Effects of Alveolar Bone Width and Density on the Rate of Orthodontic Tooth Movement

Nawaporn Ritwiroon
Boonsiva Suzuki
Eduardo Yugo Suzuki

Reprinted from The Journal of The Dental Association of Thailand
Volume 71 Number 1 January – March 2021
page 53-63

Original article

Effects of Alveolar Bone Width and Density on the Rate of Orthodontic Tooth Movement

Nawaporn Ritwiroon[1], Boonsiva Suzuki[1], Eduardo Yugo Suzuki[1]

[1]Department of Orthodontics, Faculty of Dentistry Bangkokthomburi University, Bangkok, Thailand

Abstract

Accelerated orthodontic tooth movement (OTM) has been widely explored. However, the influence of individual characteristics of alveolar bone on the rate of OTM has not been fully investigated. Therefore, this study aimed to evaluate the influence of morphological features and the density of the alveolar process on the rate of OTM. The study included 24 participants (15 females, 9 males) with an average age of 20.9 years (SD± 3.4 years). Maxillary canines were retracted for three months using a standardized OTM protocol with segmental archwires and superelastic NiTi closed coil springs (50 gm) to provide light continuous force. No functional or localized occlusal interferences affected tooth movement. Pre- and post-canine retraction records were obtained with an intraoral dental scanner from which 3D dental models were created and superimposed to evaluate the amount and rate of OTM. Pre-treatment cone-beam computed tomography images of patients were used to measure alveolar bone width and density on the distal aspect of each canine. The correlation between the rate of OTM and the measured variables was investigated. The results show the mean rate OTM was 0.91 mm/month (range 0.80 - 1.03 mm/month). The rate of OTM was weakly positively correlated with the alveolar bone width to root ratio (r = 0.334, $P < 0.05$) and negatively correlated with cortical bone density (r = -0.297, $P < 0.05$). A wide range of OTM variation (range 0.04 - 0.86 mm/month) within the same individual, between right and left sides was observed in 75 % of cases indicating an asymmetric OTM pattern. The rate of OTM is influenced by alveolar bone width to root ratio and bone density which vary within the same individual. Teeth with higher bone width to root ratio and lower density tend to move faster than those with a lower ratio and higher density.

Keyword: Bone density, Bone width, Cone-beam computed tomography, Orthodontic tooth movement

Date: Jun 4, 2020 **Revised Date:** Jun 30, 2020 **Accepted Date:** Aug 11, 2020

doi: 10.14456/jdat.2021.6

Correspondence to:

Eduardo Yugo Suzuki, Department of Orthodontics, Faculty of Dentistry, BangkokthonburiUniversity, 16/10 Leabklongtaweewatana Rd., Taweewatana District, Bangkok 10170 Thailand, Tel: +66-53-274420, E-mail: eduardo.suz@bkkthon.ac.th

