

“Safe Zones” for miniscrew implant placement in different dentoskeletal patterns

Pajongjit Chaimanee^a; Boonsiva Suzuki^b; Eduardo Yugo Suzuki^c

ABSTRACT

Objective: To assess the influence of different dentoskeletal patterns on the availability of interradicular spaces and to determine the safe zones for miniscrew implant placement.

Materials and Methods: Periapical radiographs of 60 subjects with skeletal Class I, II, or III patterns were examined. For each interradicular site, the areas and distances at 3, 5, 7, 9, and 11 mm from the alveolar crest were measured.

Results: In the maxilla, the greatest interradicular space was between the second premolar and the first molar. In the mandible, the greatest interradicular space was between the first and second molars, followed by the first and second premolars. Significant differences in interradicular spaces among the skeletal patterns were observed. Maxillary interradicular spaces, particularly between the first and second molars, in the subjects with skeletal Class II patterns, were greater than those in the subjects with skeletal Class III patterns. In contrast, in the mandible, interradicular spaces in the subjects with skeletal Class III patterns were greater than those in the subjects with skeletal Class II patterns.

Conclusions: For all skeletal patterns, the safest zones were the spaces between the second premolar and the first molar in the maxilla, and between the first and second premolars and between the first and second molars in the mandible. (*Angle Orthod.* 2011;81:397–403.)

KEY WORDS: Miniscrew; Interradicular spaces; Safe zones; Dentoskeletal patterns

INTRODUCTION

Recently, the use of miniscrew implants has become an accepted and reliable method for providing orthodontic anchorage.^{1–3} The placement of miniscrews in the interradicular bone has been frequently recommended by the specialized literature for allowing simple placement and removal procedures, and for allowing the application of relatively simple force

systems.^{4,5} However, concerns about damaging dental roots, allied with the limited interradicular space, still represent a barrier for the clinical application of these miniscrews.^{6–8}

Several studies have been performed to assess the safe locations in the interradicular spaces for miniscrew placement, the so-called “safe zones.”^{9–15} A minimal clearance of 1 mm of alveolar bone around the screw has been recommended to preserve the periodontal health.¹⁰ Therefore, when the diameter of the miniscrew and the minimum clearance of alveolar bone are considered, interradicular space larger than 3 mm is needed for safe miniscrew placement.^{9,10}

However, in these studies, the assessments of the safe zones were performed in samples with minor or no malocclusions. Moreover, subjects with skeletal discrepancies were not included in the assessment of availability of interradicular spaces.

Dentoalveolar compensation is a common adaptive feature observed in subjects with different skeletal patterns.^{16,17} Excessive proclined mandibular incisors and retroclined maxillary incisors are typically observed in subjects with skeletal Class II discrepancies, while retroclination of the lower incisors combined with proclination of the maxillary incisors are observed in

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subjects with skeletal Class III discrepancies.^{16,17} Therefore, we hypothesized that such characteristic dentoalveolar compensation observed in different skeletal discrepancies might affect the availability of interradicular spaces.

The purposes of this study were to assess the influence of different dentoskeletal patterns on the availability of interradicular spaces and to determine the safe zones between the dental roots of the posterior teeth for miniscrew placement in different dentoskeletal patterns.

MATERIALS AND METHODS

Samples

Pretreatment lateral cephalograms and periapical radiographs, made using the paralleling technique, of Thai subjects (both male and female; age range: 15–30 years) were selected from the database of the Department of Orthodontics and Pediatric Dentistry, Faculty of Dentistry, Chiang Mai University. Selection criteria included acceptable radiographic quality, a full complement of erupted teeth from second molar to second molar, and no history of previous orthodontic or prosthodontic treatment. Dental arches with severe crowding or rotation in the posterior region, missing teeth, or radiographic signs of periodontal disease were excluded.¹⁰ In the experimental group, 60 subjects were selected and divided into Class I ($n = 20$), Class II ($n = 20$), and Class III ($n = 20$) skeletal patterns on the basis of the ANB angle measured on the lateral cephalograms.

In the control group, 60 subjects with natural optimal occlusion and normal facial profile (appropriate for race) were selected. The selection criteria for optimal occlusion samples were as follows¹⁸:

- Class I molar and canine relationships with normal occlusal interdigitation;
- 2.0–4.0 mm overjet and overbite; and
- Minimal crowding (less than 3.0 mm) and spacing (less than 1.0 mm).

