Relationship between Alveolar Arch Form and Sagittal Root Angulation in Maxillary Esthetic Area: A Cone Beam Computed Tomography Study

Suweera Petaibunlue[1], Pravej Serichetaphongse[2] and Atiphan Pimkhaokham[3*]

[1]Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand
[2]Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand
[3]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand
[*]Corresponding author, E-mail: atiphan.p@chula.ac.th

Abstract

This study determined the relationship of the angulation between tooth root axis and alveolar bone axis to the anterior alveolar (AA) arch forms in the anterior maxillary region using CBCT images. The CBCT images of 98 patients were classified into four groups according to the novel classification of AA arch forms. The classification of AA arch forms comprised of long narrow, short medium, long medium, and long wide arches. The sagittal views of maxillary anterior teeth and first premolars were measured the angulations of the axis of root and alveolar bone. The relationship of the angulations in each AA arch forms were analyzed using one-way ANOVA. The results showed that the maxillary central incisor had the largest angulation. The statistical differences of the angulation of the root axis and alveolar bone axis between the right and left sides were not found. The mean angulations of the short medium arch were significantly lower than that of the long medium and the long wide arches. Thus, the angulation of the axis of root and alveolar bone showed the relationship to the classification of anterior alveolar arch forms. This information could help implant surgeons in treatment planning.

Keywords: *Alveolar arch form, root angulation, Cone-beam computed tomography*

1. Introduction

Nowadays, dental implants have become the standard treatment for dental reconstruction due to their high survival rate and success rate of both osseointegration and restoration. However, in the esthetic zone of maxilla (anterior teeth and first premolars), it has been a challenge to clinicians due to the high esthetic expectation of patients and several risk factors affecting the treatment outcomes (Buser, Martin, & Belser, 2004; Januario et al., 2011; Johnson, 1969; Misch, 2008; Moy, Pozzi, & Beumer III, 2016).

From a biomechanical aspect, the implant placed in the anterior maxilla was the weakest section, so implants should be placed in appropriate three-dimensional position and angulation in the alveolar arch because it affected various outcomes such as esthetics, phonetics, load distribution, and loss of bone and soft tissue around implants (Buser et al, 2004). However, after tooth extraction, hard and soft tissue alterations would occur in both vertical and horizontal dimensions, especially on the facial aspect of the alveolar ridge (Jahangiri, Devlin, Ting, & Nishimura, 1998; Van der Weijden, Dell'Acqua, & Slot, 2009). Therefore, an alveolar bone would be insufficient in width for an implant placement in anterior maxilla (Misch, 2008). This information might provide needs of using clinical examination and radiographic images.

Maxillary arch form and dental arch form were classified in many aspects. Previous studies of maxillary arch form or dental arch form were used as measurement from models (Ferrario, Sforza, Miani, Jr., & Tartaglia, 1994; Preti, Pera, & Bassi, 1986; Sagat, Yalcin, Gultekin, & Mijiritsky, 2010) or human cadavers (Pietrokovski, Starinsky, Arensburg, & Kaffe, 2007). This technique was not suitable for alveolar arch form measurement. Therefore, cone beam computed tomography (CBCT) was used to analyze and classify the alveolar arch form at anterior maxilla (Bulyalert & Pimkhaokham, 2018; Suk et al., 2013).

According to recent literature review, anterior alveolar arch forms were classified according to the study of Bulyalert et al. using intercanine width, interpremolar width, intercanine depth and intercanine width/depth ratio to divide the arch into 4 groups, including long narrow arch, short medium arch, long medium arch, and long wide arch as shown in Figure 1 (Bulyalert & Pimkhaokham, 2018).

