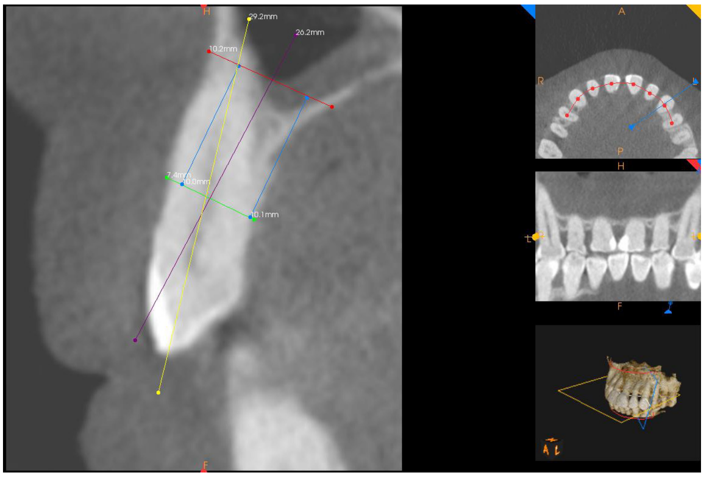

Figure 3 *SRP determinations*

The mean values and standard deviations were calculated for all parameters. The average facial bone thickness in each reference points (R1, R2 and R3), the prevalence of root position's classification and the relationship between the bone thickness and root angulation in each classification were analyzed by using Simple correlation.

Results

This study consisted of 420 teeth from 70 Thai subjects (35 males and 35 females) with the range of age 21 to 66 years old (mean±SD = 47.14±11.97). After the inclusion and exclusion criteria were applied, 406 teeth were recruited. All CBCT scans were taken between 2013 and 2016 at the Department of Oral Radiology, Rangsit University. The distribution of the analyzed subjects was presented in Table 1.

Table 1 *Distribution of the analyzed teeth (N=406).*

	Distribution of the analyzed teeth						
Tooth	13	12	11	21	22	23	Total
No. of the analyzed data	69	68	64	69	70	66	406

The mean facial bone thickness of central incisors at reference R1, R2 and R3 were 1.02, 0.96 and 0.93 mm respectively. The mean facial bone thickness of lateral incisors at reference R1, R2 and R3 were 0.85, 0.76 and 0.76 mm respectively. The mean facial alveolar bone thickness of canine at reference R1, R2 and R3 were 1.00, 0.91 and 0.94 mm respectively. The standard deviation of mean facial alveolar bone thickness was presented in Table 2.

Table 2 The mean and standard deviation of facial alveolar bone thickness of maxillary anterior teeth.

		Central incisor	Lateral incisor	Canine
R1	Range	0.40-1.62	0.09-1.52	0.26-1.78
	Mean±SD	*1.02±0.59*	*0.85±0.66*	*1.00±0.69*
R2	Range	0.42-1.50	0.00-1.46	0.15-1.67
	Mean±SD	*0.96±0.50*	*0.76±0.69*	*0.91±0.69*
R3	Range	0.05-1.44	0.00-1.50	0.14-1.71
	Mean±SD	*0.93±0.49*	*0.76±0.69*	*0.94±0.69*
n		64	68	69

At R1 of the central incisors exhibited the mean facial alveolar bone thickness 0 mm, between 0-1 mm, between 1.01 - 2 mm and >2mm as 13.37 %, 35.09 %, 43.19 % and 8.36 % respectively. For the lateral incisors presented mean facial alveolar bone thickness 0 mm, between 0-1 mm, between 1.01 - 2 mm and >2mm as 23.19 %, 31.88 %, 39.86 % and 5.07 % respectively. For the canines, the examined teeth exhibited mean facial alveolar bone thickness between 0-1 mm, between 1.01 - 2 mm and >2mm as 17.88 %, 25.35 %, 49.20 % and 7.57 % respectively, as shown in Fig. 4.