Measurements

Lateral Cephalometric Measurements. Lateral cephalometric measurements were obtained using Smart'n Ceph Researcher V 9.0 software (Y&B Products, Chiang Mai, Thailand) that was designed for this study. The cephalometric measurements were as follows (Figure 1):

- SNA angle: angle formed by the SN line and the NA line¹⁹;
- SNB angle: angle formed by the SN line and the NB line¹⁹;

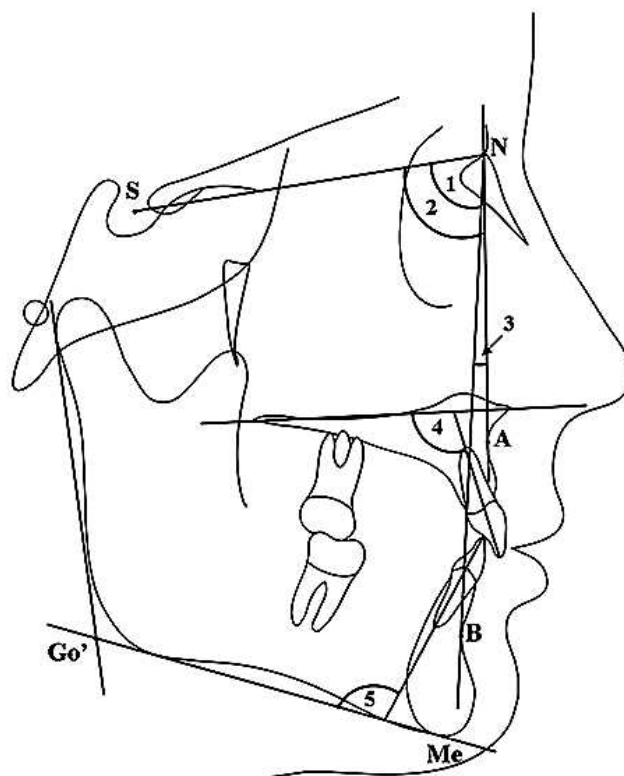


Figure 1. Cephalometric measurements. (1) SNA angle. (2) SNB angle. (3) ANB angle. (4) U1-PP. (5) L1-MP.

- ANB angle: angle formed by the NA line and the NB line¹⁹;
- U1-PP: angle formed by the maxillary central incisor axis and the palatal plane (ANS-PNS)¹⁹; and
- L1-MP: angle formed by the mandibular central incisor axis and the mandibular plane (Me-Go').¹⁹

Interradicular space measurements. A total of 12 posterior tooth interradicular sites were examined in each experimental subject (Figure 2). All periapical radiographs were photographed as digital images at fixed magnification with a resolution of 600 DPI and then transferred to the computer. Each measurement was performed with custom-made software, Smart'n Ceph V 15.0 software (Y&B Products).

Linear and area measurements were as follows (Figure 3):

- Interradicular distances (mesiodistal dimension): the horizontal measurements between the lamina dura of adjacent tooth roots, at 3, 5, 7, 9, and 11-mm depths from the alveolar crest. This measurement was made perpendicularly to a vertical line extended from the alveolar crest.
- Interradicular area: the area between the lamina dura of adjacent tooth roots was calculated using the reference landmarks at the alveolar crest and at 3, 5, 7, 9, and 11-mm depths from the alveolar crest.