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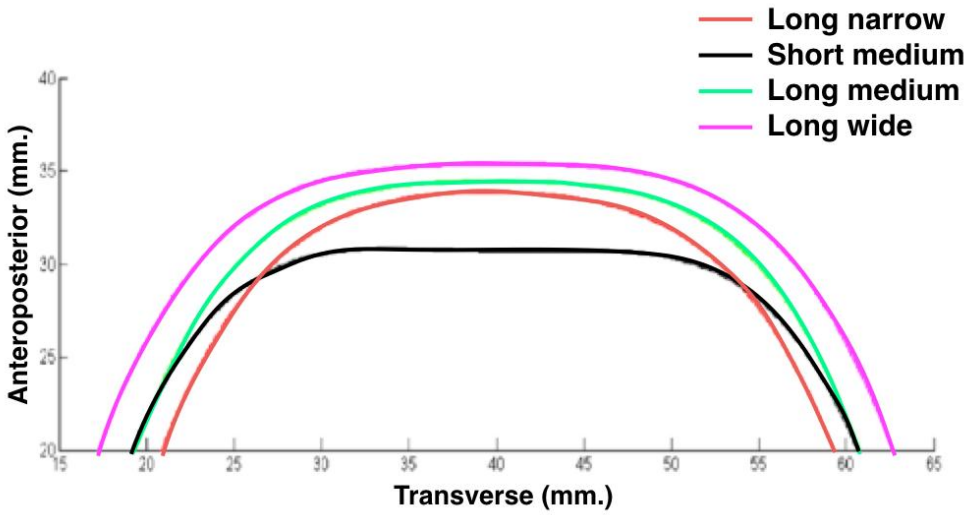

Figure 1 The characteristics of alveolar arch form. Type1 (long narrow), type 2 (short medium), type 3 (long medium), and type 4 (long wide) were showed by the red, black, green, and purple curves respectively (Bulyalert & Pimkhaokham, 2018).

Several studies reported the angulation of alveolar bone axis and long axis of the whole tooth of anterior maxillary teeth in sagittal view which was suitable for orthodontic therapy (Wang et al., 2014; Zhang, Shi, & Liu, 2015; Masunaga, Ueda, &Tanne, 2012). Nonetheless, the sagittal implant angulation should mimic naturally and be parallel to the tooth root axis in both three-dimensional root positions and sagittal root angulation. The sagittal root angulation was defined as the angulation between the alveolar bone axis and the tooth root axis at a midpoint in mesiodistal distance. However, none of the studies demonstrated the proper sagittal root angulation of the natural tooth root and the alveolar bone axis so far.

Taken together, to achieve the long-term successful outcome of implant therapy, the implant fixture should be placed in an alveolus in the optimal implant position, including angulation and depth in a different situation such as arch form. However, none of studies related maxillary anterior alveolar arch form and angulation of root axis and alveolar bone axis was assessed. Thus, this study aimed to determine the relationship of alveolar arch forms and the angulation of alveolar bone axis and tooth root axis in anterior maxillary regions using CBCT images.

2. Objectives

To evaluate the relationship of the angulation between tooth root axis and alveolar bone axis to the anterior alveolar (AA) arch forms in the anterior maxillary region using CBCT images.

3. Materials and Methods

This study was conducted with the approval of the ethical committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (HREC-DCU-P 2016 -011). Ninety-eight CBCT images of the right to the left maxillary first premolars without any artifacts and defects of patients were received from the computer record at the Esthetics and implant clinic of Chulalongkorn University from January 2013 to December 2016. The measurements were performed using computer software (*i-Dixel One Volume Viewer software* Ver.1.5.0; J. Morita Mfg. Corp., Kyoto, Japan) under 300 percent magnification.

3.1 Classification of anterior alveolar arch form and measurement

Anterior alveolar arch classification was defined as the categories of curve of anterior maxillary alveolar arch from right to left maxillary first premolar teeth at the implant related levels which was the level of 3 mm below cemento-enamel junction (CEJ) of the maxillary right and left canines. Intercanine and

interpremolar width, depth, and width/depth ratio were used to classify anterior alveolar arch forms. The classification and the measurement of anterior maxillary alveolar arch form in esthetic regions were cited from the study of Bulyalert et al. (Bulyalert & Pimkhaokham, 2018). This classification categorized anterior maxillary alveolar arch forms into 4 groups comprising: long narrow arch forms, short medium arch forms, long medium arch forms, and long wide arch forms.

