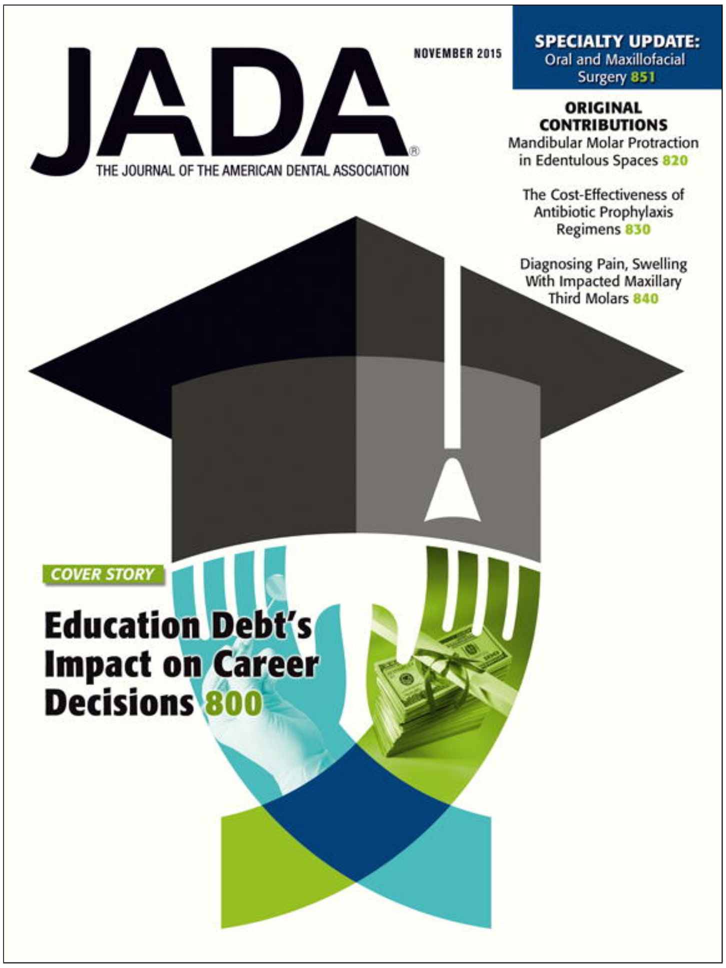
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Mandibular molar protraction as an alternative treatment for edentulous spaces

Focus on changes in root length and alveolar bone height

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ABSTRACT

Background. The authors conducted a retrospective cohort study to investigate external apical root resorption (EARR) and alveolar bone loss (ABL) after protraction of the mandibular molars by using miniscrews.

Methods. The authors protracted 51 mandibular molars in 37 adults into an edentulous area by using sliding mechanics with a lever arm or a miniscrew-supported root spring. The authors measured root length and alveolar bone height on panoramic radiographs and corrected according to the crown length registration method. The authors measured the amounts of crown movement (CM) and root movement (RM) on the superimposed lateral cephalometric radiographs along the mandibular occlusal plane. The authors used a linear mixed model to determine the risk factors for EARR and ABL.

Results. All edentulous spaces closed successfully in an average of 31.7 months, and the average CM and RM were 4.97 and 8.64 millimeters, respectively, with an RM:CM ratio of 2.81. The root length decreased significantly by 0.80 mm (5.53%), but EARR of more than 2 mm occurred in only 4.0% of molars. The alveolar bone height was reduced significantly by 0.56 mm, but ABL of more than 2 mm occurred in only 2.0% of molars. Linear mixed model results revealed that EARR and ABL correlated only with RM and age, respectively.

Conclusions. Protraction of the mandibular molars into an edentulous area by using miniscrews was effective and safe, especially in younger adults.

Practical Implications. Protraction of the mandibular molars can be considered as an alternative treatment to conventional prosthetic treatment in the restoration of edentulous space, especially in young adults, if patients accept longer treatment duration.

Key Words. Edentulism; orthodontic space closure; bone loss; root resorption.
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Mandibular molars are lost frequently in adults.[1,2] Untreated missing permanent molars cause tipping or migration of adjacent teeth and thereby form plaque-harboring pseudopockets, supraeruption of opposing teeth, and reduced alveolar bone height and width, which lead to collapse of occlusion and considerable periodontal problems.[3-6] The conventional treatment option for the missing mandibular molars is prosthetic restoration of the missing teeth with a fixed partial denture or dental implants. However, the survival rate of a fixed partial denture after a 20-year follow-up ranged from 65% to 66.2%,[7,8] and the survival rate of a dental implant after a 16-year follow-up was 82.94%,[9] which implies that the longevity of these prostheses may not be ideal.