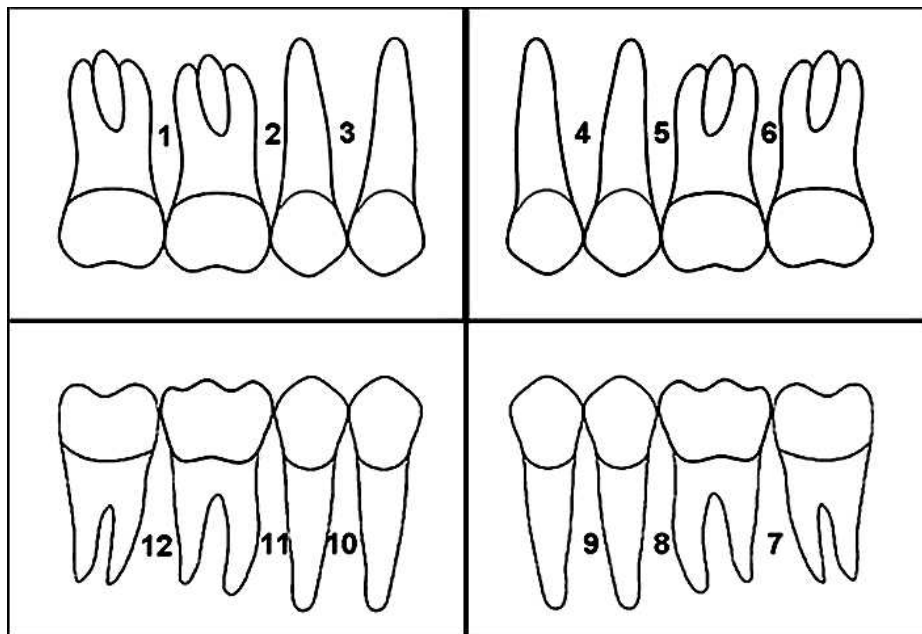


Figure 2. A schematic of periapical radiographs indicating locations of measurements.

Statistical Analysis

The statistical analyses were performed using the SPSS program (SPSS Inc, Chicago, Ill). Mean and standard deviation of the measurements were calculated. One-factor analysis of variance (ANOVA) was used to compare means of measurements between different skeletal patterns. Post hoc multiple comparisons were also performed with Tukey test when ANOVA yielded significant results indicating that there was a difference. Results were considered statistically significant at $P < .05$.

RESULTS

Sample Characteristics

Comparisons between lateral cephalometric measurements of the control group and the different skeletal patterns are presented in Table 1.

The ANB angles were significantly different in all skeletal patterns ($P < .01$). Significant differences in the SNB angle were observed between the control group and the subjects with skeletal Class II and III patterns ($P < .01$).

The maxillary incisors of the subjects with skeletal Class III patterns were significantly more proclined than were those of the control group or of the subjects with skeletal Class II patterns ($P < .01$ and $P < .05$, respectively). In contrast, the mandibular incisors of the subjects with skeletal Class III patterns were significantly retroclined when compared with those of the control group or of the subjects with skeletal Class I or II patterns ($P < .01$).

Interradicular Spaces

Linear measurements (interradicular distances). Table 2 shows the interradicular distance measurements and comparisons between different skeletal patterns.

In the maxilla, the greatest interradicular distances were between the second premolar and the first molar, at 11-mm depth (Class I = 3.9 ± 1.7 mm; Class II = 4.0 ± 1.8 mm; Class III = 3.8 ± 1.8 mm); the least was between the first and second molars.

In the mandible, the greatest interradicular distances were between the first and second molars, at 11-mm

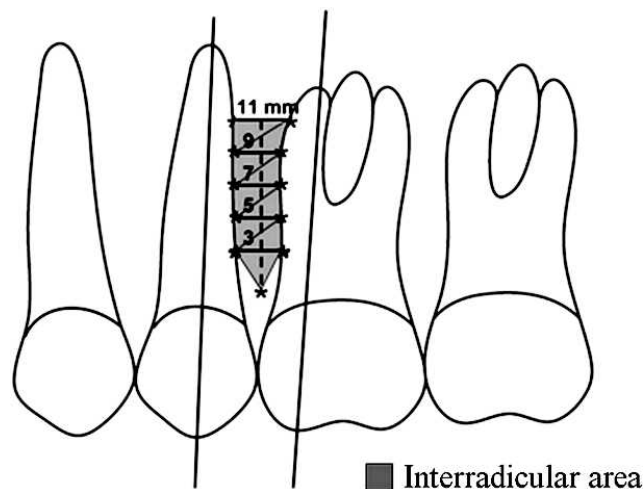


Figure 3. Angle formed between tooth axes, interradicular area, and interradicular distance measurements at 3, 5, 7, 9 and 11 mm from the alveolar crest.

