

ORIGINAL ARTICLE

Evaluation of changes in trabecular alveolar bone during growth using conventional panoramic radiographs

DIANE PHAM & STAVROS KILIARIDIS

Department of Orthodontics, University of Geneva, Geneva, Switzerland

Abstract

Objective. To assess changes of the alveolar trabecular bone during growth using panoramic radiographs and to detect possible differences in trabecular bone patterns when comparing individuals of various ages and genders. **Materials and methods.** Conventional panoramic radiographs of 18 young (eight females, 10 males) and 21 adult (12 females, nine males) subjects were taken at 2 years (T1) and 10 years (T2) after the end of orthodontic treatment. At T1, mean ages were 15.6 ± 0.9 years and 31.3 ± 9.7 years in the young and the adult groups, respectively. A three-scale visual analysis was used to evaluate bilaterally the alveolar bone trabeculation in the interdental spaces, from the distal side of the first mandibular premolar to the mesial side of the second lower molar. An analysis of variance (ANOVA), associated with *t*-tests whenever significance was found, was used to appraise the role of the age, the extent of the follow-up period and the gender on trabecular bone structure. **Results.** The adult group had a denser alveolar bone trabeculation, compared to the young group. This was also observed in the 8 years follow-up recordings among the adults, but no statistically significant differences were found in the growing individuals. No gender discrepancy was detected. **Conclusions.** From puberty to the middle age adulthood, denser alveolar bone trabeculation in the mandible seems to be related to the age. No differences were found between male and female subjects in the sample.

Key Words: *assessment, alveolar trabecular bone, growth, panoramic radiographs*

Introduction

The mandible shows anatomical and functional characteristics different of the skeletal bones. The intramembranous origin leads to formation of two distinct bony parts: the basal bone and the alveolar process (commonly called the alveolar bone), the latter constituting support for teeth. Both parts are made of an external dense cortical bone and an internal trabecular bone. Like the skeletal bone system, the mandibular alveolar bone is subjected to a remodeling process. Mechanical stimulation, originating from muscular function, is a major regulatory factor in bone homeostasis [1]. It superimposes on and interacts with all other systemic and local mediators of bone metabolism. The alveolar bone is a skeletal part that is dependent on the presence of teeth and masticatory function, since, in the absence of teeth [2] or lack of mechanical stimulation transmitted by implant supported overdenture, it undergoes disuse atrophy [3]. Independently of the age, there is a great inter-individual variation

in trabecular volume and interconnections, leading to variable trabecular bone patterns [4]. Variation in the trabecular bone microstructure is also site-dependent within individuals [5,6]. Recently in orthodontics, the focus has been on miniscrew implants as a skeletal anchorage system that does not require patient compliance. Many studies have investigated the factors related to stability because the failure rate of mini-implants, ranging from 9 to 30%, is high compared to that of osseointegrated endosseous implants [7–10]. Among the factors related to failure, it has been reported that the implantation site has an important role [9,11]. A review on endosseous implants has shown that jaw bone with reduced density correlates with a reduced primary stability and a significantly higher implant failure rate [12]. Consequently, the density and architecture of the trabecular host bone are crucial to the stability of an endosseous implant in the alveolar ridge. Regarding mini-implants, younger patients seem to exhibit a greater risk of failing compared to adult patients [13].

Correspondence: Diane Pham, Department of Orthodontics, University of Geneva, 19, rue Barthélemy-Menn, 1205 Geneva, Switzerland.
Tel: +41 (0)22 379 40 84. Fax: +41 (0)22 379 40 22. E-mail: diane.pham@unige.ch

(Received 11 October 2010; revised 16 February 2011; accepted 12 March 2011)

ISSN 0001-6357 print/ISSN 1502-3850 online © 2012 Informa Healthcare
DOI: 10.3109/00016357.2011.600706

The alveolar bone density has been quantitatively measured on computed tomographic (CT) images [14–18]. Results showed significant differences of bone density values between the alveolar and basal bone of both maxilla and mandible, with progressively increasing values from anterior to posterior areas and with higher values in the mandible. Thus, bone densities may vary when different areas of jaws are compared.