3.2 Angulation evaluation

The angulation of alveolar bone axis and tooth root axis is defined as the angle between alveolar bone axis and tooth root axis of maxillary central and lateral incisors, maxillary canine and maxillary first premolar teeth. To measure the angulation of the alveolar bone axis and tooth root axis, the labio-lingual cross-section at the middle of the tooth was measured through the CBCT images according to the study of Lau (Lau, Chow, Li & Chow, 2011). The measurement of alveolar bone axis was done by drawing the buccal (Line 1) and palatal line (Line 2). The alveolar line (Line A) was marked by bisecting angle between the buccal (Line 1) and the palatal line (Line 2). The alveolar line represented the axis of the alveolar bone. Whereas, the measurement of tooth root axis (Line B) was marked by the connecting line from a midpoint of the cervical line (Line 3) to the root apex. The angle (C◦) between the alveolar bone axis (Line A) and the tooth root axis (Line B) were measured. The measurements are shown in the figure 2.

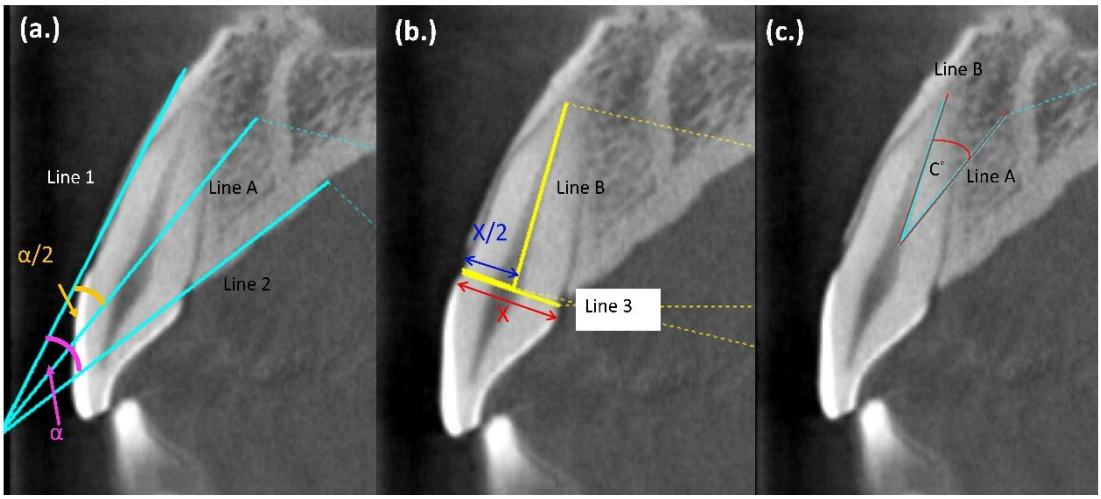

Figure 2 – (a.) Long axis of alveolar bone. Line A represented alveolar bone axis which was the line that bisected the angle of buccal line (Line 1) and palatal line (Line 2). (b.)Long axis of tooth root. Line B represented tooth root axis which was the line drawn from midpoint of the cervical line (Line 3) to the root apex. (c.) Angulation between the long axis of alveolar bone and the long axis of tooth root. C° represented the angle between the long axis of alveolar bone (Line A) and the long axis of tooth root (Line B).

The angulation between the tooth root axis of both right and left maxillary central incisors, maxillary lateral incisors, maxillary canines and maxillary first premolars and the alveolar bone axis were determined.