An alternative treatment option is the closure of the edentulous space by means of orthodontic protraction of the second and third molars, which eliminates the need for prosthetic work and restores the deficient alveolar bone.[10] However, it requires an adequate anchorage unit to avoid the loss of the anterior anchorage. There are concerns regarding attachment loss when the tooth is moved into the reduced alveolar bone height.[11] Results from animal studies show that a tooth can be moved orthodontically into a reduced alveolar bone height while maintaining the height of the periodontal tissues, although results from clinical studies indicate that adults frequently have incomplete space closure of the edentulous area and marked reduction of alveolar bone height.[12-14] This result is probably because of insufficient

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anchorage and extrusive mechanics that may produce trauma from occlusion and worsen the attachment loss.[12,15]

Authors of several case reports showed successful protraction of the mandibular molars into the edentulous space by using temporary anchorage devices,[16-19] which are characterized by absolute anchorage and intrusive mechanics.[20] However, the predictability and safety of this treatment modality have not been verified in terms of external apical root resorption (EARR) and alveolar bone loss (ABL), which jeopardize the longevity of teeth, if severely affected.[21] The purposes of this study were as follows: to analyze the treatment results of protraction of the mandibular molars by using miniscrews in terms of the amount of space closure and the type of tooth movement, to investigate their effects on EARR and ABL, and to determine the risk factors related to EARR and ABL.

METHODS

This retrospective study was approved by the Yonsei Dental Hospital institutional review board. We calculated the sample size on the basis of the clinically meaningful differences in root resorption and ABL of 1.0 millimeter after treatment, and we obtained the expected standard deviations (SDs) from previous studies on the protraction of mandibular molars.[12,13] The power analysis showed that 34 patients were required for a study with a power of 80% and an α of .05.

We audited the records of all patients who visited the Department of Orthodontics at Yonsei University and started orthodontic treatment between January 1, 2004, and December 31, 2011. The inclusion criteria were that patients were postpubertal (> 16 years) and had one or more missing mandibular molars treated with protraction of the adjacent molars by using miniscrews by one of us (K.J.L.) and that patients had had panoramic radiographs and lateral cephalometric radiographs obtained before and after protraction. The exclusion criteria were that patients had received prosthetic treatment that substantially changed the reference structure between 2 time points of radiographic imaging and that patients had signs of active periodontal disease before and during the treatment. Among 40 patients who met the inclusion criteria, 3 patients were excluded because 1 of them had received prosthetic treatment before the second radiographic imaging and the other 2 patients had active periodontal disease during orthodontic treatment; therefore, we included 51 mandibular molars in 37 patients in this study. Table 1 shows the characteristics of the patients.

For the protraction, we bonded or banded the second molar, the third molar, or both with 0.018 × 0.025-inch preadjusted edgewise tubes, and we protracted them by using sliding mechanics in which the molars were moved along the 0.016 × 0.022-inch stainless steel continuous archwire. We placed miniscrews (7.0-mm length × 1.8-mm diameter; ORLUS, Ortholution, or 7.0-mm length × 1.5-mm diameter; ACR screw, BioMaterials Korea, depending on the interradicular space) between the mandibular first and second premolars and applied the protraction force to the lever arm engaged in the auxiliary tube to lower the line of action close to the furcation of the molar, approximating the center of resistance (Figure 1A). When the molar was tipped mesially, which prevented the use of the continuous archwire, we uprighted it by using a miniscrew-supported root spring with elastic chain, as described by Lee and colleagues[10] (Figure 1B), and then protracted it by using sliding mechanics. In the case of miniscrew failure, we placed another miniscrew immediately at the next available adjacent area or 3 months after failure at the same place to allow for bone healing.

We measured only mesial root length and mesial alveolar bone height of the molar adjacent to the edentulous space on the panoramic radiographs (Cranex 3+, Soredex). We used perpendicular projections from the mesial cementoenamel junction to the mesiobuccal cusp tip, alveolar bone crest, and mesial root apex to determine the crown height, root length, and alveolar bone height, respectively. With regard to the alveolar bone height, the alveolar bone crest apical to the

TABLE 1

Patient characteristics.

VARIABLE	NO. (%)	MEAN (STANDARD DEVIATION)	RANGE
Sex			
Male	18 (48.6)	–*	–
Female	19 (51.4)	–	–
Treatment Site			
Unilateral protraction	23 (62.2)	–	–
Bilateral protraction	14 (37.8)	–	–
Protracted Tooth			
Second molar	36 (70.6)	–	–
Third molar	15 (29.4)	–	–
Age, y	–	23.2 (6.9)	16-39
Treatment Time, mo	–	31.7 (11.5)	17-60
CM† (millimeters)	–	4.97 (2.44)	0.26-11.56
RM‡ (mm)	–	8.64 (3.30)	4.00-15.80
RM:CM Ratio	–	2.81 (4.61)	1.01-11.34

* Not applicable.
† CM: Crown movement.
‡ RM: Root movement.