Table 1. Results of Cephalometric Measurements^a

Variable	Control		Skeletal I		Skeletal II		Skeletal III		Tukey Test, Significance of <i>P</i>					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Control-I	Control-II	Control-III	I-II	II-III	I-III
SNA	84.4	3.4	83.5	2.4	85.3	4.0	82.7	3.8						
SNB	81.5	3.2	80.5	2.4	78.1	4.0	85.3	3.8	**	**		**	**	**
ANB	2.9	1.6	3.0	0.9	7.2	1.3	-2.6	2.4	**	**	**	**	**	**
U1-PP	114.6	6.9	119.2	7.4	117.8	11.1	124.4	6.7			**		*	
L1-MP	96.7	4.8	93.5	4.0	98.1	4.2	88.7	5.3			**		**	**

^a SD, indicates standard deviation; U, maxillary teeth; L, mandibular teeth; PP, palatal plane; MP, mandibular plane; I, skeletal Class I; II, skeletal Class II; and III, skeletal Class III.

* $P < .05$; ** $P < .01$.

depth (Class I = 5.3 ± 1.8 mm; Class II = 6.0 ± 1.6 mm; Class III = 5.5 ± 1.7 mm), followed by between the first and second premolars. Significant differences in interradicular distances between different dentoskeletal patterns were observed. The interradicular distances between the maxillary first and second molars, at 3-mm depth, in the subjects with skeletal Class II patterns were significantly greater than those in the subjects with skeletal Class III patterns ($P < .05$). In contrast, in the mandible, the interradicular distances between the first and second premolars, at all depths of measurement, were greater in the subjects with skeletal Class III patterns than those of the subjects with skeletal Class II patterns ($P < .05$). The same result was observed between the second premolar and the first molar, at 7-, 9- and 11-mm depths. However, the interradicular distances between the first and second molars, at 3- and 5-mm depths, in the subjects with skeletal Class II patterns were greater than those in the subjects with skeletal Class I patterns ($P < .01$ and $P < .05$, respectively).

Area measurements (interradicular areas). Table 3 shows the interradicular area measurements and comparisons between different dentoskeletal patterns.

In the maxilla, the greatest interradicular areas were also between the second premolar and the first molar (Class I = 34.2 ± 10.6 mm²; Class II = 38.7 ± 13.2 mm²; Class III = 33.3 ± 12.7 mm²); the least was between the first and second molars.

In the mandible, the greatest interradicular areas were between the first and second premolars (Class I = 53.2 ± 15.5 mm²; Class II = 45.6 ± 17.8 mm²; Class III = 57.9 ± 13.6 mm²). Significant differences in interradicular areas between different dentoskeletal patterns were also observed. In the maxilla, the interradicular areas between the first and second molars in the subjects with skeletal Class III patterns were significantly less than those in the subjects with skeletal Class II patterns ($P < .05$).

In contrast, in the mandible, the interradicular areas between the first and second premolars and between the second premolar and the first molar in the subjects with skeletal Class III patterns were significantly larger

than those in the subjects with skeletal Class II patterns ($P < .01$ and $P < .05$, respectively).

However, the subjects with skeletal Class II patterns presented significantly more interradicular areas between the mandibular first and second molars than did the subjects with skeletal Class III patterns ($P < .05$).

DISCUSSION

In our study, only subjects with well-defined skeletal patterns (Classes I, II, and III) were included. Therefore, the influence of different skeletal patterns and their characteristic dentoalveolar compensation on the availability of interradicular spaces were analyzed.

Excessive proclination of the mandibular incisors and retroclination of the maxillary incisors were observed in the subjects with skeletal Class II discrepancies. In contrast, retroclination of the mandibular incisors combined with proclination of the maxillary incisors were observed in the subjects with skeletal Class III discrepancies. The characteristics of dentoalveolar compensation observed in this study are in agreement with those described by Ishikawa et al.¹⁶ and by Solow.¹⁷

For all skeletal patterns, the safest zone in the interradicular space of the posterior maxilla was the space between the second premolar and the first molar. In the posterior mandible, the safest zones were located between the first and second premolars and between the first and second molars. These results are in agreement with those of previous studies that assessed the interradicular spaces in subjects with minor or no malocclusion.¹⁰⁻¹⁵

However, significant differences in the interradicular spaces between different dentoskeletal patterns were observed. Subjects with Class II skeletal patterns presented significantly greater interradicular distances and larger areas in the maxilla when compared with the subjects with skeletal Class III patterns. In contrast, in the mandible, the interradicular distances and areas in the subjects with skeletal Class III patterns were greater than those in the subjects with skeletal Class II patterns.

