Original Article

Root proximity and cortical bone thickness effects on the success rate of orthodontic micro-implants using cone beam computed tomography

Kyung-Inn Min[a]; Sang-Cheol Kim[b]; Kyung-Hwa Kang[c]; Jin-Hyoung Cho[c]; Eon-Hwa Lee[d]; Na-Young Chang[d]; Jong-Moon Chae[e]

ABSTRACT

Objective: To evaluate factors (root proximity and cortical bone thickness) affecting the success rate of orthodontic micro-implants (OMIs) using cone-beam computed tomography (CBCT) images.

Materials and Methods: We examined 172 OMIs (1.2–1.3 mm in diameter, 8 mm in length) implanted into the maxillary buccal alveolar bone of 94 patients (33 men, 61 women) with malocclusion. Root proximity and cortical bone thickness were measured, and the correlations between these measurements and OMI success rates were evaluated.

Results: The overall success rate was 90.7% (156/172). The success rate increased as the distance between the root surface and OMI increased, showing a highly significant statistical correlation ($P < .05$). As the cortical bone thickness increased, the success rate increased, showing a slight, nonsignificant correlation ($P > .05$). Thus, the success rate of OMIs was affected more significantly by root proximity than cortical bone thickness.

Conclusions: When inserting OMIs, increasing the distance from the OMI to the root surface will significantly improve success rates. (*Angle Orthod.* 2012;82:1014–1021.)

KEY WORDS: Root proximity; Cortical bone thickness; CBCT; Success rate; Orthodontic micro-implant (OMI)

INTRODUCTION

Anchorage is the cornerstone of the orthodontic force system. Various techniques to reinforce anchorage have been devised and used in orthodontic practice. For over a decade, orthodontists have been able to achieve absolute anchorage with bony anchorage techniques, which are now widely used. Compared to other methods of bony anchorage, orthodontic micro-implants (OMIs) have been hailed as particularly efficient for orthodontic treatment, having advantages such as a wide variety of application areas, reduced need for patient cooperation, and fewer side effects on teeth. As the frequency of OMI use increases, clinicians are becoming more concerned about the factors affecting its success rate.

The success rate of OMIs has been reported very differently due to several variables.[1–10] In addition, many studies have recently been performed to determine factors affecting the success rate. Among them, root proximity to the orthodontic implant and cortical bone thickness have been reported frequently.[11–17]

Kuroda et al.[11] concluded that the proximity of a miniscrew to the root was a major risk factor for failure of the screw. In contrast, Kim et al.[12] reported that the

[a] Graduate student, Department of Orthodontics, School of Dentistry, University of Wonkwang, Iksan, South Korea.
[b] Professor, Department of Orthodontics, School of Dentistry, University of Wonkwang, Wonkwang Dental Research Institute, Iksan, South Korea.
[c] Associate Professor, Department of Orthodontics, School of Dentistry, University of Wonkwang, Wonkwang Dental Research Institute, Iksan, South Korea.
[d] Assistant Professor, Department of Orthodontics, School of Dentistry, University of Wonkwang, Wonkwang Dental Research Institute, Iksan, South Korea.
[e] Associate Professor, Department of Orthodontics, School of Dentistry, University of Wonkwang, Wonkwang Dental Research Institute, Iksan, Wonkwang Bone Regeneration Research Institute, The Korean Orthodontic Research Institute Inc, Daejeon, South Korea.
Corresponding author: Jong-Moon Chae, Department of Orthodontics, School of Dentistry, Wonkwang University, Daejeon Dental Hospital, 1268 Doonsan–Dong, Seo-Gu, Daejeon, 302-120, South Korea
(e-mail: jongmoon@wonkwang.ac.kr)

Accepted: January 2012. Submitted: June 2011.
Published Online: March 14, 2012

 DOI: 10.2319/091311-593.1

Table 1. Patient Characteristics (n = 94)

Sex	Number	Mean Age ± SD, Y
Male	33	17.69 ± 3.86
Female	61	20.30 ± 6.34
Total	94	19.36 ± 5.66

amount of root contact area of a mini-implant was more important for its stability than root proximity. Park and Cho[13] suggested that the interradicular spaces between the second premolar and the first molar in the maxillary buccal alveolar bone were adequate and safe locations for OMI placements.

Baumgaertel and Hans[14] suggested that knowledge of the pattern of variation in cortical bone thickness and its mean values could aid in mini-implant site selection and preparation, but future studies would be needed to determine the exact relationship between cortical bone thickness, the method of implant site preparation, and success rates. Deguchi et al.[15] suggested that angling the implant at approximately 30° would increase the contact with the cortical bone by as much as 1.5 times more than placing implants perpendicular to the long axis of the teeth. Lim et al.[16] also suggested that placing mini-implants at 30° or 45° would increase the contact with the cortical bone.

Many studies have also investigated factors affecting the success rate of OMIs using three-dimensional (3D) computed tomography (CT) imaging in addition to 2D radiography. Recently, cone-beam CT (CBCT) has been widely used in the field of orthodontics to reduce the shortcomings of conventional CT such as radiation dosage, cost, and device size. However, there are few clinical reports of CBCT imaging analysis of OMIs implanted in patients for orthodontic anchorage. Therefore, in this study, root proximity and cortical bone thickness were measured using CBCT imaging, and the correlation between the measurements and OMI success rates was evaluated.