ABBREVIATION KEY. AB: Alveolar bone height. **ABL:** Alveolar bone loss. **C:** Crown height. **CF:** Correction factor. **CM:** Crown movement. **EARR:** External apical root resorption. **R:** Root length. **RM:** Root movement. **T_0:** Before treatment. **T_1:** After treatment.

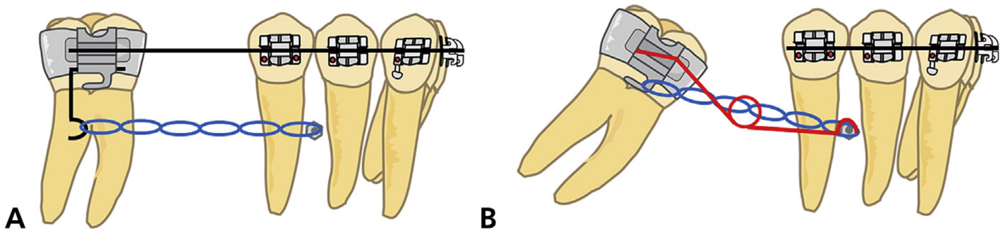

Figure 1. Treatment mechanics used in this study. **A**. Sliding mechanics with continuous archwire (black line) and lever arm. **B**. Miniscrew-supported root spring. The 0.017 × 0.025-inch titanium molybdenum alloy spring (red line) produces counterclockwise moment to the upright molar, while extrusion and distal crown movement was counteracted by intrusive protraction force from the miniscrew. Blue (circled) line indicates elastic chain.

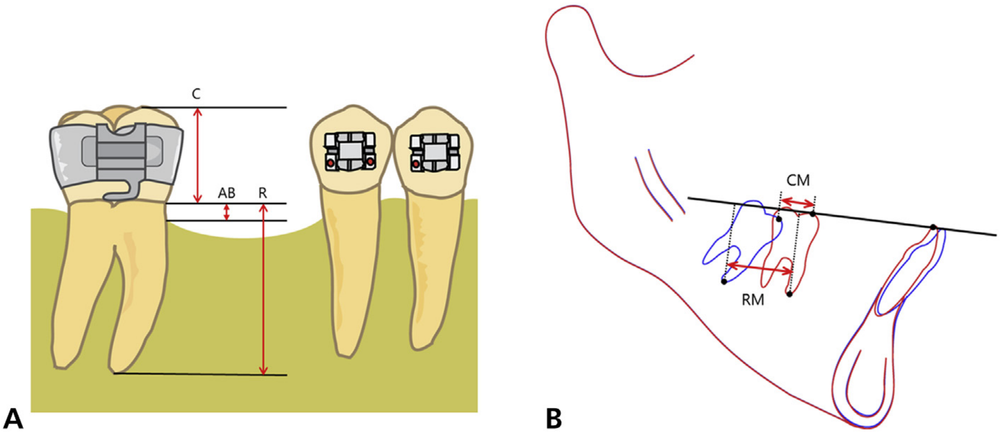

Figure 2. A. Measurement of the alveolar bone height and root length. **B**. Measurement of the amount of crown movement (CM) and root movement (RM) on the superimposed tracing of the lateral cephalometric radiograph. Blue lines depict position before treatment, and red lines depict position after treatment. AB: Alveolar bone height. C: Crown height. R: Root length.

cementoenamel junction was designated by a minus sign. We used the crown length registration method described in previous studies[22-26] to correct any differences in image magnification or distortion between pretreatment and posttreatment radiographs. We calculated the correction factor (CF) as the ratio of the pretreatment crown height and posttreatment crown height measured on the radiographs. We defined the EARR and ABL as the difference in the root lengths and alveolar bone heights, respectively, before and after treatment; we calculated them as follows (Figure 2A):

$$\text{CF} = \text{pretreatment crown height/posttreatment crown height}$$

$$\text{EARR} = \text{root length after treatment} \times \text{CF} - \text{root length before treatment}$$

$$\text{ABL} = \text{alveolar bone height after treatment} \times \text{CF} - \text{alveolar bone height before treatment}$$

A minus sign for EARR and ABL indicates shortening of the root and resorption of the alveolar bone, respectively.

We also calculated the EARR as the percentage of the initial root length.