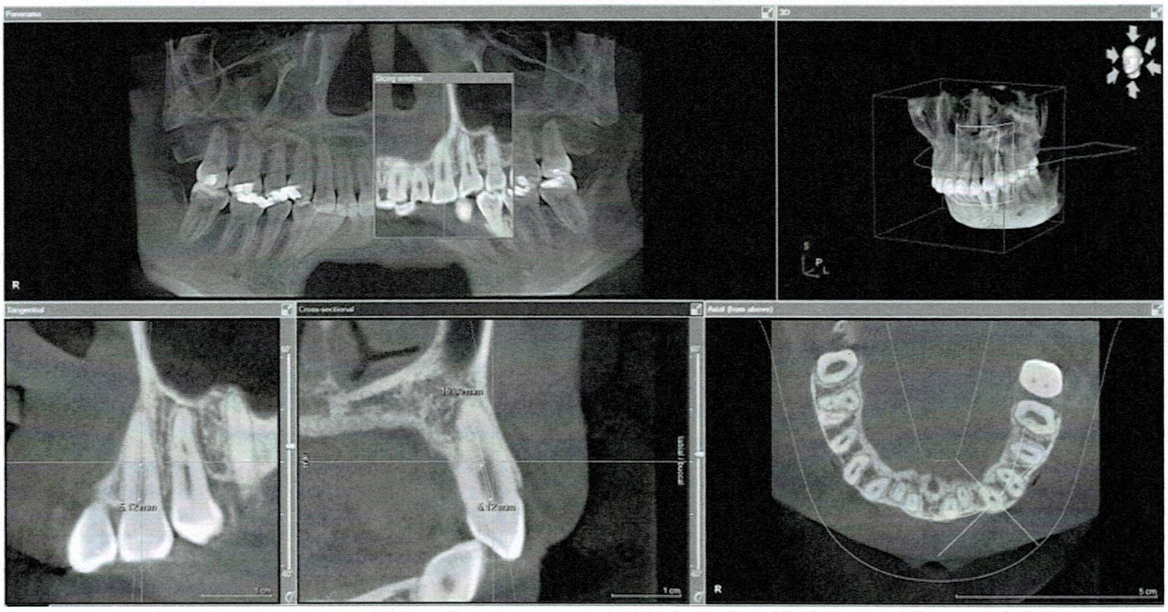

Figure 1 *Plane setting along the long axis of the maxillary canine and root length measurement*

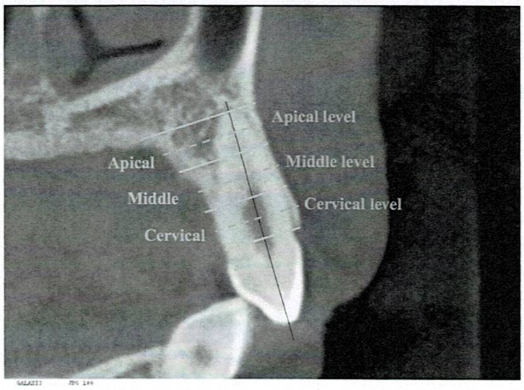

Figure 2 *The root equally divided into three parts (orange lines) and axial slices were obtained from the middle of each part as cervical, middle and apical levels (blue lines)*

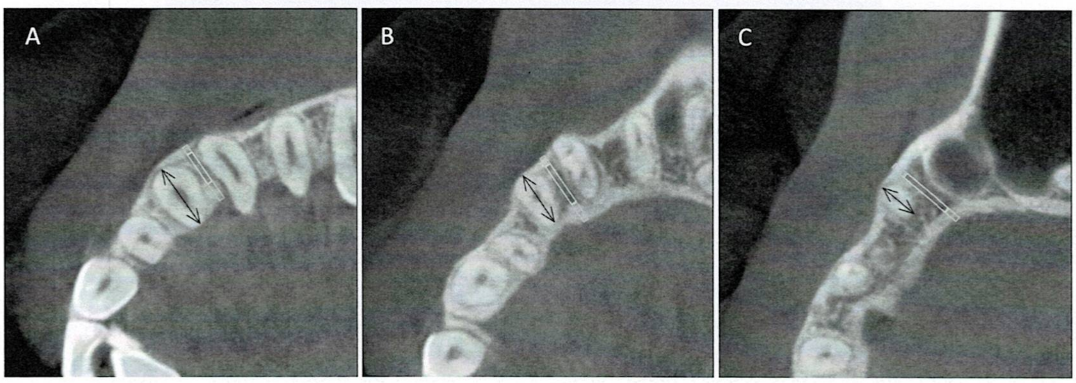

Figure 3 *Measurement of alveolar bone width and bone density in ROI (width = 1 pixel, length depends on alveolar bone width on each slice) and root width in the axial slices at cervical, middle and apical levels (A, B and C respectively); Red rectan gular lines indicate cortical bone; yellow rectangular lines indicate cancellous bone; the combination of red and yellow rectangular lines indicate total alveolar bone; black arrows indicate root width in buccolingual dimension*

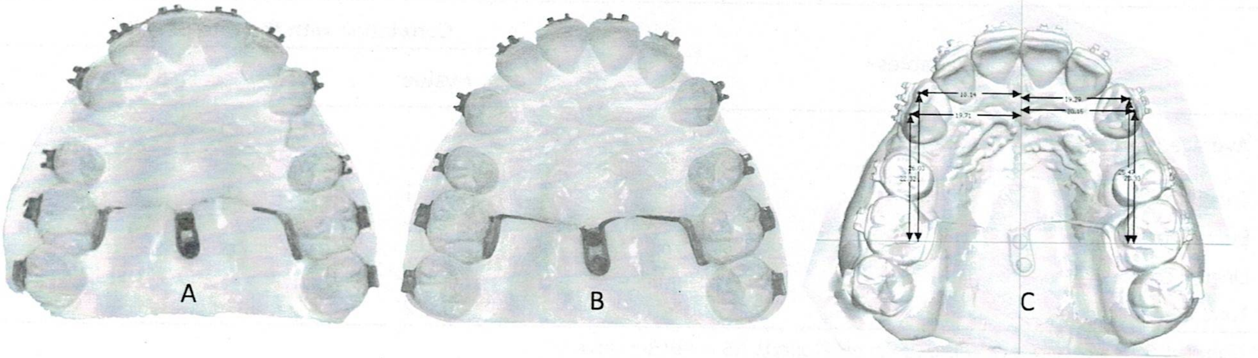

Figure 5 The intraoral scans before (A) and after (B) canine retraction and the digital 3D model superimposition and measurement (C)