MATERIALS AND METHODS

Before this study, a power analysis with G*Power 3.1.3 (Franz Faul, Christian-Albrechts-Universität, Kiel, Germany) was performed to estimate the sample size. The sample size for the study was calculated based on a significance level of .05 and a power of 80%. The power analysis showed that 88 patients were required. Institutional Review Board approval was granted by the Wonkwang University Dental Hospital (IRB WKD IRB 20101201) to conduct this study.

The sample consisted of CBCT images of all 94 consecutive patients (33 men, 61 women; mean age, 19.36 years; SD, 5.66 years) who received OMIs into the maxillary buccal alveolar bone for orthodontic anchorage from a single operator at the Department of Orthodontics, Wonkwang University Daejeon Hospital, in Daejeon, Korea, from January 2008 to November 2009 (Table 1). Before implantation, the patients were informed of the advantages and disadvantages of this procedure, and informed consent was obtained from all patients. We also evaluated the range of bone availability at interradicular locations using panoramic radiographs. The patients agreed to have CBCT scans after placement of OMIs into the maxillary buccal alveolar bone. The images were taken with a CBCT device (PSR 9000N, Asahi Alphard Vega, Kyoto, Japan) with dosimetry parameters of 12 mA, 80 kV, and a 17-second scan time on a dental mode (D mode, scan size 51 × 51 mm, voxel size 0.1 mm).

The CBCT data were saved as digital imaging and communications in medicine (DICOM) files, and Simplant CMF software (version 13, Materialise NV, Leuven, Belgium) was used for analysis of the DICOM data to generate quantitative measurements.

We examined 172 OMIs (1.2–1.3 mm in diameter; 8 mm in length; implant type: AbsoAnchor SH1312-08 [self-drilling style], Dentos, Taegu, Korea) implanted into the maxillary buccal alveolar bone. All OMIs were placed directly with a hand driver, according to the self-drilling procedure, by a single operator at the Department of Orthodontics, with patients under local anesthesia. The OMIs were inserted into the attached gingiva just adjacent to the mucogingival junction, and immediately loaded with orthodontic forces of about 50 to 200 g with elastic chains (Figure 1).

OMIs that were maintained in the bone and acted as an appropriate anchorage unit for over 1 year under orthodontic force during treatment were considered successful. Success rates according to age, sex, and side of placement (right or left) and the overall success rate were calculated (Table 2). To assess the effect of age on the success rate, the patients were divided into two groups according to age: young patients (less than 20 years of age) with 93 OMIs and adult patients (20 years of age or older) with 79 OMIs (Table 2).

Root proximity to the OMI was determined by measuring the shortest distance between the root surface and the long axis or center of the OMI on both the axial and sagittal views of the CBCT image (Figures 2 and 3). The thickness of the cortical bone was measured on the coronal view of the CBCT image as the depth of the cortical bone contacting the OMI. We selected an average of two measurements of cortical bone thickness in contact with the OMI (Figure 4).

Statistical Analysis

To test the reliability of the measurements, a single investigator randomly selected 20 subjects for duplicate measurements 2 weeks after the initial measurement,