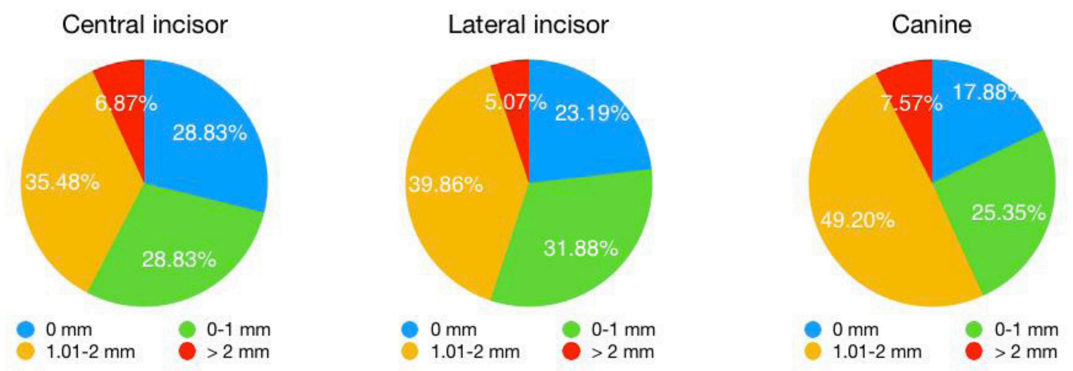

Figure 4 The percentage of each group of facial alveolar bone thickness at R1 by each tooth type.

At R2, the central incisors, the majority of examined teeth exhibited the mean facial alveolar bone between 1.01 - 2 mm as 50.38 %. Most of lateral incisors exhibited mean facial alveolar bone between 0-1 mm as 45.65%. For the canines shown the mean facial alveolar bone thickness 0 mm, between 0-1 mm, between 1.01 - 2 mm and >2mm as 19.26 %, 26.67 %, 45.92 % and 8.15 % respectively, as shown in Fig. 5.

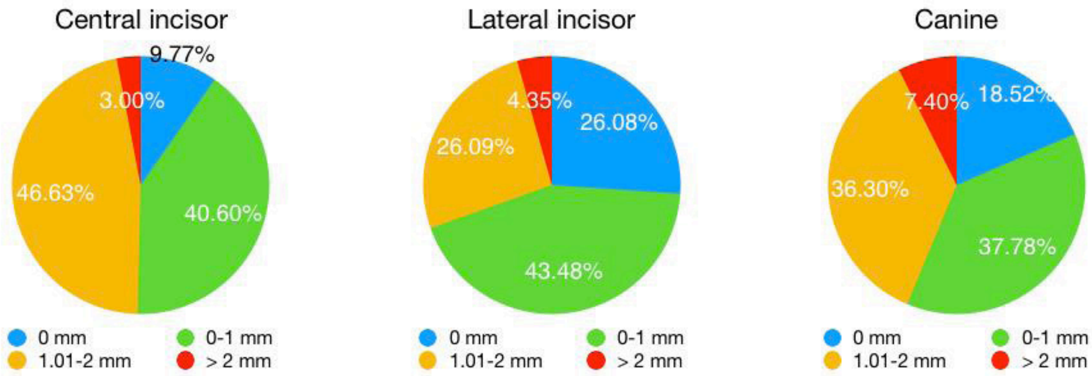

Figure 5 *The percentage of each group of facial alveolar bone thickness at R2 by each tooth type.*

At R3, the central incisors, the majority of examined teeth exhibited the mean facial alveolar bone between 0-1 mm and 1.01 - 2 mm 40.60 % and 46.63 % respectively. 43.48 % of the examined lateral incisors teeth exhibited mean facial alveolar bone thickness between 1.01 - 2 mm. For the canines, the examined teeth exhibited facial alveolar bone thickness 0 mm, between 0-1 mm, between 1.01 - 2 mm and >2mm as 18.52 %, 37.78 %, 36.30 % and 7.40 % respectively, as shown in Fig. 6.