3.3 Data analysis

Each CBCT image evaluated the classification of the anterior alveolar arch forms and the angulation of the long axis of tooth root and the long axis of alveolar bone. The statistical software (SPSS 22.0, SPSS, Chicago, IL, USA) analyzed the data. The Reliability test was performed twice on separate days 1 month after the initial measurement. Descriptive statistics were presented as means with standard

deviations. *One-way ANOVA* was used to consider the influence of types of alveolar arch forms on the angulation of the root axis and the alveolar bone axis of the maxillary central incisors, lateral incisors, canines and first premolars. A comparative analysis with Student's t-Test and Pearson Product Moment Correlation was applied between sides. *P*-values < 0.05 were adjudged as statistically significant differences.

4. Results and Discussion

The CBCT images of 196 of each maxillary central incisors, lateral incisors, canines and first premolars were evaluated. Of the included 98 patients, 52 were males and 46 were females. The mean sagittal angles between the dental root axis and the respective alveolar bone axis of each tooth were shown in Table 1. The largest sagittal angle was found in the maxillary central incisor. The angulation of root axis and alveolar bone axis did not differ significantly between the right and left sides. However, moderate correlation was found between the right and the left sides (r= 0.657; p< 0.001).

Table 1 Mean and standard deviation (SD) of sagittal angle between root axis and alveolar bone axis

Tooth	**Angle (degrees) mean ± SD**
Maxillary central incisor (n =196)	16.52° ± 5.98°
(range)	(1.10 – 33.12)
Maxillary lateral incisor (n =196)	13.55° ± 6.45°
(range)	(-9.49 – 32.41)
Maxillary canine (n =196)	14.91° ± 5.98°
(range)	(-0.61 – 35.23)
Maxillary first premolar (n =196)	13.34° ± 6.40°
(range)	(1.01 – 30.64)

The anterior alveolar arch forms were classified according to the Bulyalert's study. There were 30 long narrow arches, 12 short medium arches, 30 long medium arches, and 26 long wide arches. The short medium arch showed a significantly lower sagittal angulation than that of not only the long medium arch at the maxillary central incisor and canine, but also, the long wide arch at the central incisor (Table 2).

Table 2 Comparison of means and standard deviations of sagittal angle of root axis and alveolar bone axis between the four groups of anterior alveolar arch form

Arch form / Tooth	**Long narrow (n=60)**	**Short medium (n=24)**	**Long medium (n=60)**	**Long wide (n=52)**
Central incisor	$15.34 \pm 5.88^{A,B,C,D}$	13.49 ± 4.93^{A}	$18.01 \pm 5.19^{B,D}$	$17.81 \pm 6.64^{C,D}$
Lateral incisor	13.40 ± 6.35	11.24 ± 6.62	14.78 ± 5.75	14.66 ± 5.79
Canine	$15.06 \pm 6.79^{A,B,C}$	11.57 ± 4.42^{B}	16.10 ± 5.99^{C}	$14.99 \pm 5.29^{A,B,C}$
First premolar	12.35 ± 5.97	13.60 ± 6.28	13.05 ± 6.46	14.86 ± 6.98
Overall	$14.04 \pm 6.34^{A,B,C,D}$	12.48 ± 5.65^{A}	$15.09 \pm 6.37^{B,D}$	$15.58 \pm 6.30^{C,D}$

*Sagittal angulation of each tooth in different arch is given in degrees; measurements are given as mean standard deviation.

**The same superscript capital letters indicate the absence of significant differences in sagittal angulation for each horizontal row ($p > 0.05$).

The determination and analysis from anterior alveolar arch forms showed moderate correlation between the right and the left sides. The angulation between the dental root axis and the alveolar bone axis was found that of the right side were correlated in the same direction to that of the left side. Thereby, in the anterior maxillary region, the position of the implant can be guided by the contralateral tooth root. And adjunctive bone augmentation might be required to build an appropriate contour of anterior alveolar arch.