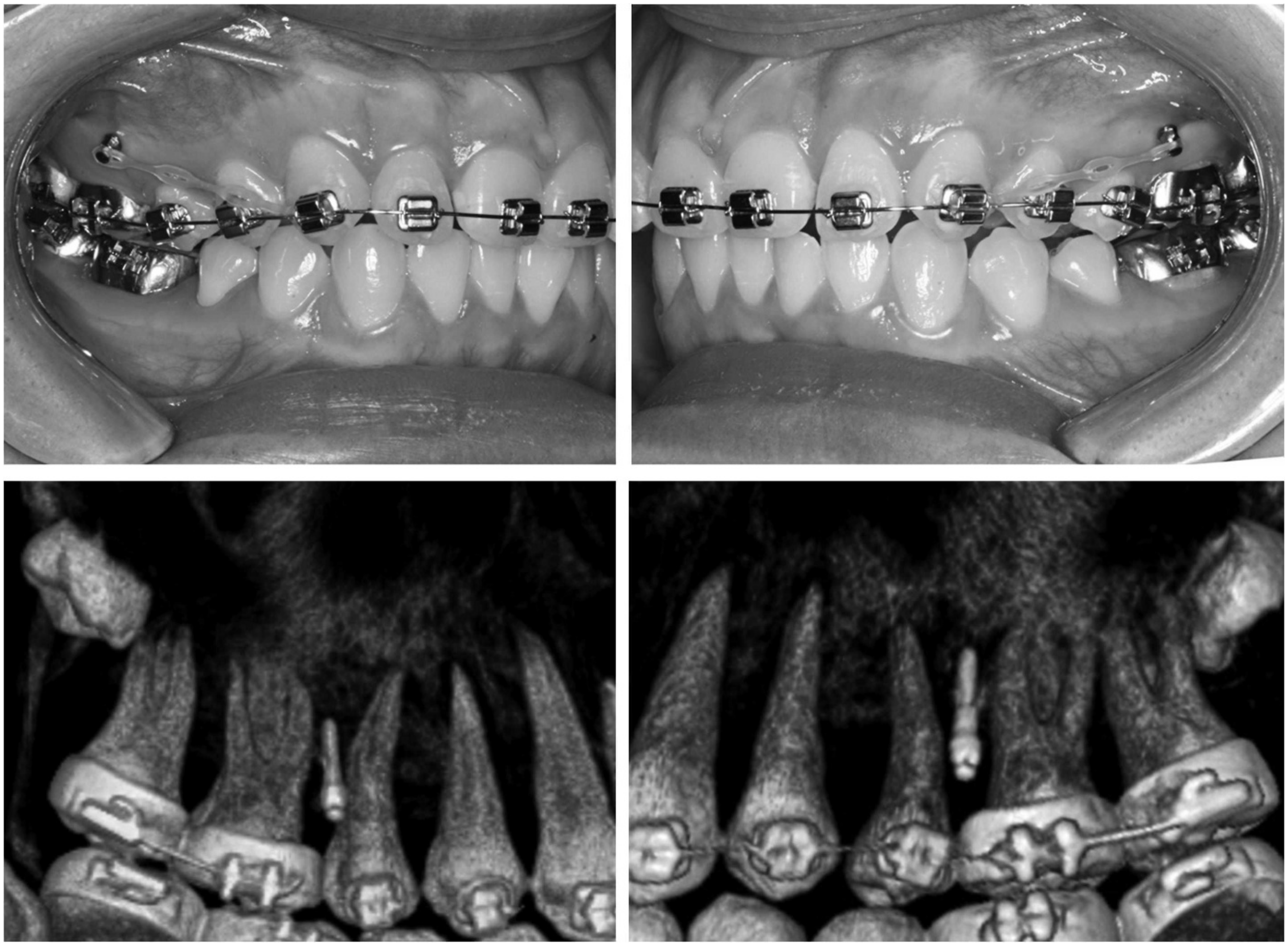

Figure 1. Intraoral photographs and 3D images after placing orthodontic micro-implants.

which showed no significant differences ($P > .05$) in the intraclass correlation coefficient (ICC). The ICC showed excellent test-retest reliability of 3D measurements of OMIs at 95% confidence interval: 0.951 for the root proximity and 0.985 for the cortical bone thickness.

The measurement error was calculated using the Dahlberg formula. The greatest mean error for all linear measurements did not exceed 0.53 mm. Descriptive statistics were initially performed to calculate the overall success rate of the OMIs, as well as their specific success rates with regard to the patients' age, sex, and placement side, and for root proximity and cortical bone thickness. All values recorded in this study were presented as mean ± SD. Logistic regression multivariate analysis was used to examine the correlations between success rates and age, sex, and placement side (right or left). SPSS software (version 18.0, SPSS, Chicago, Ill) was used for all statistical calculations. Logistic regression analysis was carried out to evaluate the correlation between measurements (root proximity and cortical bone thickness) and success rates. The statistical significance was set at $P < .05$ for all tests.

Table 2. Success Rates and Number of Orthodontic Micro-implants (OMIs) According to Sex, Age, and Side of Placement

	Success Rate, %	Success/Total OMIs
Sex		
Male	89.6	43/48
Female	91.1	113/124
Age, y		
<20	89.2	83/93
≥20	92.4	73/79
Side of placement		
Right	88.9	80/90
Left	92.7	76/82
Total	90.7	156/172

RESULTS

The overall success rate was 90.7% (156 of 172 OMIs). All 172 OMIs were inserted into the maxillary buccal alveolar bone; 90 were placed on the right side and 82 on the left side. Placement side was related to