We measured the amount of crown movement (CM) and root movement (RM) of the protracted molar on the lateral cephalometric radiographs (Cranex 3+ Ceph, Soredex). We traced the cephalometric radiographs and carefully superimposed the mandibular tracings by means of a structural method of using inferior alveolar canals and the fine structures of the symphysis.[27] We distinguished left and right molars by referring to the panoramic radiographs. We used the mesiobuccal cusp tip and the mesial root apex of the protracted molar as the landmarks for the CM and the RM, respectively. We measured them along the posttreatment mandibular occlusal plane connecting the incisor tip and mesiobuccal cusp of the first or second molar (Figure 2B). We evaluated the type of tooth movement by using the RM:CM ratio.

The same examiner (S.-J.K.) performed all measurements twice in a 2-week interval, and we calculated intraclass correlation coefficients for the repeated measurements to examine intraexaminer reliability. We calculated the method errors by using the Dahlberg formula: standard error = $\sqrt{(\Sigma d^2/2n)}$, in which d is the difference between measurements and n is the number of pairs of measurements.[28]

We used the Shapiro-Wilk test to confirm that all measurements were distributed normally ($P > .05$). Because we performed bilateral protraction of 2 mandibular molars in some patients and they might be correlated according to the individual patients, we compared the root length and alveolar bone height before and after treatment by using a linear mixed model. We investigated the distributions of EARR and ABL. We also analyzed the changes in the root length (EARR) and alveolar bone height (ABL) by using univariate and multiple linear mixed models including sex, tooth type, age, treatment duration, CM, RM, initial root length, and initial alveolar bone height as covariates. We treated patients as the random effect, and all other effects were fixed. We assumed the model to have a compound-

TABLE 2

Changes in root length and alveolar bone height (linear mixed model).

MEASUREMENT	T_0,* MEAN (SD†)	T_1,‡ MEAN (SD)	T_1-T_0, MEAN (SD)	T_1-T_0, 95% CONFIDENCE INTERVAL	*P* VALUE
Root Length (millimeters)	14.63 (2.26)	13.83 (2.33)	−0.80§ (0.66)	−1.00 to −0.61	< .001
Root Length (%)	100 (0)	94.47 (4.72)	−5.53§ (4.72)	−6.92 to −4.15	< .001
Alveolar Bone Height (mm)	−1.37 (1.03)	−1.93 (1.33)	−0.56¶ (0.70)	−0.78 to −0.34	< .001

* T_0: Before treatment.
† SD: Standard deviation.
‡ T_1: After treatment.
§ Minus sign indicates shortening of the root.
¶ Minus sign indicates reduction of alveolar bone height.