To assess the relationship between the root-to-bone angulation and the human arch form, several studies selected arch width, arch depth, and arch width/depth ratio as the variables in their whole alveolar arch form classification (Bayome et al., 2011; Braun, Hnat, Fender, & Legan, 1998; Suk et al., 2013; Park

et al., 2015). However, Bulyalert et al. classified anterior alveolar arch form based on intercanine width, intercanine depth, interpremolar width and intercanine width/depth ratio (Bulyalert & Pimkhaokham, 2018). This study found that intercanine depth were predominant variables for arch form classification due to describing as anterior arch curve. The results demonstrated that the angulation of the tooth root axis and alveolar bone axis decreased with a reduced intercanine depth of the alveolar arch. Thus, the type of anterior alveolar arch form could be used to predict the angulation of the tooth root axis and the alveolar bone axis.

The angulations between whole tooth axis and alveolar bone axis were determined by various studies for a benefit in orthodontic treatment (Wang et al., 2014; Zhang et al, 2015; Jung, Cho, & Hwang, 2017; Kim, Lee, Han, & Kim, 2011).On the other hand, this study determined the angulations between tooth root axis and alveolar bone axis which was suitable for dental implant placement. Since the mean angle between the long axis of crown and root of maxillary central incisor was 1.74 degrees (Bryant, Sadowsky and Hazelrig, 1984), so the angulations between the whole tooth axis and the root axis inside the alveolar bone were different.

On the basis of the results, the implant position should mimic the long axis of dental roots, parallel to the labial cortical bone, and inclined towards the labial more than the incisal edge, so the thinned alveolar bone, especially in the labial aspect, tended to increase bone resorption during osteotomy. The labial bone thickness of 1-2 mm. was sufficient to minimize labial recession (Grunder, Gracis, & Capelli, 2005). As the result, it was recommended to have a gap by placing a proper sized and shaped implant fixture.

5. Conclusion

The anterior alveolar arch forms had a relationship to the angulation between the dental root axis and the alveolar bone axis in the anterior maxillary region. The angulation of the dental root axis and the alveolar bone axis was significant in the implant position and angulation among the different anterior alveolar arch forms. This information could help implant surgeons in treatment planning.

6. Acknowledgements

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7. References

Bayome, M., Han, S. H., Choi, J. H., Kim, S. H., Baek, S. H., Kim, D. J., & Kook, Y. A. (2011). New clinical classification of dental arch form using facial axis points derived from three-dimensional models. *Australian Orthodontic Journal*, *27*(2), 117-124.

Braun, S., Hnat, W. P., Fender, D. E., & Legan, H. L. (1998). The form of the human dental arch. *The Angle Orthodontist*, *68*(1), 29-36.

Bryant, R. M., Sadowsky, P. L., & Hazelrig, J. B. (1984). Variability in three morphologic features of the permanent maxillary central incisor. *American Journal of Orthodontics*, *86*(1), 25-32.

Bulyalert, A, & Pimkhaokham, A. (2018). A novel classification of anterior alveolar arch forms and alveolar bone thickness: A cone beam computed tomography study. *Imaging Science in Dentistry*, *48*(3), 191-199.

Buser, D., Martin, W., & Belser, U. C. (2004). Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *International Journal of Oral & Maxillofacial Implants*, 19 Suppl, 43-61.

Ferrario, V. F., Sforza, C., Miani, A., Jr., & Tartaglia, G. (1994). Mathematical definition of the shape of dental arches in human permanent healthy dentitions. *The European Journal of Orthodontics*, *16*(4), 287-294.

Grunder, U., Gracis, S., & Capelli, M. (2005). Influence of the 3-D bone-to-implant relationship on esthetics. *International Journal of Periodontics & Restorative Dentistry*, *25*(2), 113-119.

Jahangiri, L., Devlin, H., Ting, K., & Nishimura, I. (1998). Current perspectives in residual ridge remodeling and its clinical implications: a review. *The Journal of Prosthetic Dentistry*, *80*(2), 224-237.

