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Original article

Change in alveolar bone level of mandibular second and third molars after second molar protraction into missing first molar or second premolar space

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Summary

Objective: To investigate the factors associated with the change in alveolar bone level of mandibular second and third molars after second molar protraction into the space of the missing first molar (L6) or second premolar (LE).

Methods: Fifty-one patients in whom space of the missing L6 or LE was treated with second molar protraction (13 males, 38 females, mean age 19.6 ± 4.7 years) from 2003 to 2015 were included. The alveolar bone level and position and angulation of the mandibular second and third molars were measured in panoramic radiographs at pre-treatment (T1), and after the alignment of the third molars following second molar protraction (T2). Factors associated with alveolar bone loss on the distal aspect of the mandibular second molars were assessed using linear regression analysis.

Results: Age at T1 ($P < 0.001$) and third molar angulation at T1 ($P = 0.002$) were significant factors for the prediction of alveolar bone level distal to the second molars.

Limitation: This study used two-dimensional panoramic radiographs, and we could observe only the interproximal bone level.

Conclusions: After second molar protraction into the missing first molar or second premolar space, mandibular second molars may exhibit alveolar bone resorption in the distal root in older patients and in those with mesially tilted third molars before treatment.

Introduction

Edentulous space caused by a missing mandibular first molar (L6) or a mandibular second premolar with a retained deciduous molar (LE) is a common problem for clinicians. Several methods such as molar uprighting followed by fixed prostheses or dental implants (1), autotransplantation (2), and space closure with orthodontics have been considered as solutions (3). The space caused by missing molars can be closed through protraction of the second molar with the aid of temporary skeletal anchorage devices (TADs). When an impacted third molar is present, it can be erupted to attain appropriate posterior occlusion (4–9). Impacted third molars are expected to erupt into occlusion when a posterior space is created (10–16), such as when first or second molars are extracted.

Whereas previous studies have focused on the successful eruption of impacted third molars after second molar protraction (13–15,17), the periodontal health of the protracted second molar has received little attention. After a substantial amount of second molar