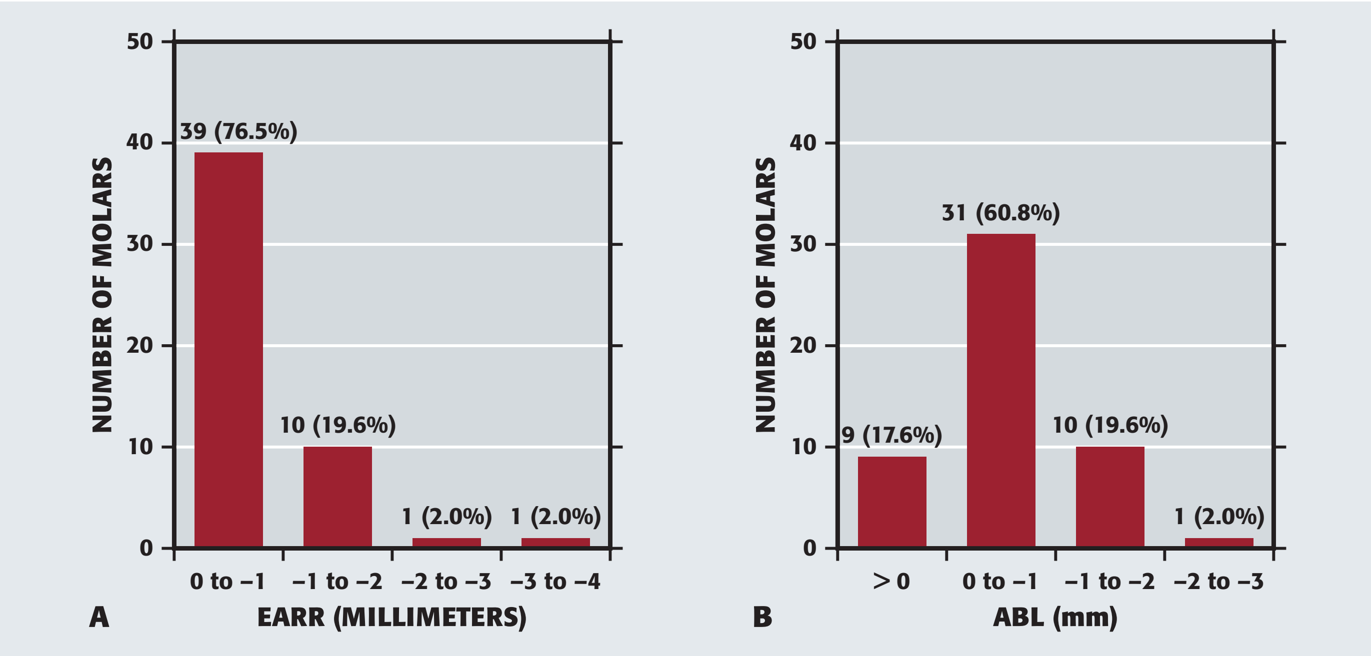

Figure 3. Distribution of (**A**) external apical root resorption (EARR) and (**B**) alveolar bone loss (ABL) in millimeters. Percentages may not add up to 100% due to rounding.

symmetry variance-covariance structure. We performed statistical evaluations at the 5% level of significance by using SPSS for Windows, Version 20.0 (IBM).

RESULTS

Intraclass correlation coefficients ranged from 0.908 to 0.921, indicating excellent intraexaminer reliability. The method errors ranged from 0.15 to 0.82 mm. Among 51 miniscrews required, initial placement was successful in 41 miniscrews. Eight miniscrews required second placement, and only 2 miniscrews required third placement, resulting in an overall success rate of 81.0%. All edentulous spaces closed successfully. The average CM and RM were 4.97 and 8.64 mm, respectively, with an average RM:CM ratio of 2.81 (range, 1.01-11.34). This result indicated that the treatment mechanics used in this study reliably achieved closure of edentulous space with a considerable amount of RM and CM (Table 1).

The root length decreased significantly after protraction, with an average EARR of 0.80 mm (5.53%; $P < .001$) (Table 2). However, 76.5% of molars had an EARR of less than 1 mm, and only 4.0% of molars had an EARR of more than 2 mm (Figure 3A). The alveolar bone height also reduced significantly after protraction, with an average ABL of 0.56 mm ($P < .001$) (Table 2). However, almost 80% of molars demonstrated an ABL of less than 1 mm, and only 2.0% of molars demonstrated an ABL of more than 2 mm (Figure 3B).

Results from the univariate linear mixed models indicated that EARR measured in mm was correlated only with the amount of RM ($P = .003$) and that EARR measured as a percentage was correlated with the amount of CM ($P = .024$) and RM ($P = .001$). However, results from the multiple analysis for adjusting possible correlations between covariates showed that EARRs measured either in mm or as a percentage were

TABLE 3

Univariate and multiple linear mixed models for the EARR.*

INDEPENDENT VARIABLE	EARR (mm†)‡					
	Univariate Analysis			Multiple Analysis		
	Unstandardized coefficient	95% CI§	P value	Unstandardized coefficient	95% CI	P value
Constant				0.954	−1.132 to 3.040	.359
Sex (1, Male; 0, Female)	0.225	−0.190 to 0.639	.265	0.171	−0.273 to 0.615	.400
Tooth Type (1, Second Molar; 0, Third Molar)	−0.326	−0.760 to 0.108	.129	−0.352	−0.972 to 0.268	.226
Age, y	0.003	−0.027 to 0.033	.841	−0.022	−0.061 to 0.016	.211
Treatment Duration, mo	0.009	−0.010 to 0.027	.340	0.009	−0.011 to 0.029	.329
Crown Movement (mm)	−0.071	−0.153 to 0.011	.085	−0.052	−0.168 to 0.063	.327
Root Movement (mm)	−0.092	−0.147 to −0.036	.003#	−0.083	−0.158 to −0.008	.034¶
Initial Root Length (mm)	−0.013	−0.103 to 0.078	.764	−0.027	−0.159 to 0.106	.657
Initial Alveolar Bone Height (mm)	0.019	−0.186 to 0.225	.842	−0.012	−0.256 to 0.232	.911

* EARR: External apical root resorption.
† mm: Millimeters.
‡ Minus sign indicates shortening of the root.
§ CI: Confidence interval.
¶ $P < .05$.
# $P < .01$.

correlated only with the amount of RM ($P = .034$ and .042, respectively), which indicated that a large amount of RM increased root resorption (Table 3). In addition, ABL was correlated only with age ($P < .001$, univariate analysis; $P < .001$, multiple analysis), which indicated that older patients showed more ABL after protraction (Table 4).

Figure 4 shows serial panoramic radiographs and clinical photographs obtained in 2 representative patients who were treated by means of protraction of the mandibular second molar by using sliding mechanics with a lever arm (Figure 4A) and a miniscrew-supported root spring (Figure 4B). In both cases, the edentulous space closed successfully by means of considerable RM with minimal ABL and root resorption.