Table 2. Interradicular Distance Measurements in the Maxillae and Mandibles, and Comparisons Between Different Dentoskeletal Patterns^a

Location	Measurement Level (Depth)												Tukey Test, Significance of P									
	3-mm			5-mm			7-mm			9-mm			11-mm			7-mm		9-mm		11-mm		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I-II	II-III	I-III	I-II	II-III	I-III	
Maxillae	U4-5 Mean	1.3	1.4	1.5	1.7	1.8	1.9	2.0	1.9	1.9	2.2	2.1	2.0	2.6	2.7							
	SD	0.6	0.5	0.7	0.7	0.5	0.8	0.8	0.6	0.9	0.9	0.7	0.9	1.1	1.1							
U5-6	Mean	1.7	1.7	1.5	2.0	2.3	1.9	2.4	2.6	2.1	3.0	3.1	2.8	3.9	4.0							
	SD	0.6	0.5	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.4	1.4	1.7	1.8							
U6-7	Mean	1.3	1.5	1.1	1.4	1.5	1.1	1.4	1.4	1.0	1.6	1.6	1.3	2.4	2.4	*						
	SD	0.5	0.7	0.6	0.6	0.7	0.7	0.7	0.9	0.8	0.9	1.0	0.9	1.2	1.2							
Mandibles	L4-5 Mean	2.6	2.4	3.0	3.3	3.0	3.7	3.7	3.4	4.3	4.3	3.9	4.9	5.1	4.6	**						*
	SD	0.8	0.9	0.9	1.0	1.1	1.0	1.1	1.3	1.2	1.2	1.4	1.5	1.3	1.6				**			
L5-6	Mean	2.2	2.1	2.4	2.5	2.4	2.8	2.9	2.6	3.2	3.5	3.2	3.9	4.6	4.3		*					*
	SD	0.7	0.8	0.9	0.8	0.9	1.0	1.0	1.0	1.1	1.2	1.3	1.2	1.5	1.6							
L6-7	Mean	2.3	2.8	2.5	2.7	3.2	2.8	3.2	3.7	3.3	4.0	4.5	4.2	5.3	6.0	**					*	
	SD	0.7	0.8	0.6	0.8	1.0	0.7	1.1	1.2	0.9	1.4	1.4	1.2	1.8	1.6							

^a SD indicates standard deviation; U, maxillary teeth; L, mandibular teeth; I, skeletal Class I; II, skeletal Class II; and III, skeletal Class III.

* P < .05; ** P < .01.

A probable explanation for the results is the difference in dentoalveolar compensation observed between these groups. Subjects with skeletal Class II patterns presented with retrognathic mandibles and more upright maxillary incisors than did the subjects with skeletal Class III patterns; as a result, the subjects with skeletal Class II patterns presented with greater amounts of interradicular space in the maxillary arch. In contrast, subjects with skeletal Class III patterns presented with prognathic mandibles combined with excessively retroclined mandibular incisors; therefore, greater amounts of mandibular interradicular space were observed in these subjects than in the subjects with skeletal Class II patterns.

Accordingly, it is possible to conclude that the availability of interradicular space was mainly influenced by the axial inclination of teeth due to dentoalveolar compensatory changes for variations in sagittal skeletal discrepancies. Greater dental inclination presented with less interradicular space, whereas more upright teeth presented with more interradicular space. In our study, only the effect of different skeletal patterns and their characteristic dentoalveolar compensation on the availability of interradicular spaces were analyzed. Several factors that would potentially affect the availability of interradicular spaces (such as severity of crowding, tooth anatomy, larger sinuses, ethnic variability, and path of eruption of the third molars) were not addressed.