Januario, A. L., Duarte, W. R., Barriviera, M., Mesti, J. C., Araujo, M. G., & Lindhe, J. (2011). Dimension of the facial bone wall in the anterior maxilla: a cone-beam computed tomography study. *Clinical Oral Implants Research*, *22*(10), 1168-1171.

Johnson, K. (1969). A study of the dimensional changes occurring in the maxilla following tooth extraction. *Australian Dental Journal*, *14*(4), 241-244.

Jung, Y. H., Cho, B. H., & Hwang, J. J. (2017). Analysis of the root position of the maxillary incisors in the alveolar bone using cone-beam computed tomography. *Imaging Science in Dentistry*, *47*(3), 181-187.

Kim, J. H., Lee, J. G., Han, D. H., & Kim, H. J. (2011). Morphometric analysis of the anterior region of the maxillary bone for immediate implant placement using micro-CT. *Clinical Anatomy*, *24*(4), 462-468.

Lau, S. L., Chow, J., Li, W., & Chow, L. K. (2011). Classification of maxillary central incisors-implications for immediate implant in the esthetic zone. *Journal of Oral and Maxillofacial Surgery*, *69*(1), 142-153.

Masunaga, M., Ueda, H., & Tanne, K. (2012). Changes in the crown angulation and dental arch widths after nonextraction orthodontic treatment: Model analysis of mild crowding with high canines. *Open Journal of Stomatology*, *2*, 188-194.

Misch, C. E. (2008). Anterior single-tooth replacement: surgical considerations. *Contemporary implant dentistry* (pp. 739-768). Canada: Mosby Elsevier.

Moy, P. K., Pozzi, A., & Beumer III, J. (2016). Surgical Considerations for the Esthetic zone. *Fundamentals of Implant Dentistry: Surgical Principles* (pp. 291-332). China: Quintessence Publishing.

Park, K. H., Bayome, M., Park, J. H., Lee, J. W., Baek, S. H., & Kook, Y. A. (2015). New classification of lingual arch form in normal occlusion using three dimensional virtual models. *The Korean Journal of Orthodontics*, *45*(2), 74-81.

Pietrokovski, J., Starinsky, R., Arensburg, B., & Kaffe, I. (2007). Morphologic characteristics of bony edentulous jaws. *Journal of Prosthodontics*, *16*(2), 141-147.

Preti, G., Pera, P., & Bassi, F. (1986). Prediction of the shape and size of the maxillary anterior arch in edentulous patients. *Journal of Oral Rehabilitation*, *13*(2), 115-125.

Sagat, G., Yalcin, S., Gultekin, B. A., & Mijiritsky, E. (2010). Influence of arch shape and implant position on stress distribution around implants supporting fixed full-arch prosthesis in edentulous maxilla. *Implant Dentistry*, *19*(6), 498-508.

Suk, K. E., Park, J. H., Bayome, M., Nam, Y. O., Sameshima, G. T., & Kook, Y. A. (2013). Comparison between dental and basal arch forms in normal occlusion and Class III malocclusions utilizing cone-beam computed tomography. *The Korean Journal of Orthodontics*, *43*(1), 15-22.

Van der Weijden, F., Dell'Acqua, F., & Slot, D. E. (2009). Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review. *Journal of Clinical Periodontology*, *36*(12), 1048-1058.

Wang, H. M., Shen, J. W., Yu, M. F., Chen, X. Y., Jiang, Q. H., & He, F. M. (2014). Analysis of facial bone wall dimensions and sagittal root position in the maxillary esthetic zone: a retrospective study using cone beam computed tomography. *International Journal of Oral & Maxillofacial Implants*, *29*(5), 1123-1129.

Zhang, S., Shi, X., & Liu, H. (2015). Angulations of Anterior Teeth With Reference to the Alveolar Bone Measured by CBCT in a Chinese Population. *Implant Dentistry*, *24*(4), 397-401.