DISCUSSION

Investigators have demonstrated the clinical usefulness of miniscrews in systematic reviews, reporting mean success rates of 83.6% to 87.7%.[29-31] In this study, the overall success rate of the miniscrew was 81.0%, which is comparable with those data. We attributed the successful space closure in this study to the miniscrews that provided stable anchorage during the slow remodeling of cortical bone necessary for the orthodontic space closure of the edentulous area. Protraction of molars often requires a considerable amount of RM because an untreated missing molar usually causes tipping of the adjacent molars. Thus, the use of proper mechanics and stable anchorage is mandatory for successful protraction of the molars. In this study, we protracted all mandibular molars with an average RM of 8.64 mm and an RM:CM ratio of 2.81, which demonstrates the effectiveness of using miniscrew-supported root springs and sliding mechanics with a lever arm.

With regard to treatment efficiency, the average treatment duration was 31.7 months; therefore, the average rate of RM was 0.27 mm per month. The treatment duration was inflated because it included the duration of active protraction and the finishing stage after the protraction was completed. These results, nevertheless, are comparable with those of Roberts and colleagues,[32] which showed that the rate of mandibular molar translation was 0.32 mm per month in 5 adults. The treatment duration reported in other case reports of mandibular molar protraction ranged from 28 to 50 months[16-19,33]; therefore, the treatment mechanics in this study were deemed efficient. However, it is also true that it requires longer treatment duration than would a conventional fixed partial denture or dental implant, although their long-term survival rates decrease over time.[7-9] Therefore, mandibular molar protraction can be an alternative treatment for the edentulous area, if a patient accepts longer treatment duration.

EARR is a common iatrogenic consequence of orthodontic treatment that affects most orthodontic patients.[34] Although extensive studies have been performed regarding EARR of the incisors, EARR of molars has received little attention because of the low incidence of EARR in the posterior teeth, probably because of the minor RM of the molars during routine orthodontic treatment.[35] However, protraction of the molars requires a large amount of tooth movement, so

TABLE 3 (CONTINUED)

EARR (%)‡					
Univariate Analysis			Multiple Analysis		
Unstandardized coefficient	95% CI	P value	Unstandardized coefficient	95% CI	P value
			1.768	−13.036 to 16.571	.810
1.950	−0.940 to 4.839	.170	1.186	−1.959 to 4.331	.410
−1.198	−4.350 to 1.953	.426	−2.615	−7.012 to 1.782	.208
0.034	−0.177 to 0.246	.734	−0.155	−0.425 to 0.115	.222
0.047	−0.085 to 0.180	.456	0.058	−0.082 to 0.199	.365
−0.677	−1.248 to −0.106	.024¶	−0.404	−1.225 to 0.416	.289
−0.720	−1.103 to −0.337	.001#	−0.559	−1.092 to −0.026	.042¶
0.264	−0.376 to 0.903	.390	0.151	−0.788 to 1.091	.720
−0.331	−1.793 to 1.131	.633	−0.253	−1.983 to 1.477	.745

EARR of the protracted molars needs to be evaluated. In this study, the mean (SD) root length significantly decreased by 0.80 (0.66) mm (5.53% [4.72%]). These results are somewhat larger than the results in the report by Sameshima and Sinclair,[35] which showed that the average root resorption of mandibular molars after routine orthodontic treatment was 0.42 mm. However, 96.1% of the molars had an EARR of less than 2 mm, which is classified as minor resorption, according to Levander and Malmgren.[36] The amount of EARR in the maxillary incisors after orthodontic treatment is reportedly 1.23 to 1.79 mm.[35,37,38] Therefore, the amount of EARR in this study may be considered negligible and likely would not affect the longevity of the teeth, which strongly supports this orthodontic option for missing areas rather than placing dental implants. Despite the large amount of tooth movement, a relatively small amount of root resorption may be attributed to the fact that the roots of the mandibular molars move through the trabecular bone during protraction, whereas the roots of the incisors are frequently in contact with cortical bone, which significantly increases the risk of EARR.[39]

In this study, EARR was correlated with RM, which is generally in agreement with the findings in previous studies.[39-43] The mechanism of EARR has not been understood fully, although it appears to be a damage of root structure caused by the cellular activity that

TABLE 4

Univariate and multiple linear mixed models for the alveolar bone loss, in millimeters.