Dental radiographs are not exclusively used in dentistry and their utilization has been extended to other domains. For example, periapical radiographs have been used to assess the trabecular alveolar bone in relation to bone disease [19–21]. Panoramic radiographs have been routinely made for diagnosis purposes in many dental fields. However, this radiologic tool could be used to add further knowledge on how the alveolar trabecular pattern changes with aging, from adolescence, through adulthood to old age. In a previous study, it has been shown that the mandibular trabecular bone assessment on panoramic radiographs, using a visual index, fairly corresponds to the evaluation obtained from periapical radiographs [22]. A correlation has also been found between mandibular trabecular patterns depicted in panoramic radiographs and the density of the same region as measured on CT scans [23].

To date, no study comparing the functioning alveolar bone of a young (growing) group to an adult (non-growing) group has been found in the literature. Also, no conclusions have been established when looking for possible gender differences in the healthy alveolar bone.

Thus, the aims of the present study are to assess changes of the alveolar trabecular bone during growth using panoramic radiographs and to detect possible differences in trabecular bone patterns when comparing individuals of various ages and gender.

Materials and methods

Material

The material consisted of 39 sets of two panoramic radiographs from patients treated in our dental

school, divided into two groups: the young group (growing individuals) and the adult group (non-growing individuals). For each subject selected, the panoramic radiographs were taken at 2 years (T1) and 10 years (T2) after completion of their orthodontic treatment. In the young group, the mean age at T1 was 15.6 ± 0.9 years (range = 14.2–16.8 years) and 23.9 ± 1.1 at T2 (range = 21.1–25.4 years). The mean age difference between T2 and T1 ($\Delta T2-T1$) was 8.3 ± 1.3 years. The mean age of the adult group at T1 was 31.3 ± 9.7 years (range = 20.1–46.4 years) and 39.5 ± 10.1 years at T2 (range = 27.4–55.1 years). The mean age difference between T2 and T1 ($\Delta T2-T1$) was 8.2 ± 1.3 years. The age distribution within each group is shown in Table I. The panoramic radiographs were examined at 2 years (T1) and at 10 years after completion of orthodontic treatment (T2). Eighteen subjects for the young group (eight females, 10 males) and 21 subjects for the adult group (12 females, nine males) met the following inclusion criteria:

- Panoramic radiographs diagnostically acceptable at T1 and at T2;
- Age at T1 must be up to 17 years in the young group and over 20 years in the adult group;
- No active orthodontic treatment and no tooth extraction (except for third molars) between T1 and T2;
- No periodontal disease with no alveolar bone loss; and
- Healthy general conditions, with no medication or disease according to the medical history.

Methods

The radiographs were digitized at 600 dpi and in grayscale mode, with a flatbed scanner (Epson Expression 1600 Pro, Seiko Epson Corp., Japan) and a non-compressed TIFF format was used for disk storage. The images were examined with image software allowing a combined adjustment of the light intensity and the contrast (Adobe Photoshop 7.0, Adobe Systems Corporation Inc, San Jose, California, USA). The panoramic radiographs of both groups and at both

Table I. Age distribution of the female and male subjects when the first (T1) and second (T2) panoramic radiographs were obtained, in the adult and the young group.

		T1 (years) \pm SD	T2 (years) \pm SD	$\Delta T2-T1$ (years) \pm SD
Adult	12 f	34.5 ± 9.4	43.0 ± 10.1	8.5 ± 1.4
	9 m	27.0 ± 6.8	34.8 ± 8.4	7.8 ± 1.1
	Total 21	31.3 ± 9.7	39.5 ± 10.1	8.2 ± 1.3
Young	8 f	15.3 ± 0.9	23.7 ± 0.8	8.3 ± 0.5
	10 m	15.9 ± 0.9	24.2 ± 1.3	8.3 ± 1.7
	Total 18	15.6 ± 0.9	23.9 ± 1.1	8.3 ± 1.3

T1 and T2 have been previously mixed in a random way and blinded for examination. One operator (DP) did all evaluations of the trabeculation of alveolar bone using the following three-scale visual analysis: when the trabecular pattern was evaluated as sparse (score 1), the criterion was large inter-trabecular spaces especially in the cervical dentate premolar area; when the trabecular pattern was evaluated as dense (score 3), the entire radiographed area had an equal degree of trabeculation and the inter-trabecular spaces were small even under the roots; when the trabecular pattern was assessed as alternating dense and sparse (score 2) the trabeculation was normally denser cervically and sparser apically, as described in the previous study (Figure 1) [22]. The reliability of this method, as introduced earlier, has been shown to be sufficient, with a Kappa value of 0.79 obtained for the assessor (DP) based on 32 panoramic radiographs evaluated twice at an interval of 60 days.