Statistical analysis

The reliability of the measurements was tested by a re-evaluation of five randomly chosen participants two weeks after the initial measurement. The rate of OTM and alveolar bone width measurements showed good reliability (intraclass correlation coefficient; ICC = 0.90 to 0.95). Bone density measurements showed acceptable reliability (ICC = 0.86-0.91).

SPSS software (version 23.0; IBM, Armonk, NY) was used for all statistical analyses. Pearson correlation was used to carry out the correlation between the rate of OTM and the characteristics of the alveolar bone. Additionally, to support the correlation analysis, the values of the canines with the rate of OTM more than the upper bound of 95%CI and those with the lower rate were divided and compared by an independent *t*-test. Moreover, to compare the measurement values between the right and left side, the values were categorized into two subgroups regarding the rate of OTM as canine with a low rate of OTM and the contralateral with a high rate of OTM subgroups and analyzed by a paired *t*-test. Significance at $p < 0.05$ was established.

Results

A total of 24 patients following the inclusion and exclusion criteria were included in this study. The average patient ages were 20.9 ± 3.4 years (9 males and 15 females). The mean rate OTM was 0.91 ± 0.35 mm/month mm/month (95%CI; 0.80 - 1.03 mm/month).

According to Pearson correlation analysis, the rate of OTM was weakly positively correlated with the alveolar bone width to root width ratio (r = 0.334, $P < 0.05$) as shown in Table 2 and negatively correlated with buccal cortical bone density (r = -0.297, $P < 0.05$) as shown in Table 1.

Table 1 Pearson correlation coefficients between the rate of OTM and the absolute bone width and densities

Variables		Correlation with the rate of OTM	
		r-value	*p*-value
Bone width			
Total alveolar bone width	Cervical	0.249	NS
	Middle	0.110	NS
	Apical	0.257	NS
Cancellous bone width	Cervical	0.174	NS
	Middle	0.187	NS
	Apical	0.224	NS

Table 3 Comparison of the alveolar bone width to root ratio width and bone densities between the canines with the rate of OTM <1 and ≥ 1 mm/month

Variable		Rate of orthodontic tooth movement				*p*-value
		< 1 mm/month (n=13)		≥ 1 mm/month (n=35)		
		Mean	SD	Mean	SD	
Total alveolar bone width/root width ratio	Cervical	1.10	0.15	1.24	0.19	**
	Middle	1.46	0.26	1.54	0.27	NS
	Apical	2.58	0.61	2.99	1.24	NS
Cancellous bone width/ root width ratio	Cervical	0.77	0.16	0.88	0.11	*
	Middle	0.91	0.17	1.02	0.23	NS
	Apical	1.76	0.42	2.12	1.09	NS
Bone density (GVs)	Cancellous bone	370.26	170.70	265.82	185.29	NS
	Buccal cortex	1199.93	222.23	1104.85	252.48	NS
	Lingual cortex	964.33	191.73	900.99	211.83	NS
	Total alveolar bone	619.82	162.37	516.11	189.29	NS

*** P < 0.01; * P <0 .05; NS = not significant*

When comparing between each side, the rate of OTM and buccal cortical bone density were significantly different between the individual canines with a low and high rate of OTM ($p < 0.05$), whereas bone width to root width ratio and other densities were not (Table 4).