INDEPENDENT VARIABLE	ALVEOLAR BONE LOSS*					
	Univariate Analysis			Multiple Analysis		
	Unstandardized coefficient	95% CI†	P value	Unstandardized coefficient	95% CI	P value
Constant				1.681	−0.002 to 3.365	.050
Sex (1, Male; 0, Female)	−0.022	−0.497 to 0.453	.924	−0.157	−0.509 to 0.195	.334
Tooth Type (1, Second Molar; 0, Third Molar)	0.096	−0.348 to 0.541	.647	−0.078	−0.576 to 0.420	.727
Age, y	−0.070	−0.091 to −0.049	< .001‡	−0.085	−0.115 to −0.054	< .001‡
Treatment Duration, mo	−0.009	−0.029 to 0.012	.395	−0.001	−0.017 to 0.014	.834
Crown Movement (mm§)	0.060	−0.024 to 0.143	.149	0.007	−0.087 to 0.101	.869
Root Movement (mm)	0.002	−0.059 to 0.063	.938	−0.037	−0.098 to 0.023	.198
Initial Root Length (mm)	0.001	−0.088 to 0.091	.974	−0.001	−0.108 to 0.107	.989
Initial Alveolar Bone Height (mm)	0.041	−0.177 to 0.259	.693	−0.153	−0.349 to 0.044	.112

* Minus sign indicates reduction of alveolar bone height.
† CI: Confidence interval.
‡ $P < .001$.
§ mm: Millimeters.

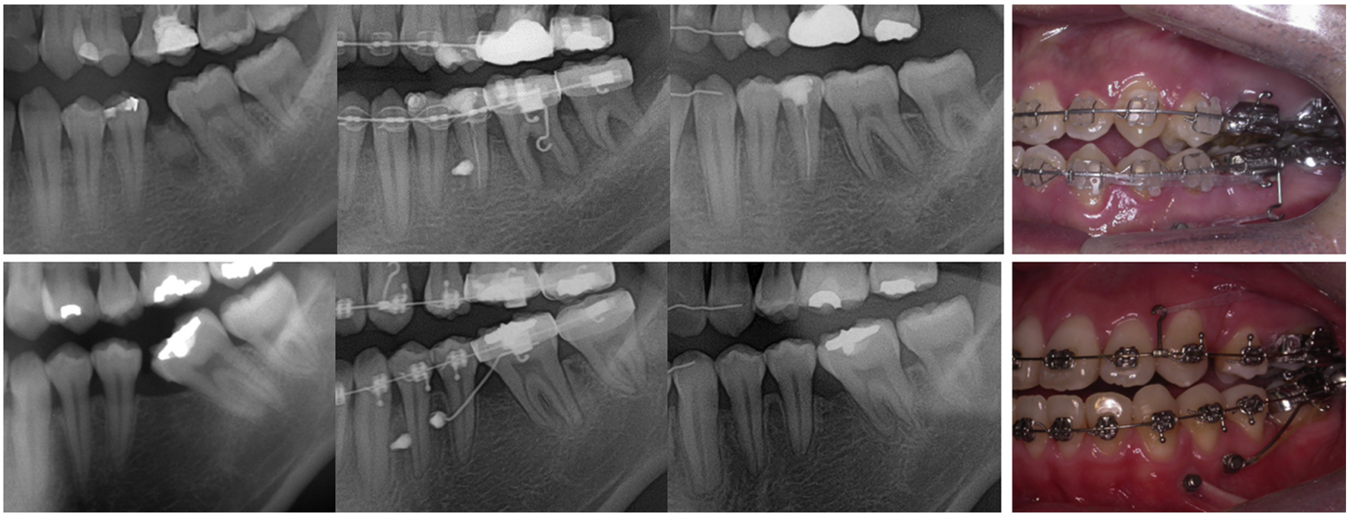

Figure 4. Serial panoramic radiographs and clinical photographs obtained in 2 patients who were treated by means of the 2 different types of mechanics used in this study. **A**. Sliding mechanics with lever arm. **B**. Miniscrew-supported root spring.

removes necrotic hyalinized tissue, which occurs routinely during orthodontic tooth movement.[44] A greater amount of RM causes a larger amount of hyalinized tissue to be removed; therefore, it is reasonable to infer that EARR is related to the amount of RM.

The results also showed that sex, treatment duration, age, and initial root length were not correlated with EARR. Investigators generally have reported that sex is not associated with EARR.[35,42] However, treatment duration is reportedly a strong predictor of EARR, which may be because of the difference between the active treatment duration in which the targeted tooth is moving and the prolonged whole treatment duration because some patients repeatedly missed appointments.[43] However, current evidence is inconclusive with regard to the patient's age and the initial root length. Investigators in 2 studies have reported that EARR is lesser in children or adolescents than in adults.[35,45] In this study, we included only postpubertal and adult participants. Other study results indicate that age may not have a significant role as a risk factor for EARR in adults.[41,42] With regard to the initial root length in the anterior teeth, investigators in some studies[35,42] have found positive correlations, but investigators in other studies[36,46] have found negative correlations. It appears that the initial root length of the molars is less variable and has a minor role in determining EARR.