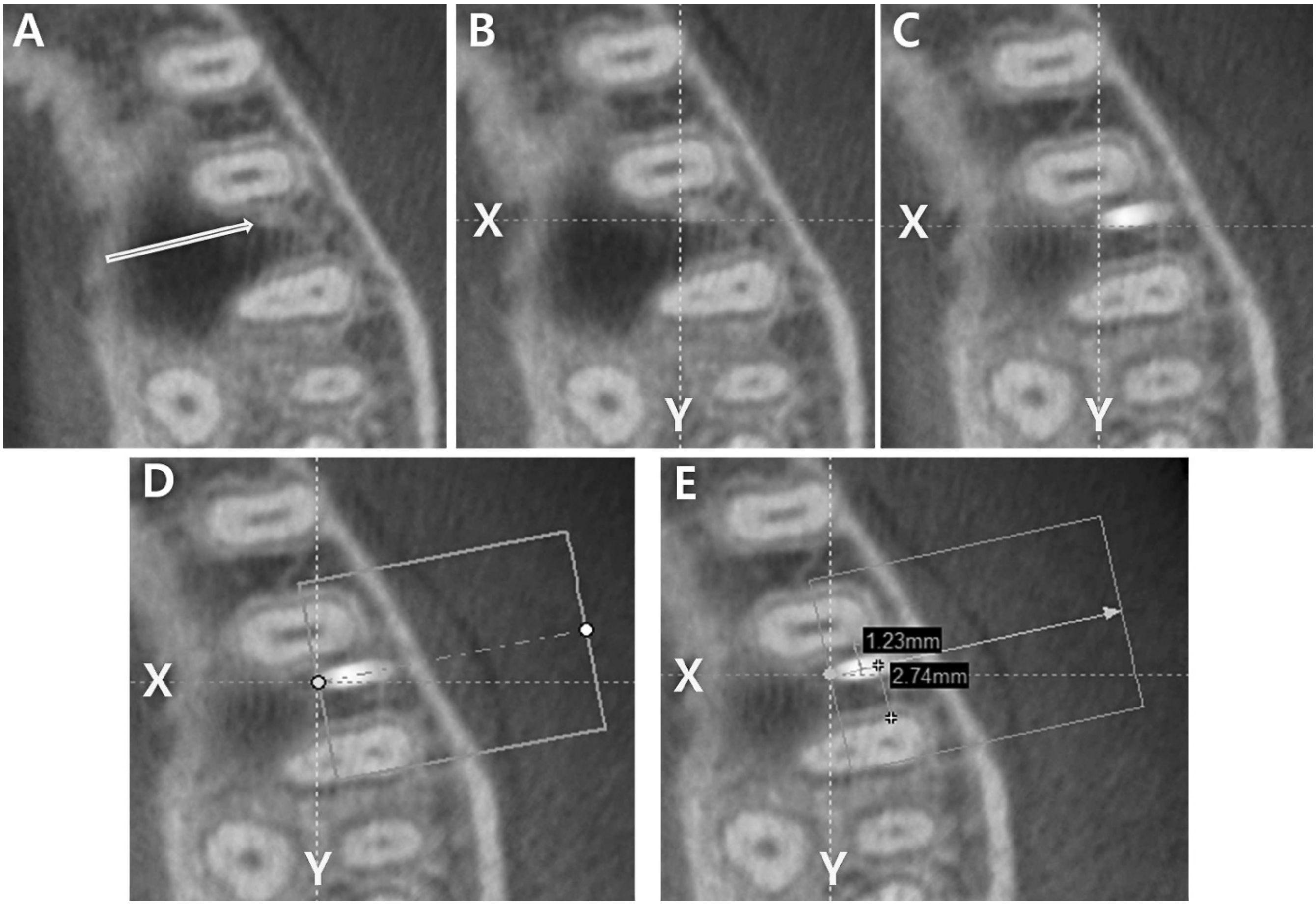

Figure 2. Root proximity measurements in axial views. (A) Image of an OMI tip. (B) Fixing X, Y axis intersecting on the OMI tip. (C) Image of the OMI body. (D) Drawing of a reference line connecting the long axis of the OMI and intersecting point of the fixed X, Y axis. (E) Shortest distance from the reference line to the mesial and distal root surface. X axis, buccolingual direction; Y axis, mesiodistal direction.

success rate: right side success rate was 88.9% (80 of 90 OMIs), and left side success rate was 92.7% (76 of 82 OMIs). Age was also related to success rate: in young patients (<20 years), the success rate was 89.2% (83 of 93 OMIs), and in adult patients (≥20 years), the success rate was 92.4% (73 of 79 OMIs). Finally, sex was related to success rate. The success rate in men was 89.6% (43 of 48 OMIs) and that in women was 91.1% (113 of 124 OMIs). Thus, the success rates were higher in the left side than in the right side, higher in adult patients than in young patients, and higher in female than in male patients, although these trends were not statistically significant (Tables 2 and 3).

Table 4 shows the averages and standard deviations of the root proximity to the OMI (the shortest distance between the root surface and the long axis or center of the OMI) on both axial and sagittal views of the CBCT image, and also the cortical bone thickness on the coronal view of the CBCT image. Table 5 and Figure 5 show the values and distribution of the root proximity and cortical bone thickness according to success and failure of OMIs. The mean values of root proximity were 1.33 (0.71) mm and 0.66 (0.04) mm in the success and failure groups, respectively. In parenthesis is the value minus the mean radius of the OMI (0.625 mm) from the shortest distance between the root surface and axis the implant. Sixteen OMIs were contacted with the root surface (16/172, 9.3%) and 11 of 16 OMIs were failed, which showed a failure rate of 68.8%. And, the mean values of cortical bone thickness were 1.23 and 1.06 mm in the success and failure groups, respectively (Table 5).

The results of the logistic regression analysis are shown in Table 6. Since exp(6.6546) = 696.448 in the results of root proximity, a 0.1-mm increase in the distance between the root surface and OMI increased the success rate 69.6448 times. Thus, the success rate increased as the shortest distance between the root surface and OMI increased, showing a statistically significant association of success rate with root proximity ($P < .05$). Since exp(1.297) = 3.660 in the results of cortical bone thickness, a 0.1-mm increase in the cortical bone thickness increased the success rate 0.3660 times. Thus, the success rate also increased