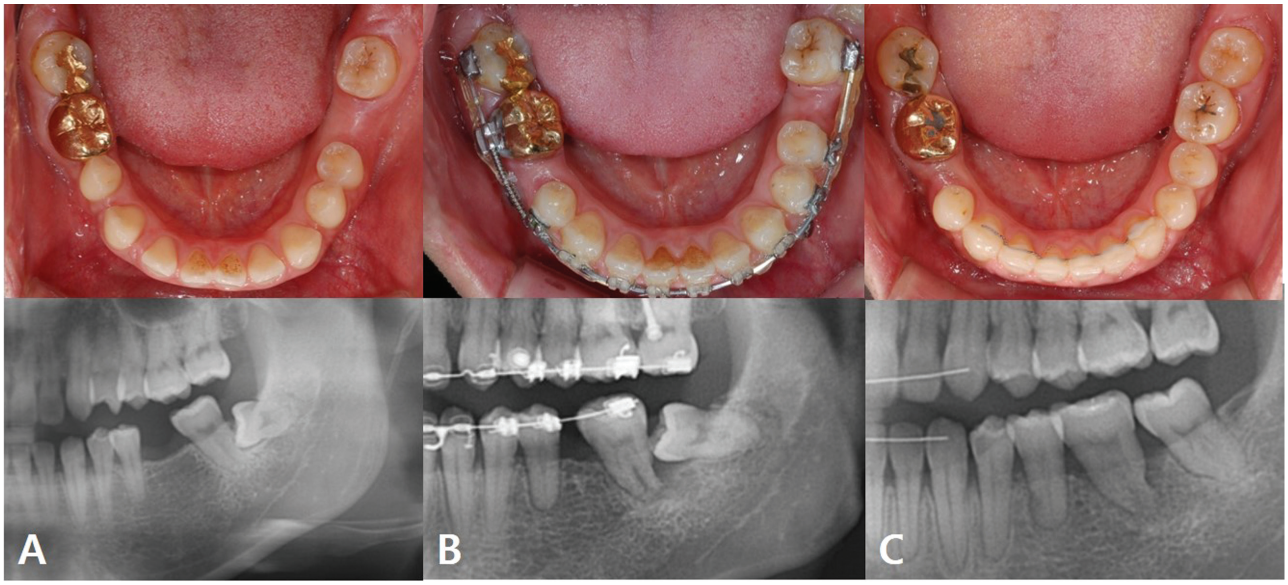

Figure 1. Case of alveolar bone resorption of the mandibular second molar after protraction into the missing first molar space. (A) Before treatment; (B) during protraction; (C) after treatment. Significant alveolar bone loss distal to the mandibular second molar was observed.

protraction, alveolar bone resorption may sometimes occur on the distal side of the mandibular second molar (Figure 1). However, most patients show normal periodontal support of the mandibular second molar (Figure 2). To the best of our knowledge, no research has been conducted on the alveolar bone level of mandibular second molars after protraction into the first molar position.

The purpose of this study was to assess the alveolar bone level of mandibular second and third molars after second molar protraction and to investigate the factors that are associated with the alveolar bone level of the distal root of the mandibular second molars in patients with missing L6 and LE treated with second molar protraction.

Patients and methods

Patients

This retrospective study was approved by the Institutional Review Board of Korea University Anam Hospital (IRB 2018AN0333). One hundred and seventy-five treatment records of healthy orthodontic patients whose missing molar or premolar space was orthodontically closed through second molar protraction with the use of TADs between 2003 and 2015 were reviewed for the study. The inclusion criteria were as follows: 1. closure of missing L6 and LE spaces through second molar protraction, 2. impacted mandibular third molars present at the start of treatment, 3. missing space successfully closed through protraction of second molars with the use of TADs, 4. second molar roots aligned in parallel with the adjacent teeth at the time of space closure, 5. third molars erupted and aligned into occlusion, and 6. healthy periodontium at the start of treatment. The exclusion criteria were 1. malformation of the third molar root and 2. generalized periodontitis.

A total of 59 pairs of second and third molars in 51 patients (13 males and 38 females; mean age 19.6 ± 4.7 years) satisfied the inclusion criteria. However, in eight patients who had second molar protraction on both sides, only one side was randomly selected for analysis to ensure that the study variables were independent, resulting in 51 pairs of second and third molars for analysis.

Methods

Panoramic radiographs were collected from each patient at pre-treatment (T1) and after the full eruption and alignment of the third molars following second molar protraction (post-treatment, T2). Nolla's tooth developmental stage was recorded for the impacted third molars at T1. The panoramic radiographs at T1 and T2 were digitized by a single investigator (HBC). For calculation of the magnification rate of the panoramic radiograph, the mesiodistal width of the mandibular second molar of each patient was measured on diagnostic dental casts by using a digital calliper (Mitutoyo, Kawasaki, Japan), and on panoramic radiographs by using the V-Ceph software (version 6.0; Osstem, Seoul, South Korea). The ratios of the size of the second molars on the diagnostic cast to those on the panoramic radiograph were used in the V-Ceph software for panoramic radiograph analysis.

For the periodontal analysis of the mandibular second molar, the cemento-enamel junction (CEJ) of the second molar was identified. The landmarks used were distal CEJ of the second molar (A), mesial CEJ of the second molar (B), the most apical point of mesial alveolar bone (C), and the most apical point of distal alveolar bone (D, Figure 3). At T1, only the measurement of the mesial alveolar bone level of the second molar was feasible because the third molar was impacted and the distal bone of the second molar was not visible on the panoramic radiograph. At T2, alveolar bone level mesial and distal to the second molars and mesial to the third molars was measured.