The effect of orthodontic treatment on the height of the alveolar bone is another issue. The results of this study showed that a small but significant amount of ABL (mean [SD], 0.56 [0.70] mm) occurred after protraction. This amount is smaller than what was reported in previous studies regarding protraction of the mandibular molars (1.3-2.0 mm).[12,13] Almost 80% of molars had an ABL of less than 1 mm, and the alveolar bone height increased in 17.6% of molars. Investigators in 2 meta-analyses reported that average marginal bone loss around implant-supported single crowns in the posterior region was 0.83 mm[47] and that routine orthodontic therapy also leads to minor ABL[48]; therefore, the ABL in this study was clinically acceptable. This encouraging result may be partly attributable to the intrusive mechanics of using temporary anchorage devices to avoid trauma from occlusion, which reportedly accelerates attachment loss in the presence of the periodontal inflammation.[15] Transient gingival inflammation commonly is observed during orthodontic treatment; therefore, the use of proper mechanics to avoid trauma from occlusion is also mandatory in terms of ABL.

With regard to the risk factors correlated with ABL, we found a significant correlation only for age. This result is consistent with findings by Stepovich,[12] who reported that patients younger than 17 years experienced less ABL than did patients older than 23 years, although he did not perform proper statistical analysis in his study. A possible explanation for this result is growth-related extrusion, followed by positive modeling of the alveolar bone.[49] Vertical growth of the mandible usually continues until the early 20s; it also accompanies vertical growth of the alveolar bone.[50] Also contributing to this finding may be histologic factors such as less dense alveolar bone and a greater amount of cellular periodontal ligament in younger patients.[49] In terms of periodontal health, the clinical significance of this finding is that it may be advantageous to start treatment at a younger age.

The results also showed that ABL was not correlated with sex, treatment duration, and the amount of crown and RM, which is generally in agreement with results from previous studies.[13,51-53] In this study, we found no significant correlations with ABL with regard to the initial alveolar bone height, whereas Hom and Turley[13] reported that molars with a higher alveolar bone height showed greater ABL. However, they also questioned their result, probably because of the small sample size or lack of standardized measurement technique in their study. The finding that the amount of ABL was irrelevant to the initial alveolar bone height and in a clinically acceptable range is encouraging in that molars can be protracted in patients with a reduced alveolar bone height.

There are some study limitations that need to be clarified. First, it is a retrospective study, which may be subjective to potential sources of bias. To reduce selection bias, we included all patients who met the criteria, and we addressed the detailed procedure of sample recruitment as a study flow diagram according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[54] However, there still might be a possibility that we excluded patients who were predicted to show poor prognosis for protraction at the treatment planning step. A prospective clinical trial will be needed for more thorough investigation of the treatment effect.

Second, we evaluated EARR and ABL from panoramic radiographs in this study. Periapical or panoramic radiographs traditionally have been used to evaluate EARR and ABL, and there have been several studies in which the investigators have compared the accuracy of these 2 methods in detecting EARR and ABL.[55-60] With regard to root resorption, panoramic radiographs tend to exaggerate the amount of root resorption when compared with periapical radiographs, primarily because of the magnification factor.[55] Thus, in this study, we evaluated only the mesial roots of the mandibular molars, which did not show a statistically significant difference in root resorption,[55] and we used the crown length registration method to correct for the magnification factor. With regard to ABL, periapical radiographs are reportedly superior to panoramic radiographs for detecting periodontal osseous destruction.[57,58] However, investigators in other studies concluded that readings of the 2 methods are in great agreement and that panoramic radiographs can be used to evaluate ABL.[59,60] Therefore, we deemed the use of panoramic radiographs appropriate for the purposes of this study.

Lastly, we did not evaluate alveolar bone width in the edentulous area because there was no tool to evaluate it properly. Narrow alveolar bone width may be a potential risk factor for ABL, although initial alveolar bone height was not correlated with ABL in this study. Cone-beam computed tomography is a powerful tool for evaluating the anatomy of alveolar bone and root in 3 dimensions and includes volumetric measurements.[61-63] Investigators in future studies may incorporate cone-beam computed tomography as an evaluation tool for alveolar bone width, as well as for EARR and ABL.

CONCLUSIONS

Protraction of the mandibular molars by using miniscrews was not only effective for space closure of the edentulous area with considerable RM but also safe in terms of EARR and ABL. Small but statistically significant EARR (mean [SD], 0.80 [0.66] mm) and ABL (mean [SD], 0.56 [0.70] mm) occurred after the protraction, but they were in the clinically acceptable range. Greater amounts of RM and increased patient age were risk factors for EARR and ABL, respectively. Mandibular molar protraction can be considered as an alternative treatment to conventional prosthetic treatment for the edentulous area, especially in young adults. ■

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