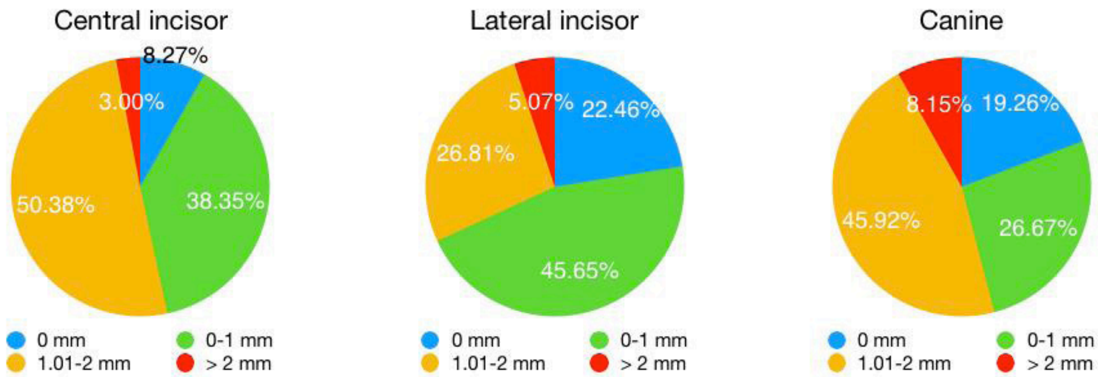

Figure 6 *The percentage of each group of facial alveolar bone thickness at R3 by each tooth type.*

The sagittal root position classification

The CBCT data from the 406 teeth, 378 teeth (92.87 %) were Class I, 22 teeth (5.40 %) were Class II, 0 (0 %) were Class III, and 7 teeth (1.73 %) were Class IV. The frequency distributions of SRP classification (class I, II, III and IV) in each tooth type were calculated. The central incisors (134 teeth) presented with 93.28 %, 5.22 %, 0 %, and 1.50 %, respectively. The lateral incisors (138 teeth) presented with 89.85 %, 8.70 %, 0 %, and 1.45 %, respectively. The canines (135 teeth) presented with 95.56 %, 2.22 %, 0 %, and 2.22 %, respectively. In the present study, the frequency distributions of the SRP classification of each tooth type are presented in Table 3.

Table 3 *Prevalence of SRP classification in each tooth type.*

	Frequency distribution of SRP							
	Overall		Central		Lateral		Canine	
SRP	%	n	%	n	%	n	%	n
Class I	92.87	378	93.28	125	89.85	124	95.56	129
Class II	5.40	22	5.22	7	8.70	12	2.22	3
Class III	0	0	0	0	0	0	0	0
Class IV	1.73	7	1.50	2	1.45	2	2.22	3
Total	**100**	**406**	**100**	**134**	**100**	**138**	**100**	**135**

The correlation analysis between the facial alveolar bone thickness and SRP classifications shown no significant different at reference points of any teeth.

Discussion

Replacement of failing teeth in esthetic area has been considered as a critical challenge to both functional and esthetic outcomes.[12] Establishing an appropriate treatment plan prior to any procedures produces more predictable outcomes and complications that help the patient to decide which kind of prosthesis would be most likely to meet patients' requirements and expectation. When a dental implant was put into one of the treatment plan, both prosthetic and surgical consideration should be carefully assessed in order to confirm both quantitative and qualitative considerations of the area that will support the dental implant.[13] Also, the sagittal root position of the tooth to be extracted is important in determining the immediate implant placement site to gain adequate primary stability of the implant.

In the present study, most of the studied teeth exhibited a facial alveolar bone thickness less than 1 mm at all reference points (R1, R2, and R3). This is in agreement with Braut *et al*[14], which classified facial bone thickness in anterior maxillary region, from right to left maxillary first premolars, into 3 thickness groups; missing (0 mm), thin (less than 1 mm), and thick (equal to, or more than 1 mm) bone thickness, at 2 radiographic reference points; MP1 (point at the crestal area), and MP2 (point at the half root length). They concluded that 62.9 % and 80.1 % of examined teeth revealed facial bone thickness less than 1 mm at MP1 and MP2 respectively. In addition, Jaidee *et al*[11] studied the average thickness of the maxillary labial plate in Thai population using CBCT scans, which included 724 anterior maxillary teeth, reporting the mean labial plate thickness varied from 0.660 (at mid root level) to 0.885 mm (at 4 mm apically to CEJ) with none of the subjects presented with labial bone thickness exceeding 2 mm. On contrary, the facial bone thickness in this study exceeded 2 mm at all points, the reason might be explained from facial bony exostoses presented in some of the subjects. Another study about facial bone thickness[15], that recruited of 250 CBCT scans with the presence of all maxillary anterior teeth in each scan, at three reference points; 1mm, 3 mm, and 5 mm apically to alveolar bone crest area, reporting the mean of the buccal plate varied from 0.5 to 0.7 mm with no missing bone wall presented. The prevalence of missing bone wall in the present study, as well as Braut *et al*[14] and Jaidee *et al*[11] was due to the constant reference points, 4 mm apically to CEJ and mid root region, was chosen, while Januário *et al* [10] evaluated reference points apically to alveolar crestal area, which may varied individually due to physiologic or pathologic changes that affect the crestal area before the more apical points. Crestal area is the most likely to be the first critical site that would show the early sign of esthetic complication, such as peri-implant mucosal recession and metal exposure, thus evaluating the existing crestal bone would be beneficial for the implant site selection in order to prevent, or predict, the outcome of the implant in esthetic region.[15]