The horizontal and angular changes of the mandibular second and third molars were measured on the panoramic radiographs at T1 and T2. Figure 4 shows the landmarks and measurements used in this study. First, the occlusal plane (OP) was established by connecting the first premolar cusp tip and second molar distal cusp tip. The mandibular plane (MP) was defined as a line tangent to the mandibular body and crossing the gonion. A line perpendicular to the OP and passing through the intersection of the OP and the anterior ramus (at the J point) was then defined as the vertical reference line (J line). For analysis of tooth position and angulation of the second and third molars, central fossa of the second molar crown (C7), central fossa of the third molar crown (C8), the root

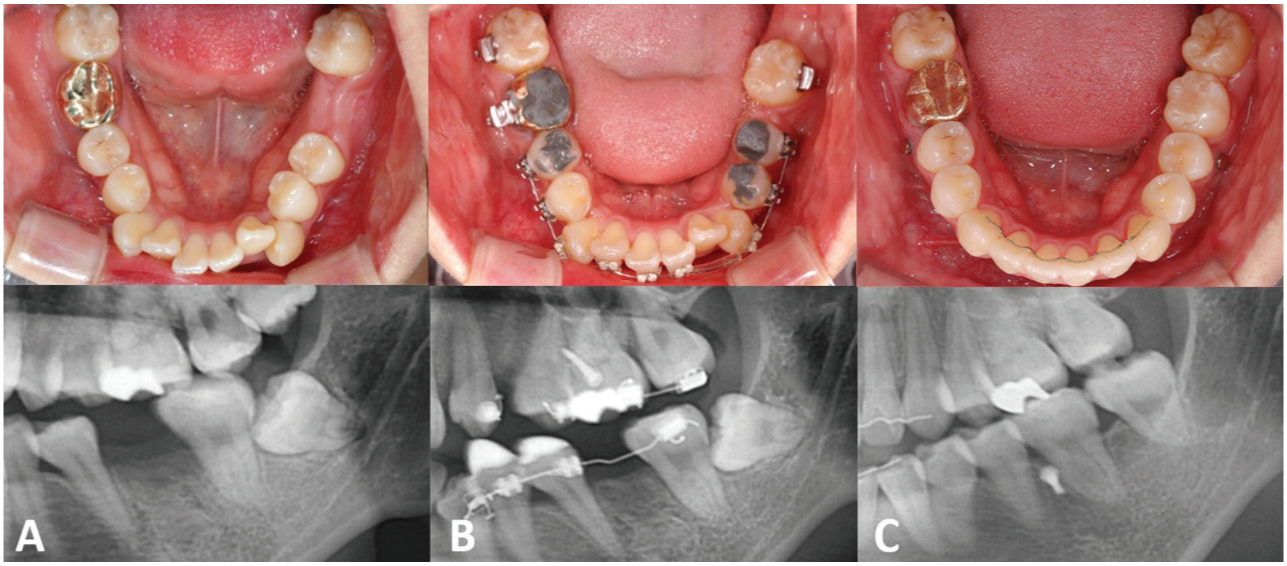

Figure 2. Case with no alveolar bone resorption distal to the mandibular second molar after protraction. (A) Before treatment; (B) during protraction; (C) after treatment.

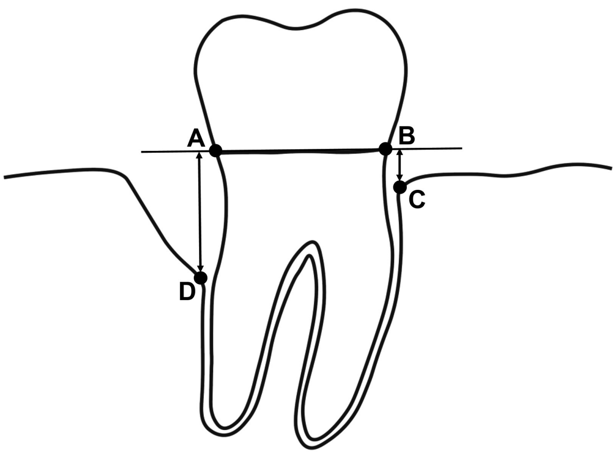

Figure 3. Alveolar bone levels of the mandibular second and third molars. Mesial bone level (mm): shortest distance from the most apical point of the mesial alveolar bone (C) to the CEJ line (AB). Distal bone level (mm): shortest distance from the most apical point of the distal alveolar bone (D) to the CEJ line (AB). CEJ, cemento-enamel junction.