Table 4 Comparison of the alveolar bone width to root width ratio and bone densities between canines with a low rate of OTM and contralateral with a high rate of OTM

Variable		Low rate of OTM		High rate of OTM		*p*-value
		Mean	SD	Mean	SD	
Rate of OTM (mm/month)		0.75	0.27	1.06	0.35	**
Total alveolar bone width/root ratio	Cervical	1.13	0.16	1.14	0.18	NS
	Middle	1.46	0.23	1.48	0.28	NS
	Apical	2.61	0.56	2.77	1.05	NS
Cancellous bone width/ root ratio	Cervical	0.78	0.13	0.82	0.17	NS
	Middle	0.94	0.18	0.94	0.20	NS
	Apical	1.78	0.50	1.93	0.82	NS
Bone density (GVs)	Cancellous bone	356.51	177.54	327.44	183.08	NS
	Buccal cortex	1214.09	237.97	1134.26	223.78	*
	Lingual cortex	964.69	201.91	929.67	194.93	NS
	Total alveolar bone	612.85	172.73	570.62	177.01	NS

*** P < 0.01; * P <0 .05; NS = not significant*

For the optimum rate of OTM, the tooth should move through the cancellous bone, which is highly cellular and vascularized, thus allowing the optimum rate of bone remodeling.

The present study also found a correlation between the relative density values of cancellous, buccal cortical, and alveolar bone and the rate of OTM (Table 1 and 2). The standardization of the absolute gray values of the bone density into the relative percentage allows for a more precise correlation between bone density and the rate of OTM.

This allowed us to state that both the alveolar bone to root width and the density of the buccal cortical bone influence the rate of OTM. On the other hand, the rate of OTM through the alveolar bone with high density tends to be slower.

The findings of this study might be used for the elaboration of proper treatment planning when a high density of buccal cortical bone surrounding the maxillary canines is observed. The use of special treatment approaches for promoting accelerated OTM such as micro-osteoperforations (MOPs)[26,27], and interseptal bone reduction[28] which increase the activity of inflammatory cytokines and osteoclast to initiate RAP (Regional Acceleratory Phenomenon) and reduce bone density can be selected.

By subdividing the samples into the canines with the rate of OTM ≥ 1 mm/month versus the canines with the rate of OTM < 1 mm/month, it was observed that those with a rate of OTM ≥ 1 mm/month had a significantly higher cancellous bone width to root width ratio at the cervical level than those with a rate of OTM < 1 mm/month. Although there were no statistically significant differences, the values of the densities of the canines with the rate of OTM < 1 mm/month were higher than those of the canines with the rate of OTM ≥ 1 mm/month (Table 4). These results demonstrated that a tooth whose root is located and moved within the cancellous bone seems to move faster than one whose root is located and moved within the buccal cortex, since the buccal cortex is denser than the cancellous bone.

The findings of the present study is in agreement with previous studies. In 1988, Bridges *et al.* indicated that a greater amount and rate of tooth movement in younger animals with significantly lower mineral density before orthodontic treatment.[11] In 2018, Machibya *et al.* evaluated the effects of bone regeneration materials and orthodontic tooth movement timing on tooth movement in beagle dogs and found slower movement in the higher bone density group. They believed that high bone density may be one of the contributing factors for the slow rate of tooth movement.[12] From the previously mentioned cellular components, the bone mineral component also has a significant impact on orthodontic treatment by influencing the rate of remodeling. Many other studies have shown faster tooth movement in cases with low bone mineral density.[29,30]

According to the wide range of the rate of OTM, the results show that the canines move at different rates even if the same mechanics and magnitude of force were used. Moreover, the different rate of OTM was found not only between persons but also found within the same individual. Clinically, an asymmetric pattern of canine movement was observed in 75 % of cases which may be influenced by the difference of morphology and density of the alveolar bone between the right and left sides. These results suggest that the intra-individual variability of characteristics of the alveolar bone between sides is a problem of the split-mouth design study.[4] When performing the study of OTM, these factors should be concerned. Moreover, since bite force and occlusion influences the alveolar bone density and morphology[31,32], the unilateral chewing or parafunctional habits might relate to the asymmetric pattern of canine movement due to the asymmetric pattern of muscle tone and activations[33,34], a well-designed study should be performed.

In the present study, the use of light continuous force (50 g) provided by closed NiTi springs was used for canine retraction in all cases. This level of force has been sufficient to provide a controlled retraction of the maxillary canines while avoiding the undesirable anchorage loss.