For immediate implant placement, primary implant stability must be achieved by engaging the fixture with palatal bone wall and beyond the root apex approximately 4-5 mm.[16,17] Kan and his collegues[2] classified SRP of anterior maxilla teeth as class I, II, III and IV according to theirs osseous housing. 600 SRP images were evaluated, 81.1 % were class I, 6.5 % were class II, 0.7 % was class III and 11.7 % were class IV. In our study, 92.87 % of class I root position was found, which is the most favorable class for immediate implant placement due to the highest amount of palatal bone availability. It would provide the best implant stability comparing to the other classification. After immediate implant placement is performed, bone grafting in the gap between implant and remaining socket would be the next procedure to be done.[18,19] 5.40 % class II and 1.73 % class IV SRP was reported in our study. Class II SRP, the roots locate in the center of alveolar bone housing. The surrounding bone would loss on both facial and palatal aspects might not be adequate to ensure implant stability, compared to class I. Class IV SRP shows the existing tooth root occupies majority of the alveolar volume, affecting further loss of facial and palatal bone after tooth extraction. Therefore, class IV SRP is considered to be relative contraindication for immediate implant placement, due to inadequate stability and compromising the esthetic outcome.

No class III root angulation classification was found in this study. The result is consistent to Lin *et al*[20] which performed the study in Taiwanese population, 93.8 % class I, 1.5 % class II, 4.7 % class IV and no class III SRP were showed. Class III SRP, the roots engage in the palatal bone, which is not suitable for immediate implant placement after extraction, due to the stability of the implant relies on its engagement in the available on the facial aspect instead of palatal aspect unlike class I. The result of engaging in facial bone might cause fenestration and affected esthetic outcome. Therefore, class III SRP is less favorable than class I and class II in immediate implant placement.

The correlation between facial bone thickness and sagittal root position of class I, II and IV were not statistically significant at any level of facial alveolar bone measurement. While class III SRP was not found in this study, thus the class III SRP data was excluded. According to Kan *et al*[2], which reported less frequency of class III SRP as 0.7 %, revealed the raring of the root position. Anatomically, class III SRP in which the entire root length engages the palatal cortical bone plate, therefore the facial alveolar bone thickness should have been high tendency of greater facial alveolar bone.

Another limitation is the image resolution. Since the original scan resolution was 0.25 mm, which might be too large for the small linear measurement, used in the study. Some of studied teeth showed the facial alveolar bone thickness less than 0.5 mm which smaller than two voxels and this led to measurement inaccuracy due to the partial volume effect. The further study should have set the smaller voxel size e.g. 0.1 or 0.2 mm, however, the radiation dose and exposure time would be also raised. All variables should be considered crucially for the next investigation.

Conclusion

Nowadays, dental implant has become a treatment of choice for tooth replacement. To achieve a successful treatment outcome with high predictability, precise assessment and careful preoperative treatment planning are required to analyze the risk factors especially in the esthetic zone. The facial bone thickness and root position are considered to be local risk factors for immediate implant placement. This study demonstrated that the ideal facial alveolar bone thickness was low prevalence. However, the class I sagittal root position, which is favorable for implant-bone engagement, was the majority of this finding. The use of CBCT is recommended for implant-based treatment planning.

Acknowledgement

We would like to express our gratitude to Clinical Prof. RADM Suchada Vuddhakanok R.T.N, Prof. Emer. Chainut Chongruk, Clinical Prof. Wichitsak Cholitgul and Dr. Piyanuch Karnasuta for providing us the opportunity of performing this study and valuable CBCT data. In addition, we are grateful to Miss Piyanut Liamthai, Miss Photchanan Ballungpattama, Miss Natnarie Sahas-olarn, Miss Luxsamee Sriurai, Miss Walailak Kunteekarn, Miss Penpitcha Kositkittiwanit and Miss Peacharat Chivaratanond for their assistance and co-operation during the period of study.