In this study, available interradicular space for miniscrew implant placement in the maxilla greater than 3 mm was found only at 9- and 11-mm depths from the alveolar crest between the first molar and second premolars, an area likely to be covered by movable mucosa. Poggio et al.¹⁰ reported that the insertion of miniscrews in the maxillary molar region above 8 mm from the alveolar crest must be avoided because of the presence of the sinus. The authors further recommended miniscrew placement in an oblique direction to the dental axis (30°–40°) to allow for miniscrew placement on the attached gingiva.¹⁰ Moreover, more available space can be obtained with angulated placement of miniscrews in an apical direction because of divergent tooth root morphology.¹⁰

In our study, assessment of both interradicular distance and area between the adjacent tooth roots was performed. Interradicular distance has been the conventional method for assessment of interradicular space using radiographic images.^{10–13} Moreover, the use of the alveolar crest as a reference for measurements is relatively simple and reliable, and provides a clinical guideline for miniscrew placement.^{10–13} However, the simple linear measurements at defined heights from the alveolar crest do not provide complete information about each interradicular space. In order

Table 3. Interradicular Area Measurements in the Maxillae and Mandibles, and Comparisons Between Different Dentoskeletal Patterns^a

Location	Interradicular Area, mm ²						Tukey Test, Significance of <i>P</i>		
	Skeletal I		Skeletal II		Skeletal III		I–II	II–III	I–III
	Mean	SD	Mean	SD	Mean	SD			
Maxillae									
U4–5	28.1	10.2	29.3	10.0	27.3	10.3			
U5–6	34.2	10.6	38.7	13.2	33.3	12.7			
U6–7	18.2	6.4	19.2	5.1	16.2	3.7		*	
Mandibles									
L4–5	53.2	15.5	45.6	17.8	57.9	13.6		**	
L5–6	41.9	12.0	37.1	12.9	44.5	14.5		*	
L6–7	39.6	15.6	45.9	16.6	37.6	10.9		*	

^a SD indicates standard deviation; U, maxillary teeth; L, mandibular teeth; I, skeletal Class I; II, skeletal Class II; and III, skeletal Class III.

* $P < .05$; ** $P < .01$.

to avoid this limitation, assessment of the interradicular area was performed in order to provide overall information of the interradicular space.

In this study, comparisons of the interradicular space between different skeletal patterns were performed using both distances and areas. Similar results were observed both in areas and in distances at all sites, except for the mandibular site between the first and second molars. A probable explanation was the presence of the third molars. Fayad et al.²⁰ showed that the eruption of maxillary third molars played an important role in the sagittal inclination of adjacent molars. Therefore, the presence of third molars influences the inclination of maxillary molars and may play an important role in the availability of the interradicular space. Further studies are necessary to investigate the influence of the third molars on the availability of the interradicular space.

A limitation of our study was the use of periapical radiographs to assess the interradicular space since they provide limited, two-dimensional representations of three-dimensional anatomic structures.²¹

Although all periapical radiographs were made using the long-cone paralleling technique, thus providing images with minimal distortion, the use of cone-beam computed tomography with three-dimensional images would provide more accurate and reliable results.²² Moreover, the use of periapical radiographs is the practical approach to assess the safe space for miniscrew placement.²³ Therefore, it might be preferable to use cone-beam computed tomography to assess the amount of interradicular space in different dentoskeletal patterns in a future study.

The authors acknowledge the study performed by Poggio et al.,¹⁰ which described the safe zones for miniscrew placement in subjects with minor or no malocclusions. In the present study, similar methodology was applied to assess the availability of interradicular spaces in subjects with skeletal discrepancies.

CONCLUSIONS

- The availability of interradicular space was mainly influenced by the axial inclination of teeth due to dentoalveolar compensatory changes for variations in sagittal skeletal discrepancies.
- For all skeletal patterns, the safest zone in the interradicular space of the posterior maxilla was the space between the second premolar and the first molar. In the posterior mandible, the safer zones were located between the first and second premolars and between the first and second molars.
- Understanding the relationship between the skeletal pattern and the availability of interradicular space may aid the clinician in planning appropriate surgical sites for miniscrew implant placement.