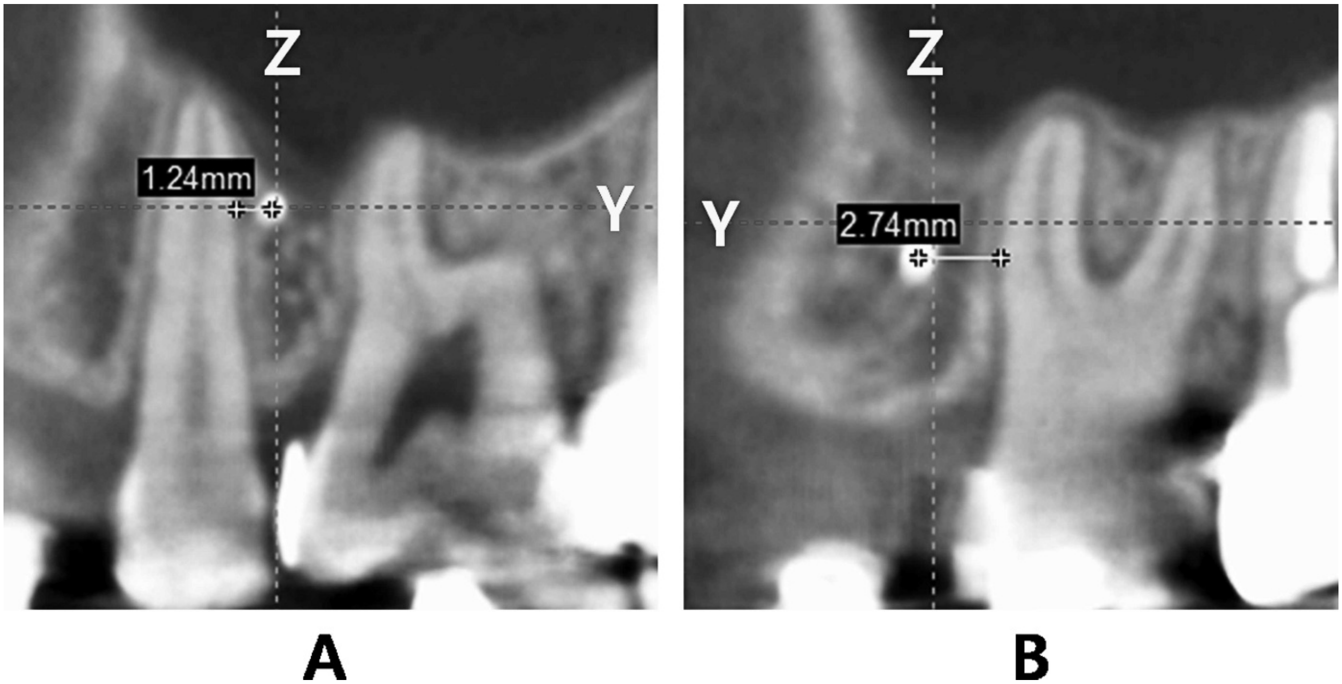

Figure 3. Root proximity measurements in sagittal views. The shortest distance from the center of an OMI to the mesial (A) and distal (B) root surface. Y axis, mesiodistal direction; Z axis, occlusogingival direction.

as the cortical bone thickness increased, although this association was not significant ($P > .05$). Wald was 19.510 and 1.796 in the results of the root proximity and cortical bone thickness, respectively. Therefore, the success rate of OMIs was affected more significantly by the root proximity than the cortical bone thickness.

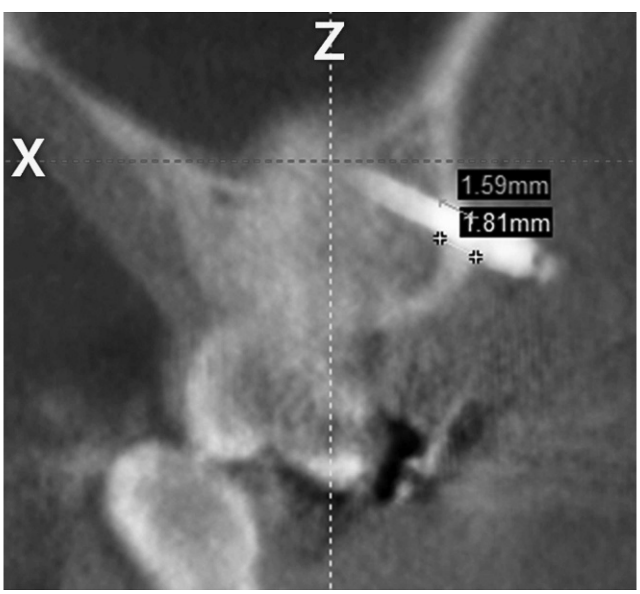

Figure 4. Cortical bone thickness measurement in a coronal view. X axis, buccolingual direction; Z axis, occlusogingival direction.

DISCUSSION

Although various studies have reported the use of OMIs as anchorage for orthodontic tooth movement for several decades, their clinical performance and the crucial factors affecting their success are not well known. The quality of orthodontic treatment has been increasingly affected by the success or failure of OMIs as clinicians have increased the frequency of their use. Therefore, they have become more concerned about the factors affecting the success rate of OMIs.