References

1. Kan JY, Rungcharassaeng K, Lozada J. Immediate Placement and Provisionalization of Maxillary Anterior Single Implants: 1-Year Prospective Study. *Int J Oral Maxillofac Implants* 2003;18: 31-9.

2. 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. *Int J Oral Maxillofac Implants* 2011;26:873-6.

3. Buser D, Halbritter S, Hart C, Bornstein M, Grütter L, Chappuis V, *et al.* Early Implant Placement With Simultaneous Guided Bone Regeneration Following Single-Tooth Extraction in the Esthetic Zone: 12-Month Results of a Prospective Study With 20 Consecutive Patients. *J Periodontol* 2009;80:152-62.

4. Tortamano P, Camargo LO, Bello-Silva MS, Kanashiro LH. Immediate implant placement and restoration in the esthetic zone: a prospective study with 18 months of follow-up. *Int J Oral Maxillofac Implants* 2010;25:345-50.

5. Nowzari H, Molayem S, Chiu C, Rich S. Cone Beam Computed Tomographic Measurement of Maxillary Central Incisors to Determine Prevalence of Facial Alveolar Bone Width ≥2 mm. *Clin Oral Impl Res* 2010;14:595-602.

6. Evans DJ, Chen ST. Esthetic outcomes of immediate implant placements. *Clin Oral Impl Res* 2008;19:73-80.

7. Veltri M, Ekrstubbe A, Abrahamsson I, Wennström JL. Three-Dimensional buccal bone anatomy and aesthetic outcome of single dental implants replacing maxillary incisors. *Clin Oral Impl Res* 2016;27:523-28.

8. Younes F, Eghbali A, Raes M, Bruyckere, Cosyn J, Bruyn HD. Relationship between buccal bone gingival thickness revisited using non-invasive registration methods. *Clin Oral Impl Res* 2016;27:956-63.

9.Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Invest* 2006:10;1-7.

10. Januário AL, Duarte WR, Barriviera M, Mesti JC, Araújo MG, Lindhe J. Dimension of the facial bone wall in the anterior maxilla: a cone-beam computed tomography study. *Clin Oral Implants Res* 2011;22:1168-71.

11. Jaidee T, Kasemkitwatana K, Wilaiwong K, Wongmaneerung N, Luksuwan P, Sing-usah P, *et al.* Average thickness of the maxillary labial plate in Thai population using cone beam computed tomography analysis. *Thai J Oral Maxillofac Surg* 2015;29:97-103.

12. Buser D, Born stein MM, Weber HP, Brutter L, Schmid B, Belser U. Early implant placement with simultaneous guided bone regeneration following single-tooth extraction in esthetic zone: a cross-sectional, retrospective study in 45 subjects with a 2- to 4-year follow-up. *J Periodontol* 2008;79:1773-81.

13. Buser D, Martin W, Belser U. Optimizing esthetic for implant restorations in the anterior maxilla: anatomic and surgical considerations. *Int J Oral Maxillofac Implants* 2004;19 (suppl):43-61.

14. Braut V, Bornstein MM, Belser U. Buser D. Thickness of the anterior maxilla facial bone wall: A respective radiographic study using cone beam computer tomography. *Inter J Periodontics Restorative Dent* 2011;31:125-31.

15. 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;21:37-42.

16. Kois JC, Kan JY. Predictable peri-implant gingival aesthetics: Surgical and prosthodontics rationales. *Pract Proced Aesthet Dent* 2001;13:691-98.

17. Garber DA, Salama MA, Salama H. Immediate total tooth replacement. *Compend Contin Educ Dent* 2001;22:210-16.

18. Morton D, Chen ST, Martin WC, Levine R, Buser D. Consensus statements and recommednded xlinical procedures regarding imizing esthetic outcomes in implant dentistry. *Int J Oral*

Maxillofac Implants 2014;29(Suppl):216-20.
19. Kan JY. Rungcharassang K. Immediate placement and provisonalized of maxillary anterior single implants: A surgical and prosthodontic rationale. ***Pract Periodontics Aesthet Dent*** 2000;12:817-24.
20. Lin W, Tseng C, Pang CC. Classification of the sagittal root position of maxillary anterior teeth in Taiwanese population with the cone beam computed tomography image. ***Clin Oral Impl Res*** 2014;25(Suppl 10):199.