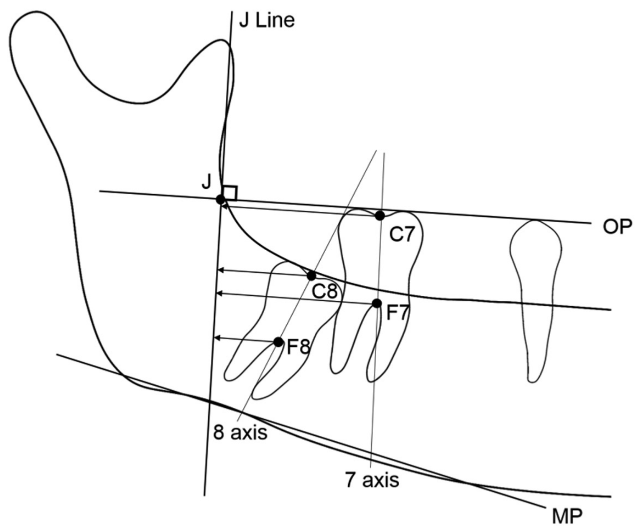

Figure 4. Landmarks and measurements used in this study. OP, occlusal plane constructed by connecting the first premolar cusp tip and the second molar distal cusp tip; MP, mandibular plane constructed by connecting a line tangent to the mandibular body; J point, intersection between the OP and the anterior ramus; J line, vertical reference line perpendicular to the OP and passing through the J point; C7, central fossa of the second molar; C8, central fossa of the third molar; F7, furcation of the second molar; F8, furcation of the third molar; 7 axis, a line connecting C7 and F7; 8 axis, a line connecting C8 and F8; J-C7 (mm), distance between the J line and C7 parallel to the OP; J-F7 (mm), distance between the J line and F7 parallel to the OP; 7-MP (°), angle between the long axis of the second molar and MP; 8-MP (°), angle between the long axis of the third molar and MP; J-C8 (mm), distance between the J line and C8, parallel to the OP; J-F8 (mm): distance between the J line and F8, parallel to the OP.

furcation of the second molar (F7), and the root furcation of the third molar (F8) were identified (Figure 4). Measurements on the panoramic radiographs were as follows: 1. horizontal changes in the second and third molars measured at the crown and root furcation (J-C7, J-F7, J-C8, J-F8), 2. angular changes of the second and third molars (7-MP, 8-MP), and 3. alveolar bone level change of the second and third molars. All measurements were performed twice by the same investigator (HBC) 4 weeks after the first measurement.

Measurement error

For analysis of the intra-investigator reliability, intra-class correlation coefficient ranged from 0.842 (alveolar bone level mesial to the third molar at T2) to 0.997 (third molar angulation at T1). There was no systemic error. Random error ranged from 0.05 to 0.37 mm.

Statistical analysis

Descriptive statistics were used for mean and standard deviation of study variables. Mann–Whitney *U*-tests were used to test the difference in age and Nolla's developmental stage of third molars between male and female patients at T1. Fisher's exact test was used to

Table 1. Patient characteristics at pre-treatment (T1). LE, mandibular second premolar with retained deciduous molar; L6, mandibular first molar

		Male (n = 13)	Female (n = 38)	Total (n = 51)	P-value
Age at T1 (y)		18.1 ± 5.3	20.1 ± 4.4	19.6 ± 4.7	0.136*
Nolla's stage† at T1 (n)		6.5 ± 2.4	7.4 ± 2.3	7.2 ± 2.3	0.287*
Missing tooth (n)	LE	3	6	9	0.676**
	L6	10	32	42	

†Nolla's developmental stage of impacted third molar.
*P-value for Mann–Whitney U-test.
**P-value for Fisher's exact test.