insertion angle, bone contact length, and bone density. *Orthod Craniofac Res* 2013;16(1):44-55.
17. Ozdemir F, Tozlu M, Germec Cakan D. Quantitative evaluation of alveolar cortical bone density in adults with different vertical facial types using cone-beam computed tomography. *Korean J Orthod* 2014;44(1):36-43.
18. Kim DG. Can dental cone beam computed tomography assess bone mineral density? *J Bone Metab* 2014;21(2):117-26.
19. Ramos AL, Dos Santos MC, de Almeida MR, Mir CF. Bone dehiscence formation during orthodontic tooth movement through atrophic alveolar ridges. *Angle Orthod* 2019.
20. Uribe F, Padala S, Allareddy V, Nanda R. Cone-beam computed tomography evaluation of alveolar ridge width and height changes after orthodontic space opening in patients with congenitally missing maxillary lateral incisors. *Am J Orthod Dentofacial Orthop* 2013; 144(6):848-59.
21. Lombardo L, Bragazzi R, Perissinotto C, Mirabella D, Siciliani G. Cone-beam computed tomography evaluation of periodontal and bone support loss in extraction cases. *Prog Orthod* 2013;14:29.
22. Suzuki EY, Suzuki B. Maxillary molar distalization with the indirect Palatal miniscrew for Anchorage and Distalization Appliance (iPANDA). *Orthodontics (Chic)* 2013;14(1):e228-41.
23. Ishida Y, Ono T. Nonsurgical treatment of an adult with a skeletal Class II gummy smile using zygomatic temporary anchorage devices and improved superelastic nickel-titanium alloy wires. *Am J Orthod Dentofacial Orthop* 2017;152(5):693-705.
24. Wainwright WM. Faciolingual tooth movement: its influence on the root and cortical plate. *Am J Orthod* 1973;64(3):278-302.
25. Krishnan V, Davidovitch Z. Cellular, molecular, and tissue-level reactions to orthodontic force. *Am J Orthod Dentofacial Orthop* 2006;129(4):469 e1-32.
26. Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, *et al.* Effect of micro-osteo perforations on the rate of tooth movement. *Am J Orthod Dentofacial Orthop* 2013;144(5):639-48.
27. Alikhani M, Alansari S, Sangsuwon C, Alikhani M, Chou MY, Alyami B, *et al.* Micro-osteoperforations: Minimally invasive accelerated tooth movement. *Seminars in Orthodontics* 2015;21(3):162-9.
28. Leethanakul C, Kanokkulchai S, Pongpanich S, Leepong N, Charoemratrote C. Interseptal bone reduction on the rate of maxillary canine retraction. *Angle Orthod* 2014;84(5):839-45.
29. Tyrovola JB, Spyropoulos MN. Effects of drugs and systemic factors on orthodontic treatment. *Quintessence Int* 2001;84(5):365-71.
30. Yamashiro T, Takano-Yamamoto T. Influences of ovariectomy on experimental tooth movement in the rat. *J Dent Res* 2001; 80(9):1858-61.
31. Shozushima M, Nakano, H., Kubota, M., Ka-megai, T., Ishikawa, F., Saito, H., *et al.* Bone mineral content of human mandible related to bite force and occlusal contact area. *Dent J Iwate Med Univ* 1996;21:215-22.
32. Thongudomporn U, Chongsuvivatwong V, Geater AF. The effect of maximum bite force on alveolar bone morphology. *Orthod Craniofac Res* 2009;12(1):1-8.
33. Koizumi Y, Ishii T, Nishii Y, Nojima K, Sueishi K. Influence of experimental hemi-occlusion on mandibular morphology and internal structure in growing rabbits. *Orthodontic Waves* 2010;2:58-65.
34. Klemetti E, Vainio P, Kroger H. Muscle strength and mineral densities in the mandible. *Gerodontology* 1994;11(2):76-9.
35. Naitoh M, Hirukawa A, Katsumata A, Ariji E. Evaluation of voxel values in mandibular cancellous bone: relationship between cone-beam computed tomography and multislice helical computed tomography. *Clin Oral Implants Res* 2009;20(5):503-6.
36. Chang HW, Huang HL, Yu JH, Hsu JT, Li YF, Wu YF. Effects of orthodontic tooth movement on alveolar bone density. *Clin Oral Investig* 2012;16(3):679-88.
37. Hsu JT, Chang HW, Huang HL, Yu JH, Li YF, Tu MG. Bone density changes around teeth during orthodontic treatment. *Clin Oral Investig* 2011;15(4):511-9.
38. Taylor TT, Gans SI, Jones EM, Firestone AR, Johnston WM, Kim DG. Comparison of micro-CT and cone beam CT-based assessments for relative difference of grey level distribution in a human mandible. *Dentomaxillofac Radiol* 2013;42(3):25117764.
39. Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL, *et al.* Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. *Am J Orthod Dentofacial Orthop* 2011;140(5):734-44.