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
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
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
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 < 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 were protracted by bodily movement by using long lever arms and TADs placed mesial to the missing tooth space. Consequently, the patients showed normal orthodontal health of the protracted second molar is not compromised. 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 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

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 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 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| 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.

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.
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.

**References**

1. Magkavali-Trikka, P., Emmanouilidis, G. and Papadopoulos, M.A. (2018) Mandibular molar uprighting using orthodontic miniscrew implants: a systematic review. Progress in Orthodontics, 19, 1.

2. Welbury, R.R. (2002) Review: autotransplantation of teeth. European Journal of Orthodontics, 24, 216.

3. Mamopoulou, A., Hägg, U., Schröder, U. and Hansen, K. (1996) Agenesis of mandibular second premolars. Spontaneous space closure after extraction therapy: a 4-year follow-up. European Journal of Orthodontics, 18, 589–600.

4. Kravitz, N.D. and Jolley, T. (2008) Mandibular molar protraction with temporary anchorage devices. Journal of Clinical Orthodontics, 42, 351–355; quiz 340.

5. Kyung, S.H., Choi, J.H. and Park, Y.C. (2003) Miniscrew anchorage used to protract lower second molars into first molar extraction sites. Journal of Clinical Orthodontics, 37, 575–579.

6. Nagaraj, K., Upadhyay, M. and Yadav, S. (2008) Titanium screw anchorage for protraction of mandibular second molars into first molar extraction sites. American Journal of Orthodontics and Dentofacial Orthopedics, 134, 583–591.

7. Baik, U.B., Chun, Y.S., Jung, M.H. and Sugawara, J. (2012) Protraction of mandibular second and third molars into missing first molar spaces for a
patient with an anterior open bite and anterior spacing. American Journal of Orthodontics and Dentofacial Orthopedics, 141, 783–795.

8. Baik, U.B., Kim, M.R., Yoon, K.H., Kook, Y.A. and Park, J.H. (2017) Orthodontic uprighting of a horizontally impacted third molar and protraction of mandibular second and third molars into the missing first molar space for a patient with posterior crossbites. American Journal of Orthodontics and Dentofacial Orthopedics, 151, 572–582.

9. Baik, U.B., Kook, Y.A., Bayome, M., Park, J.U. and Park, J.H. (2016) Vertical eruption patterns of impacted mandibular third molars after the mesialization of second molars using miniscrews. The Angle Orthodontist, 86, 565–570.

10. Bayram, M., Ozer, M. and Arici, S. (2009) Effects of first molar extraction on third molar angulation and eruption space. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics, 107, e14–e20.

11. Richardson, M.E. and Dent, M. (1974) Some aspects of lower third molar eruption. The Angle Orthodontist, 44, 141–145.

12. Yavuz, I., Baydaş, B., Ikbal, A., Dağuşuyu, İ.M. and Ceylan, İ. (2006) Effects of early loss of permanent first molars on the development of third molars. American Journal of Orthodontics and Dentofacial Orthopedics, 130, 634–638.

13. Ay, S., Ağar, U., Biçakçi, A.A. and Köşger, H.H. (2006) Changes in mandibular third molar angle and position after unilateral mandibular first molar extraction. American Journal of Orthodontics and Dentofacial Orthopedics, 129, 36–41.

14. De-la-Rosa-Gay, C., Valmaseda-Castellon, E. and Gay-Escoda, C. (2006) Spontaneous third-molar eruption after second-molar extraction in orthodontic patient. American Journal of Orthodontics and Dentofacial Orthopedics, 129, 337–344.

15. Orton-Gibbs, S., Crow, V. and Orton, H.S. (2001) Eruption of third permanent molars after the extraction of second permanent molars. Part I: assessment of third molar position and size. American Journal of Orthodontics and Dentofacial Orthopedics, 119, 226–238.

16. Begtrup, A., Gronastø̑n, H.A., Christensen, I.J. and Kjær, I. (2013) Predicting lower third molar eruption on panoramic radiographs after cephalometric comparison of profile and panoramic radiographs. European Journal of Orthodontics, 35, 460–466.

17. De-la-Rosa-Gay, C., Valmaseda-Castellon, E. and Gay-Escoda, C. (2010) Predictive model of third molar eruption after second molar extraction. American Journal of Orthodontics and Dentofacial Orthopedics, 137, 346–353.

18. Kondo, T., Hotokezaka, H., Hamanaka, R., Hashimoto, M., Nakano-Tajima, T., Arita, K., Kurohama, T., Ino, A., Tominaga, J.Y. and Yoshida, N. (2017) Types of tooth movement, bodily or tipping, do not affect the displacement of the tooth’s center of resistance but do affect the alveolar bone resorption. The Angle Orthodontist, 87, 563–569.

19. Hom, B.M. and Turley, P.K. (1984) The effects of space closure of the mandibular first molar area in adults. American Journal of Orthodontics, 85, 457–469.

20. Saga, A.Y., Maruo, I.T., Maruo, H., Guariza Filho, O., Camargo, E.S. and Tanaka, O.M. (2011) Treatment of an adult with several missing teeth and atrophic old mandibular first molar extraction sites. American Journal of Orthodontics and Dentofacial Orthopedics, 140, 869–878.

21. Singh, A., Goll, G., Kaur, H., Amhmed, M. and Jakhu, H. (2018) Role of osteopontin in bone remodeling and orthodontic tooth movement: a review. Progress in Orthodontics, 19, 18.

22. Hakami, Z., Kitaura, H., Kimura, K., Ishida, M., Sugisawa, H., Ida, H., Jafari, S. and Takano-Yamamoto, T. (2015) Effect of interleukin-4 on orthodontic tooth movement and associated root resorption. European Journal of Orthodontics, 37, 87–94.

23. Mazurova, K., Kopp, J.B., Renkema, A.M., Pandis, N., Katsaros, C. and Fudalej, P.S. (2018) Gingival recession in mandibular incisors and symphysis morphology—a retrospective cohort study. European Journal of Orthodontics, 40, 183–192.

24. Kessler, M. (1976) Interrelationships between orthodontics and periodontics. American Journal of Orthodontics, 70, 154–172.

25. Lindskog-Stokland, B., Hansen, K., Ekestubbe, A. and Wennström, J.L. (2013) Orthodontic tooth movement into edentulous ridge areas—a case series. European Journal of Orthodontics, 35, 277–285.