The assessment was performed at the level of six inter-dental sites located bilaterally, from the distal side of the first premolars to the mesial side of the second molars of the lower arch. Whenever the root proximity or any anatomical characteristics (such as idiopathic osteosclerosis) hindered accurate evaluation of the inter-dental site, the latter was not taken into account. All corresponding panoramic radiographs at T1 and at T2 had the same inter-dental sites evaluated. Figure 2 demonstrates an example of a case with inter-dental sites selected for the examination.

Statistical analyses

The scores given for each inter-dental site of each jaw have been averaged. The mean values were then used for statistical analysis. An analysis of variance (ANOVA) was first undertaken to assess differences between and within the groups according to three variables: the age group, the time spent between examinations (from T1 to T2) and the gender, after confirming normal distribution with the Shapiro-Wilk test. In addition, for each significant result following the ANOVA test, paired and unpaired *t*-tests were planned for pair comparisons: paired *t*-tests for longitudinal assessment of the alveolar

bone trabeculation in each group, unpaired *t*-tests for cross-sectional assessment of the alveolar bone trabeculation between the groups and unpaired *t*-tests for assessment of gender discrepancy. The significance level was set at 0.05. The Statistical Package for Social Science for Windows, version 13.0 (SPSS Inc., Chicago, IL) was used for these statistical tests.

Results

The analysis of variance assessing the main effects of the three variables (age, extent of the following period and gender) on the alveolar bone trabeculation scores revealed that only the factor gender did not show a significant effect on bone trabeculation scores, neither alone nor in interaction with other factors. In contrast, the factors age and time were shown to have a significant effect, but there was no interaction.

For the cross-sectional assessment of the alveolar bone trabeculation scores, the more extreme age groups studied were compared (which means the young group at T1 (15.6 ± 0.9 years) with the adult group at T2 (39.5 ± 10.1 years)) using unpaired *t*-test. It was found that the adult group at T2 had a higher alveolar bone trabeculation score than the young group at T1 ($p = 0.012$; Table II).

For longitudinal assessment of the alveolar bone trabeculation scores, paired *t*-tests comparing each group from T1 to T2 indicated significant differences only in the adult group. Namely, the alveolar bone trabeculation became denser during the 8 years follow-up of this adult group ($p = 0.011$; Table III).

Discussion

The present study has shown that the mandibular trabecular bone, as detected on panoramic radiographs, was determined to be denser in adult individuals than in young individuals. When comparing subjects of various ages, significant differences in trabecular bone patterns were found in the adult group after a mean follow-up of 8 years and between the youngest and the eldest individuals in this study. Gender differences were not found to be significant according to our results, in both groups of the present sample.



Figure 1. The three-scale visual analysis for assessment of bone trabeculation. 1 = sparse trabeculation, 2 = alternating dense and sparse trabeculation, 3 = dense trabeculation.