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REFERENCES

1. Tseng YC, Hsieh CH, Chen CH, Shen YS, Huang IY, Chen CM. The application of mini-implants for orthodontic anchorage. *Int J Oral Maxillofac Surg.* 2006;35:704–707.
2. McGuire MK, Scheyer ET, Gallerano RL. Temporary anchorage devices for tooth movement: a review and case reports. *J Periodontol.* 2006;77:1613–1624.
3. Papadopoulos MA, Tarawneh F. The use of miniscrew implants for temporary skeletal anchorage in orthodontics: a comprehensive review. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2007;103:e6–15.
4. Aranyawongsakorn S, Torut S, Suzuki B, Suzuki EY. Insertion angulation protocol for miniscrew implant placement in the dentoalveolar area. *J Dent Assoc Thai.* 2007;57:285–297.

5. Torut S, Aranyawongsakorn S, Suzuki EY, Suzuki B. Trends in miniscrew implant design and use for orthodontic anchorage: a systematic literature review. *J Dent Assoc Thai.* 2008;7:34–44.
6. Asscherickx K, Vannet BV, Wehrbein H, Sabzevar MM. Root repair after injury from mini-screw. *Clin Oral Implants Res.* 2005;16:575–578.
7. Kuroda S, Yamada K, Deguchi T, Hashimoto T, Kyung HM, Takano-Yamamoto T. Root proximity is a major factor for screw failure in orthodontic anchorage. *Am J Orthod Dentofacial Orthop.* 2007;131:S68–73.
8. Kravitz ND, Kusnoto B. Risks and complications of orthodontic miniscrews. *Am J Orthod Dentofacial Orthop.* 2007;131:S43–51.
9. Schnelle MA, Beck FM, Jaynes RM, Huja SS. A radiographic evaluation of the availability of bone for placement of miniscrews. *Angle Orthod.* 2004;74:832–837.
10. Poggio PM, Incorvati C, Velo S, Carano A. “Safe zones”: a guide for miniscrew positioning in the maxillary and mandibular arch. *Angle Orthod.* 2006;76:191–197.
11. Carano A, Velo S, Incorvati C, Poggio P. Clinical applications of the Mini-Screw-Anchorage-System (M.A.S.) in the maxillary alveolar bone. *Prog Orthod.* 2004;5: 212–235.
12. Ishii T, Nojima K, Nishii Y, Takaki T, Yamaguchi H. Evaluation of the implantation position of mini-screws for orthodontic treatment in the maxillary molar area by a micro CT. *Bull Tokyo Dent Coll.* 2004;45:165–172.
13. Hernandez LC, Montoto G, Puente Rodriguez M, Galban L, Martinez V. ‘Bone map’ for a safe placement of miniscrews generated by computed tomography. *Clin Oral Implants Res.* 2008;19:576–581.
14. Lee KJ, Joo E, Kim KD, Lee JS, Park YC, Yu HS. Computed tomographic analysis of tooth-bearing alveolar bone for orthodontic miniscrew placement. *Am J Orthod Dentofacial Orthop.* 2009;135:486–494.
15. Hu SK, Kang KM, Kim WT, Kim HK, Kim JH. Relationships between dental roots and surrounding tissues for orthodontic miniscrew installation. *Angle Orthod.* 2009;79:37–45.
16. Ishikawa H, Nakamura S, Iwasaki H, Kitazawa S, Tsukada H, Sato Y. Dentoalveolar compensation related to variations in sagittal jaw relationships. *Angle Orthod.* 1999;69: 534–538.
17. Solow B. The dento-alveolar compensatory mechanism. *Br J Orthod.* 1980;7:145–161.
18. Kim YJ, Lee JS, Kim WT, Nahm SD, Chang IY. Classification of the skeletal variation in normal occlusion. *Angle Orthod.* 2005;75:311–319.
19. Rakosi T. *An atlas and manual of cephalometric radiography.* London: Wolfe Medical Publications; 1982:55–57.
20. Fayad JB, Levy JC, Yazbeck C, Cavezian R, Cabanis AE. Eruption of third molars: relationship to inclination of adjacent molars. *Am J Orthod Dentofacial Orthop.* 2004; 125:200–202.
21. Floyd P, Palmer P, Palmer R. Radiographic techniques. *Br Dent J.* 1999;187:359–365.
22. Lubele M, Maes F, Schutyser F, Marchal G, Jacobs R, Suetens P. Assessment of bone segmentation quality of cone-beam CT versus multislice spiral CT: a pilot study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006; 102:225–234.
23. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH. Clinical application of micro-implant anchorage. *J Clin Orthod.* 2002; 36:298–302.