Table 2. Changes of tooth positions and angulations of mandibular second and third molars measured from the vertical reference line (J) at pre-treatment (T1), and post-treatment (T2), and changes from T1 to T2. J-C7, distance between the J line and C7 parallel to the OP; J-F7, distance between the J line and F7 parallel to the OP; J-C8 (mm), distance between the J line and C8 parallel to the OP; J-F8 (mm), distance between the J line and F8 parallel to the OP; 7-MP, angle between the long axis of the second molar and MP; 8-MP, angle between the long axis of the third molar and MP. MP, mandibular plane

	T1 (n = 51)	T2 (n = 51)	T2-T1	P-value*
Mesiodistal position				
J-C7 (mm)	15.4 ± 2.9	21.7 ± 3.0	6.3 ± 2.7	<0.001
J-F7 (mm)	13.7 ± 2.9	20.9 ± 3.2	7.2 ± 2.8	<0.001
J-C8 (mm)	6.2 ± 3.1	11.2 ± 3.1	5.0 ± 2.9	<0.001
J-F8 (mm)	2.0 ± 2.8	9.5 ± 3.0	7.4 ± 2.6	<0.001
Angulation				
7-MP (°)	91.5 ± 8.2	99.6 ± 6.3	8.1 ± 7.8	<0.001
8-MP (°)	64.6 ± 22.3	92.0 ± 10.3	27.3 ± 20.8	<0.001

*P-value for paired t-test.

investigate the correlation between missing teeth and gender. Paired t-test was used to assess the changes in tooth position and angulation, and alveolar bone level from T1 to T2. Linear regression analysis was performed to predict the alveolar bone loss in the distal aspect of the mandibular second molar. Alveolar bone level distal to the mandibular second molar was the dependent factor. Patients' age and gender, Nolla's developmental stage of the third molars, and position and angulation of the second and third molars at T1 were considered for inclusion as independent factors. Statistical significance was set at a P-value less than 0.05. IBM SPSS Statistics (version 20.0; IBM Armonk, New York, USA) was used for all statistical analyses.

Results

No significant differences were observed between the two genders in terms of age at T1, Nolla's developmental stage of third molars at T1, and distribution of the missing teeth (Table 1). Nine patients had missing LE and 42 patients had missing L6. The second molar was protracted by 6.3 ± 2.7 mm measured at the crown and 7.2 ± 2.8 mm measured at the root. Consequently, impacted third molars moved mesially by 5.0 ± 2.9 and 7.4 ± 2.6 mm at the crown and root, respectively. Mean second and third molar angulations measured to the MP were 99.6 ± 6.3° and 92.0 ± 10.3°, respectively, at T2 (Table 2).

The alveolar bone level of the second molar at T1 and that of the second and third molars at T2 are displayed in Table 3. The mean distal alveolar bone level of the second molar was 2.0 ± 1.5 mm, measured from the CEJ. However, the alveolar bone level ranged from 0.7 to 8.2 mm, showing great variability among the patients. The mesial alveolar bone level of the third molars was within normal ranges (Table 3).

Table 4 shows the result of linear regression analysis performed to investigate the significant factors for predicting the alveolar bone level of the distal root of the mandibular second molars after protraction. Age at T1 (Age_T1, P < 0.001) and third molar angulation at T1 (8-MP_T1, P = 0.002) were the final independent variables included in the regression model. According to the regression coefficients, increased age and mesially tilted third molars at T1 were associated with greater alveolar bone resorption distal to the mandibular second molar as a result of treatment.

Discussion

As second molar protraction is time-consuming and relatively difficult, this treatment option may be rationalized only when the periodontal health of the protracted second molar is not compromised. Mesial tipping movement has been reported to lead to alveolar bone resorption in the cervical area (18–20). Second molars were protracted by bodily movement by using long lever arms and TADs placed mesial to the missing tooth space. Consequently, the patients showed normal alveolar bone level mesial to the second molars after protraction.