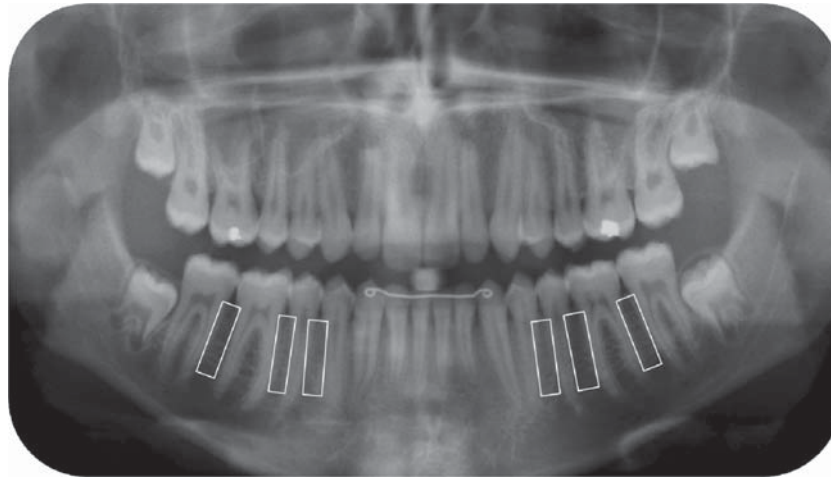


Figure 2. Example of panoramic radiograph selected for bone trabeculation evaluation. The six white rectangles represent the interdental spaces examined, when this was possible. Panoramic radiographs at T1 and at T2 of the same subject had the same interdental sites evaluated.

In a previous study, it was shown that it is possible to qualitatively assess the mandibular trabecular bone, mesially and distally of the second premolar, using a three-scale visual index on panoramic radiographs. In the present study, we used the same methodology to evaluate differences in age groups regarding the trabecular alveolar bone over a mean time of 8 years. We assessed possible age discrepancies in a cross-sectional and in a longitudinal way. To better describe long-term changes in the alveolar trabecular bone, the period of observation should have been longer. Since our samples did not allow this, a young (growing) and an adult (non-growing) group were followed and a comparison of the bone trabeculation between the youngest and the eldest subjects was undertaken. Thus, when considering the bone trabeculation over a period of ~ 8.2 years in both groups, a slight increase is observed but is not significant. Nevertheless, in the cross-sectional assessment, groups with a mean age difference of 23.9 years were compared, and the older age group appeared to have a significantly denser bone trabeculation scores than the younger one. During growth, bone modeling is taking place with changes of bone size and shape. After the end of the growth period, in early adulthood, the bone is still

remodeled by resorption performed by osteoclasts and apposition by osteoblasts [24]. Acquisition of bone mineral continues throughout childhood and adolescence, reaching a lifetime maximum ('peak bone mass') in early adulthood [25]. In old adulthood (>65 years), decrease in bone mass density is usual, due to an unbalanced remodeling process [26]. In our study, the subjects selected were representative of the young age (pubertal) and the early adulthood age. Knowing that the skeletal bone mineral density (BMD) has been found to be associated with the mandibular alveolar bone structure and the alveolar thickness [20,21], an increase in the alveolar mandibular trabeculation density can thus be expected from the puberty to early/middle age adulthood. Furthermore, our findings could be related to the adaptation of the skeleton to mechanical loads during growth [27–29]. The mandibular alveolar process is part of the skeleton and is subjected to repetitive loads during mastication, thus a denser bone structure could be expected from puberty to adulthood as the mechanical loading increases with muscular mass and strength [30,31].

No gender difference was found in our study. This was consistent with Chun and Lim [18], whose study samples were ranging between 25–35 years of age. The small sample size certainly was not representative enough. Moreover, in the adult group, the mean age of the female subjects is higher than the mean age of the male subjects, whilst it is approximately the same in the young group. Four of the 12 female subjects in the adult group were more than 50 years of age at T2 (52–55 years). However, the risk of post-menopausal osteoporosis, which would alter the bone trabeculation faster, was excluded according to the answers given in their medical history taken at T2. This can explain the absence of sex-based discrepancy in our adult group even though

Table II. Unpaired *t*-test to assess the alveolar bone trabeculation of the groups having the highest mean age difference: the comparison is between the alveolar bone trabeculation of the young on the first radiographs and the adults on the second radiograph (values are the mean of the scores given with the three-scale visual analysis).

Young T1			Adults T2			<i>p</i> -value
<i>n</i>	<i>M</i>	SD	<i>n</i>	<i>M</i>	SD	
18	1.73	0.37	21	2.04	0.35	0.012*

* $p \leq 0.05$.

Table III. Paired *t*-tests to assess the alveolar bone trabeculation scores in the adult group and the young group, from T1 to T2 (values are the mean of the scores given with the three-scale visual analysis).

Groups	<i>n</i>	T1		T2		ΔT2-T1		<i>p</i> -value
		<i>M</i>	SD	<i>M</i>	SD	<i>M</i>	SD	
Young	18	1.73	0.37	1.69	0.39	-0.04	0.38	0.664
Adult	21	1.88	0.32	2.04	0.35	0.17	0.24	0.011*

**p* ≤ 0.05.

mean ages were unfavorable for the female subjects. With larger samples and a wider range of age, more significant variations are probably to be expected.