To determine factors affecting the success rate of OMIs, various studies have been performed using radiography in clinical examinations. Dental radiographs are commonly used to investigate hard tissues in dentoalveolar regions. However, these radiographs may be subject to the methodologic errors typical of 2D evaluations. Kuroda et al.[11] evaluated the use of 3D CT to examine root proximity, and confirmed that root contact with the screw was not observed by 2D radiography, although the radiograph did show the proximity of the screw to the root. Therefore, evaluation by 3D CT is useful to determine the actual final position of OMIs and to identify risk factors such as root proximity and cortical bone thickness that could not be seen on conventional 2D radiographs.[12] CBCT has become increasingly popular in many specialties of dentistry because of reduced radiation exposure, high accessibility, and favorable cost-benefit analysis. Suomalainen et al.[18] demonstrated that the error in linear measurements was even smaller with CBCT than with multislice CT.

Table 3. Logistic Regression Analysis Results According to Sex, Age, and Side of Placement[a]

	B	SE	Wald	*df*	Sig	Exp(B)	Exp(B) (95%CI)	
							Min	Max
Sex	0.174	0.575	.092	1	0.762	1.190	0.386	3.674
Age	0.634	0.565	1.256	1	0.262	1.884	0.622	5.707
Side of placement	0.485	0.544	0.793	1	0.373	1.624	0.559	4.721
Constant term	1.701	0.557	9.335	1	0.002	5.482		

[a] B indicates coefficient; SE, standard error; *df*, degree of freedom; Sig, significance; Exp(B), Exponential B; and CI, confidence interval, minimum and maximum.

In this study, after placement of orthodontic implants into the maxillary buccal alveolar bone, images were taken with a CBCT device. Root proximity to the OMI was then measured on the axial and sagittal views of the CBCT image, and cortical bone thickness was measured on the coronal view (Figures 2 through 4).

Joo[19] used interlamina dura distances to measure the inter-root distance, whereas Kim et al.[17] used the root surface as the standard to improve consistency because the root surface was seen more clearly in the CT image. Therefore, we used the root surface for the measurement of root proximity to OMIs to improve accuracy and reproducibility.

Kuroda et al.[11] reported that the proximity of a miniscrew to the root was a major risk factor for failure of screw anchorage. They based this finding on measurements of the proximity between the lamina dura and the screw. However, the surface boundary of the lamina dura is difficult to identify. Therefore, in this study, we measured the shortest distance between the root surface and the OMI (Figures 2 and 3).

Due to the metallic blurring that occurs in CBCT imaging, it is difficult to identify the surface boundary of the OMIs from the axial and sagittal views. Therefore, we used the long axis or center of the OMI as the reference line or point and measured the shortest distance between the long axis or center of the OMI and the root surface (Figures 2 and 3).

The more variables we had in the logistic regression analysis, the less clear were the statistics. Therefore, to simplify the variables, we used a single measurement, namely the shortest distance between the OMI and the root surface in the axial and sagittal views, for further analysis (Table 7). The correlation coefficient indicator to the variables was largely positive, which affirmed the positive correlation between them. We also found that the success rate increased as the shortest distance between the root surface and the OMI increased, and there was a statistically significant association of success rate with root proximity ($P < .05$).

Some OMIs seemed to contact with the root surface because minimum distances between the screw axis and root surface were less than the radius of the screw. Sixteen OMIs were contacted with the root surface and 11 of 16 OMIs were failed, which showed the failure rate of 68.8%. In the success group, the mean value of root proximity was 1.33 (0.71) mm and the maximum value of root proximity in the failure group was 1.25 (0.63) mm (Table 5). Therefore, clinical guideline of clearance from the root surface for success of OMIs is considered more than about 1.33 (0.71) mm (Table 5 and Figure 5).

Several studies have reported that the evaluation of cortical bone thickness is important because it is the major determinant of the initial stability of an OMI.[13–16] Deguchi et al.[15] suggested that in terms of cortical bone thickness, the best available location for a miniscrew is mesial or distal to the first molar, and the best angulation is 30° from the long axis of the tooth. Lim et al.[16] reported a statistically significant increase in the cortical bone thickness when the placement angle was increased. However, Petrey et al.[20] concluded that placement of temporary anchorage devices at 90° to the synthetic cortical plate gave the best retention. However, there have been few studies on the success rate of OMIs in relation to cortical bone thickness. In this study, the success rate increased as the cortical bone thickness increased, although this association was not statistically significant ($P > .05$). More studies are needed to determine the exact

Table 4. Descriptive Statistics for Various Factors in Cone-beam Computed Tomography[a] ($n = 172$)

	Minimum	Maximum	Mean	SD
Root proximity (mesial, axial), mm	0.41 (−0.22)	4.46 (3.84)	1.89 (1.26)	0.95 (0.95)
Root proximity (mesial, sagittal), mm	0.40 (−0.23)	4.38 (3.76)	1.92 (1.30)	0.92 (0.92)
Root proximity (distal, axial), mm	0.33 (−0.30)	4.13 (3.51)	1.88 (1.26)	0.79 (0.79)
Root proximity (distal, sagittal), mm	0.32 (−0.31)	4.05 (3.43)	1.83 (1.21)	0.83 (0.83)
Cortical bone thickness, mm	0.47	2.38	1.21	0.42

[a] Parentheses include value subtracted mean radius of the orthodontic micro-implant (0.625 mm) from the shortest distance between the root surface and axis of the implant.