Third molars were impacted with various angulations ranging from 10.9° to 118.8° measured on the MP. As they erupted and the roots aligned in parallel with the adjacent teeth, no alveolar bone defect was observed. However, significant angular bone defect in the distal root area of the second molars was observed in some patients because of the treatment. Out of the 51 patients whose second molars were analysed, 5 patients showed alveolar bone level ranging from 4.1 to 8.2 mm from the CEJ. According to

Table 3. Alveolar bone levels of mandibular second and third molars of the patients at T1 and T2. 7M, alveolar bone level of the mesial root of the mandibular second molar; 7D, alveolar bone level of the distal root of the mandibular second molar; 8M, alveolar bone level of the mesial root of the mandibular third molar; T1, pre-treatment; T2, post-treatment; SD, standard deviation

	n	Mean	SD	Minimum	Maximum
7M_T1 (mm)	51	1.5	0.7	0.5	3.3
7M_T2 (mm)	51	2.0	1.2	0.6	6.4
7D_T2 (mm)	51	2.0	1.5	0.7	8.2
8M_T2 (mm)	51	1.1	0.5	0.4	2.7

Table 4. Prognostic factors for the alveolar bone level distal to the mandibular second molars at post-treatment (7D_T2, mm). T1, pre-treatment; 8-MP, angle between the long axis of the third molar and the mandibular plane; B, regression coefficient; SE, standard error

	B	SE	*P*-value
Age_T1	0.151	0.035	<0.001
8-MP_T1	−0.024	0.007	0.002

the regression analysis, young age and mesially tilted third molars were associated with alveolar bone resorption distal to the second molar after protraction, and gender was not significant as a prognostic factor. Alveolar bone level mesial to the second molar at T1 was not a significant factor for the alveolar bone level distal to the second molar. However, there was a moderate correlation between the alveolar bone levels mesial and distal to the second molar at T2 (correlation coefficient = 0.512, $P < 0.001$). As all patients included in the analysis had normal alveolar bone support with no periodontitis at T1, we may infer that factors associated with the patients' biological response, such as immune system, microbiome, periodontium biotype, and inflammatory response, may have contributed to the alveolar bone changes that occurred as a result of treatment (21–23).

In addition to the patient (host) factor, patients with mesially tilted third molars at T1 were likely to have greater alveolar bone resorption in the distal root of the second molar as a result of protraction. When the third molar was mesially angulated at T1, we observed on the panoramic radiographs that its crown was close to the distal root surface of the second molar, and almost no alveolar bone was visible in the interproximal area between the second and third molars. Although panoramic radiographs have limitations in the assessment of interproximal alveolar bone, we inferred that because of this positional relationship of the two molars, there may have been insufficient alveolar bone at the start of treatment.

Atrophy of edentulous alveolar bone should also be considered a contributing factor for alveolar bone loss. Reportedly, bone resorption may occur when molars are protracted to this edentulous area (24). By contrast, Saga *et al.* (20) reported a case of complete closure of an atrophic mandibular first molar extraction site with second molar protraction and incisor retraction. In this study, in patients with missing first molars, the alveolar ridge height was normal when observed on panoramic radiographs, and patients with missing second premolars had retained deciduous molars. As a result, alveolar bone loss was localized to the distal side of the second molar, indicating that the atrophic alveolar ridge may not have played a major role in these patients. Lindskog-Stokland *et al.* (25) also reported a case series of orthodontic tooth movement into the edentulous ridge areas in which the patients exhibited an increased width of the alveolar process in the area to which the tooth had moved.

Limitations

A limitation of this study was that it used two-dimensional panoramic radiographs, and we could observe only the interproximal bone level. Further three-dimensional analysis using cone beam computed tomography may be warranted to observe alveolar bone levels buccal and lingual to the molars after treatment.

Conclusions

When mandibular second molars were protracted to close the missing space of L6 or LE, and third molars were aligned in occlusion, the alveolar bone level of third molars was within the normal range. However, mandibular second molars may exhibit alveolar bone resorption in the distal root in older patients, and in those with mesially tilted third molars before treatment.

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Conflict of interest

None declared.

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