Among the 39 cases selected for the study, four cases presented a previous orthodontic treatment with premolars extractions in the mandibular arch. Although space closure involved considerable bone remodeling, it was unlikely that the orthodontic treatment influenced the bone trabeculation depicted on the panoramic radiograph 2 years after its completion.

The results of the present study may give an insight to the variations in tooth movement rate observed with age. In adult orthodontics, a different tissue reaction could be expected when moving teeth in bone with sparse or dense trabeculation, as was shown in an experimental animal study, in which rats with lower initial bone density have a faster orthodontic tooth movement than rats with significantly higher initial bone density [32]. Our findings may be in line with the previous investigation made on the mandibular bone and its possible influence on orthodontic treatment stability [33]. Furthermore, the observed changes in bone density taking place with age may be related to the success rate of mini-implants. Kim et al. [34] concluded that the patient's age is an influencing factor for success rates of midpalatal miniscrews used for orthodontic anchorage. Additionally, Molly [12] stated that a reduced density of the jaw bone was correlated to a significantly higher failure rate of endosseous implants. The results of the present study can apparently be linked to these observations, as they showed a significant difference in the bone trabeculation between young and adult (middle age) individuals.

Conclusions

Our study showed that a denser trabecular bone structure in the alveolar process appears related to the age. The qualitative assessment of the alveolar trabecular bone has shown longitudinal differences within the young and the adult groups, with a more significant change in the adult group.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

- [1] White SC. Oral radiographic predictors of osteoporosis. *Dentomaxillofac Radiol* 2002;31:84-92.
- [2] Carlsson GE. Responses of jawbone to pressure. *Gerodontology* 2004;21:65-70.
- [3] Doundoulakis JH, Eckert SE, Lindquist CC, Jeffcoat MK. The implant-supported overdenture as an alternative to the complete mandibular denture. *J Am Dent Assoc* 2003;134:1455-8.
- [4] Ulm C, Kneissel M, Schedle A, Solar P, Matejka M, Schneider B, et al. Characteristic features of trabecular bone in edentulous maxillae. *Clin Oral Implants Res* 1999;10:459-67.
- [5] Amling M, Herden S, Pösl M, Hahn M, Ritzel H, Delling G. Heterogeneity of the skeleton: comparison of the trabecular microarchitecture of the spine, the iliac crest, the femur, and the calcaneus. *J Bone Miner Res* 1996;11:36-45.
- [6] Moon HS, Won YY, Kim KD, Ruprecht A, Kim HJ, Kook HK, et al. The three-dimensional microstructure of the trabecular bone in the mandible. *Surg Radiol Anat* 2004;26:466-73.
- [7] Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofacial Orthop* 2003;124:373-8.
- [8] Cheng SJ, Tseng IY, Lee JJ, Kok SH. A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. *Int J Oral Maxillofac Implants* 2004;19:100-6.
- [9] Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. *Am J Orthod Dentofacial Orthop* 2006;130:18-5.
- [10] Reynders R, Ronchi L, Bipat S. Mini-implants in orthodontics: a systematic review of the literature. *Am J Orthod Dentofacial Orthop* 2009;135:564.e1-19; discussion 564-5.
- [11] Hoste S, Vercruyssen M, Quirynen M, Willems G. Risk factors and indications of orthodontic temporary anchorage devices: a literature review. *Aust Orthod J* 2008;24:140-8.
- [12] Molly L. Bone density and primary stability in implant therapy. *Clin Oral Implants Res* 2006;17(Suppl 2):124-35.
- [13] Chen YJ, Chang HH, Huang CY, Hung HC, Lai EH, Yao CC. A retrospective analysis of the failure rate of three different orthodontic skeletal anchorage systems. *Clin Oral Implants Res* 2007;18:768-75.
- [14] Turkyilmaz I, Tözüm TF, Tümer C. Bone density assessments of oral implant sites using computerized tomography. *J Oral Rehabil* 2007;34:267-72.
- [15] De Oliveira RC, Leles CR, Normanha LM, Lindh C, Ribeiro-Rotta RF. Assessments of trabecular bone density at implant sites on CT images. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:231-8.
- [16] Park HS, Lee YJ, Jeong SH, Kwon TG. Density of the alveolar and basal bones of the maxilla and the mandible. *Am J Orthod Dentofacial Orthop* 2008;133:30-7.