Table 5. Descriptive Statistics for Root Proximity and Cortical Bone Thickness According to Success or Failure of Orthodontic Micro-implants (OMIs)[a]

	Number	Minimum	Maximum	Mean	SD
Root proximity, mm	Success (156/172)	0.41 (−0.22)	2.31 (1.69)	1.33 (0.71)	0.39 (0.39)
	Failure (16/172)	0.32 (−0.31)	1.25 (0.63)	0.66 (0.04)	0.24 (0.24)
Cortical bone thickness, mm	Success (156/172)	0.47	2.38	1.23	0.43
	Failure (16/172)	0.51	1.68	1.06	0.31

[a] Parentheses include value subtracted mean radius of OMI (0.625 mm) from the shortest distance between the root surface and axis of the implant.

relationship between cortical bone thickness, insertion angle, and success rate.

A commonly preferred site for OMI placement is between the maxillary second premolars and first molars because of the large space and easy accessibility for various orthodontic mechanics. In this study, we examined only OMIs placed into the maxillary buccal alveolar bone, although further studies are planned to investigate OMIs placed in other sites, especially the mandibular buccal alveolar bone.

From our evaluation of factors affecting the success rate of OMIs using CBCT images, increasing the distance from the OMI to the root surface was found to be significantly important for improved success rates when inserting OMIs. But, in some cases of this study, there were no correlations between the success rate and root proximity. Therefore, to maximize the success of OMIs, clinicians should attempt to determine additional factors affecting the success rate.

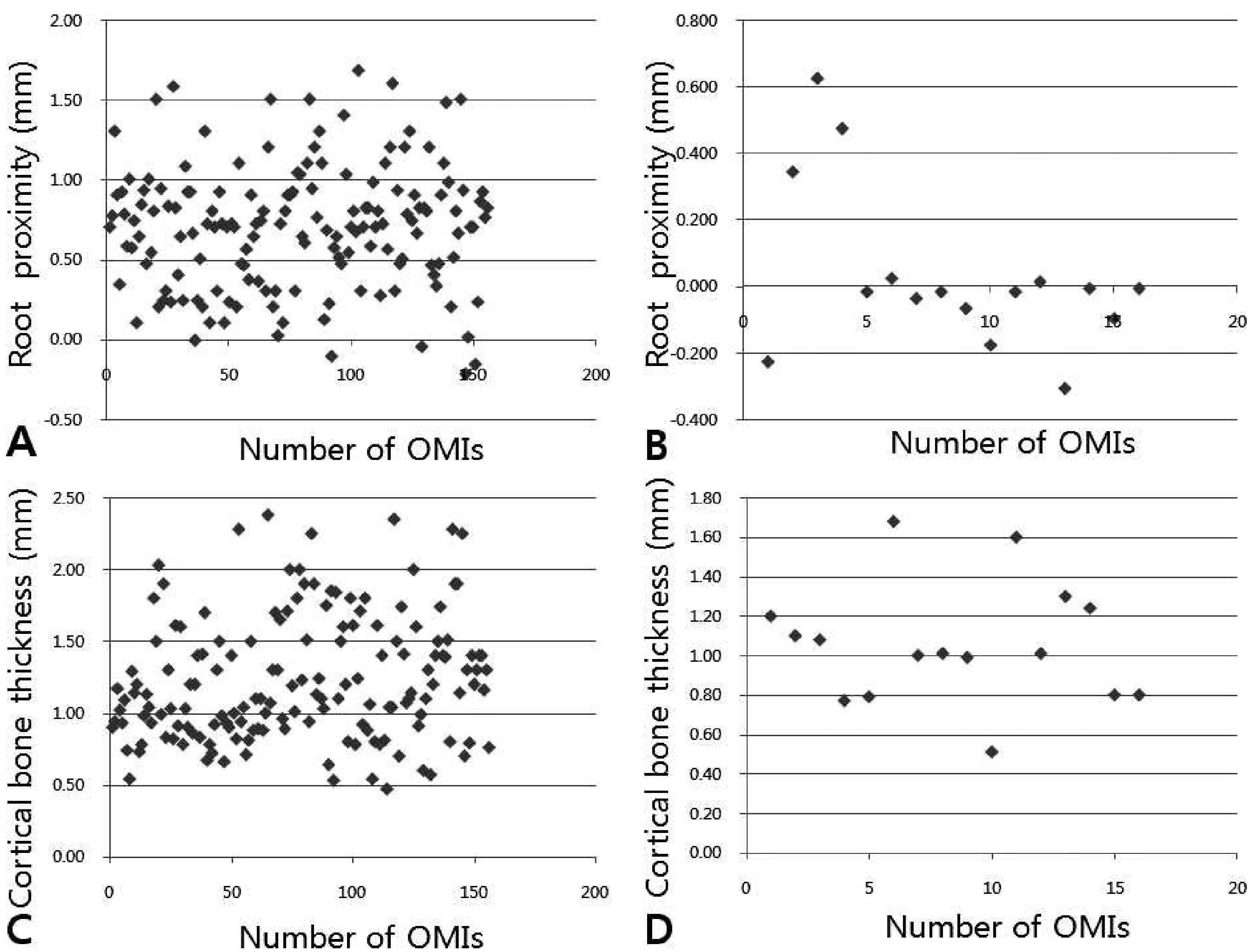

Figure 5. The distribution of values subtracted mean radius of OMI (0.625 mm) from the shortest distance between root surface and axis of OMI and cortical bone thickness according to success (A,C) or failure (B,D) of OMIs.