- [17] Choi JH, Park CH, Yi SW, Lim HJ, Hwang HS. Bone density measurement in interdental areas with simulated placement of orthodontic miniscrew implants. *Am J Orthod Dentofacial Orthop* 2009;136:766.e1–12.
- [18] Chun YS, Lim WH. Bone density at interradicular sites: implications for orthodontic mini-implant placement. *Orthod Craniofac Res* 2009;12:25–32.
- [19] Nackaerts O, Jacobs R, Horner K, Zhao F, Lindh C, Karayianni K, et al. Bone density measurements in intra-oral radiographs. *Clin Oral Investig* 2007;11:225–9.
- [20] Jonasson G, Bankvall G, Kiliaridis S. Estimation of skeletal bone mineral density by means of the trabecular pattern of the alveolar bone, its interdental thickness, and the bone mass of the mandible. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;92:346–52.
- [21] Jonasson G, Jonasson L, Kiliaridis S. Changes in the radiographic characteristics of the mandibular alveolar process in dentate women with varying bone mineral density: a five-year prospective study. *Bone* 2006;38:714–21.
- [22] Pham D, Jonasson G, Kiliaridis S. Assessment of trabecular pattern in periapical and panoramic radiographs: a pilot study. *Acta Odontol Scand* 2010;68:91–7.
- [23] Taguchi A, Tanimoto K, Akagawa Y, Suei Y, Wada T, Rohlin M. Trabecular bone pattern of the mandible. Comparison of panoramic radiography with computed tomography. *Dentomaxillofac Radiol* 1997;26:85–9.
- [24] Wang Q, Seeman E. Skeletal growth and peak bone strength. *Best Pract Res Clin Endocrinol Metab* 2008;22:687–700.
- [25] Bonjour JP, Chevalley T, Ferrari S, Rizzoli R. The importance and relevance of peak bone mass in the prevalence of osteoporosis. *Salud Publica Mex* 2009;51(Suppl 1):5–17.
- [26] Seeman E. Structural basis of growth-related gain and age-related loss of bone strength. *Rheumatology (Oxford)* 2008;47(Suppl 4):iv2–8.
- [27] Turner CH. Three rules for bone adaptation to mechanical stimuli. *Bone* 1998;23:399–407.
- [28] Turner CH, Pavalko FM. Mechanotransduction and functional response of the skeleton to physical stress: the mechanisms and mechanics of bone adaptation. *J Orthop Sci* 1998;3:346–55.
- [29] Klein-Nulend J, Bacabac RG, Mullender MG. Mechanobiology of bone tissue. *Pathol Biol (Paris)* 2005;53:576–80.
- [30] Raadsheer MC, Kiliaridis S, Van Eijden TM, Van Ginkel FC, Prah Andersen B. Masseter muscle thickness in growing individuals and its relation to facial morphology. *Arch Oral Biol* 1996;41:323–32.
- [31] Kiliaridis S, Kjellberg H, Wenneberg B, Engström C. The relationship between maximal bite force, bite force endurance, and facial morphology during growth. A cross-sectional study. *Acta Odontol Scand* 1993;51:323–31.
- [32] Bridges T, King G, Mohammed A. The effect of age on tooth movement and mineral density in the alveolar tissues of the rat. *Am J Orthod Dentofacial Orthop* 1988;93:245–50.
- [33] Rothe LE, Bollen AM, Little RM, Herring SW, Chaison JB, Chen CS, et al. Trabecular and cortical bone as risk factors for orthodontic relapse. *Am J Orthod Dentofacial Orthop* 2006;130:476–4.
- [34] Kim YH, Yang SM, Kim S, Lee JY, Kim KE, Gianelly AA, et al. Midpalatal miniscrews for orthodontic anchorage: factors affecting clinical success. *Am J Orthod Dentofacial Orthop* 2010;137:66–2.