Table 6. Logistic Regression Analysis Results According to Root Proximity and Cortical Bone Thickness[a]

	B	SE	Wald	*df*	Sig	Exp(B)	Exp(B) (95%CI) Min	Exp(B) (95%CI) Max
Root proximity, mm	6.546 (6.546)	1.482 (1.482)	19.510 (19.510)	1	.000*** (.000***)	696.448 (696.448)	38.141 (38.141)	12,716.897 (12,716.897)
Cortical bone thickness, mm	1.297 (1.297)	0.968 (0.968)	1.796 (1.796)	1	.180 (.180)	3.660 (3.660)	0.549 (0.549)	24.414 (24.414)
Constant term	2.692 (6.784)	3.599 (3.786)	0.560 (3.211)	1	.454 (.073)	14.767 (883.270)		

[a] B indicates coefficient; SE, standard error; *df*, degree of freedom; Sig, significance; Exp(B), exponential B; and CI, confidence interval, minimum and maximum. Parentheses include result for value subtracted mean radius of OMI (0.625 mm) from the shortest distance between the root surface and axis of the implant.

*** $P < .001$.

CONCLUSIONS

- Root proximity to the OMI is significantly related to the success rate of OMIs.
- To increase the success rate, attempt to increase the distance from the root surface to the OMI.

ACKNOWLEDGMENT

This paper was supported by Wonkwang University in 2010.

REFERENCES

1. Park HS. Clinical study on success rate of miniscrew implants for orthodontic anchorage. *Korea J Orthod*. 2003;33:151–156.
2. Chen CH, Chang CS, Hsieh CH, Tseng YC, Shen YS, Huang IY, Yang CH, Chen CM. The use of microimplants in orthodontic anchorage. *J Oral Maxillofac Surg*. 2006;64:1209–1213.
3. Wiechmann D, Meyer U, Büchter A. Success rate of mini- and micro-implants used for orthodontic anchorage: a prospective clinical study. *Clin Oral Implants Res*. 2007;18:263–267.
4. Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T. Clinical use of miniscrew implants as orthodontic anchorage: success rates and postoperative discomfort. *Am J Orthod Dentofacial Orthop*. 2007;131:9–15.
5. Antoszewska J, Papadopoulos MA, Park HS, Ludwig B. Five year experience with orthodontic miniscrew implants: a retrospective investigation of factors influencing success rates. *Am J Orthod Dentofacial Orthop*. 2009;136:158.e1–158.e10.
6. 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;19:100–106.
7. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. *Am J Orthod Dentofacial Orthop*. 2006;130:18–25.
8. Moon CH, Lee DG, Lee HS, Im JS, Baek SH. Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region. *Angle Orthod*. 2008;78:101–106.
9. 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;124:373–378.
10. Baek SH, Kim BM, Kyung SH, Lim JK, Kim YH. Success rate and risk factors associated with mini-implant reinstalled in the maxilla. *Angle Orthod*. 2008;78:895–901.
11. 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–S73.
12. Kim SH, Kang SM, Choi YS, Kook YA, Chung KR, Huang JC. Cone-beam computed tomography evaluation of mini-implants after placement is root proximity a major risk factor for failure? *Am J Orthod Dentofacial Orthop*. 2010;138:264–276.
13. Park J, Cho HJ. Three-dimensional evaluation of interradicular spaces and cortical bone thickness for the placement and initial stability of microimplants in adults. *Am J Orthod Dentofacial Orthop*. 2009;136:314.e1–314.e12.
14. Baumgaertel S, Hans MG. Buccal cortical bone thickness for mini-implant placement. *Am J Orthod Dentofacial Orthop*. 2009;136:230–235.
15. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. *Am J Orthod Dentofacial Orthop*. 2006;129:721.e7–e12.
16. Lim JE, Lim WH, Chun OS. Cortical bone thickness and root proximity at mandibular interradicular sites: implications for orthodontic microimplant placement. *Korean J Orthod*. 2008;38:397–406.
17. Kim SH, Yoon HG, Choi YS, Hwang EH, Kook YA. Evaluation of interdental space of the maxillary posterior area for orthodontic mini-implants with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2009;135:635–641.
18. Suomalainen A, Vehmas T, Kortesniemi M, Robinson S, Peltola J. Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. *Dentomaxillofac Radiol*. 2008;37:10–17.
19. Joo E. *Radiographic Evaluation of Interdental Distance for Orthodontic Miniscrew Application* [thesis]. Seoul, Korea: Yonsei University; 2004.
20. Petrey JS, Saunders MM, Kluemper GT, Cunningham LL, Beeman CS. Temporary anchorage device insertion variables: effects on retention. *Angle Orthod*. 2010;80:446–453.

Table 7. Correlation Coefficient Between Axial and Sagittal Values in Root Proximity (n = 172)

	Pearson Correlation Coefficient	*P* Value
Root proximity (axial/sagittal)	0.966	.000***

*** $P < .001$.