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Tancan Uysal,

Accept :

Congratulations! We are pleased to inform you that your manuscript, `Evaluation of Alveolar Bone Loss Following Rapid Maxillary Expansion Using Cone-Beam Computed Tomography`, has been accepted for publication. Soon, the editorial process will begin with more detailed attention to the text body, followed by the “File Upload for Final Editing” step where the preliminarily edited version of your article will be uploaded for further revision. Please note that it is the Editorial Review Board that makes the final decision on the publication status of any manuscripts submitted to The Korean Journal of Orthodontics. Meanwhile, you may be contacted regarding the use of color prints for figures, tables, graphs, and photographs if used in the manuscript. Once again, we thank you for your submission to The Korean Journal of Orthodontics and look forward to hearing from you again.

Sincerely,

- **Manuscript ID** : KJO-12-093
- **Manuscript Title** : Evaluation of Alveolar Bone Loss Following Rapid Maxillary Expansion Using Cone-Beam Computed Tomography

Dear Dr. Tan Can Uysal,

Thank you for your submission entitled “Evaluation of Alveolar Bone Loss Following Rapid Maxillary Expansion Using Cone-Beam Computed Tomography ”. We would like to congratulate you on the acceptance of your article for publication in the KJO. Please refer to the comments made by the reviewers and complete the revisions accordingly. Further information regarding the publication procedures will be forwarded to you via email. We look forward to working with you again in the future.

With warm regards,

Hyoung-Seon Baik, DDS, MS, PhD
Editor in Chief
Korean Journal of Orthodontics

Evaluation of Alveolar Bone Resorption Loss Rapid Maxillary Expansion Using Cone-Beam Computed Tomography

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Running Title: RME and supporting alveolar bone

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Evaluation of Alveolar Bone Loss Following Rapid Maxillary Expansion Using Cone-Beam Computed Tomography

Abstract

Objective: To evaluate the changes on cortical bone thickness, alveolar bone height and the incidence of dehiscence and fenestration in surrounding alveolar bone of posterior teeth after rapid maxillary expansion (RME) treatment using cone-beam computed tomography (CBCT).

Subjects and Methods: CBCT records of twenty-subjects, 9-boys (mean-age:13.97±1.17-year) and 11-girls (mean-age:13.53±2.12-year) that had undergone RME were selected from the archives. CBCTs had been taken before (T1) and after (T2) RME. Also ten of the subjects had six-month retention (T3) records. CBCT images were evaluated from the buccal and palatal aspects for canines, first and second premolars and first molars at 3 vertical levels. Cortical bone-thickness and alveolar bone-height at T1 and T2 was evaluated with paired-samples *t*-test or Wilcoxon signed-rank test. Repeated-measures ANOVA or Friedman-test was used to evaluate the statistical significance at T1, T2 and T3. Statistical significance was set at $p<0.05$.

Results: The buccal cortical bone thickness decreased gradually from baseline to the end of retention period. After expansion, buccal alveolar bone height reduced significantly but this change was not statistically significant after 6-month retention-period. During the course of treatment, percentages of dehiscence were found to be increased and the fenestrations decreased.

Conclusion: RME may have detrimental effects on the supporting alveolar bone as thickness and height of buccal alveolar bone decreased.

Key words: Rapid maxillary expansion, Cone Beam Computed Tomography, Periodontium

INTRODUCTION

During rapid maxillary expansion (RME), heavy orthodontic forces are transmitted to maxilla through teeth,[1] and unfavorable changes may occur in the anchor teeth and their supporting tissues such as buccal crown tipping, root resorption, reduction of buccal bone thickness and marginal bone level.[2-4]

Rungcharassaeng et al.[4] performed a study on CBCT records of 30 subjects taken before and after RME. After RME (within 3 months) buccal crown tipping, reduction of buccal bone thickness and marginal bone level were shown. Kartalian et al.[5] compared 25 patients who underwent RME with age and gender matched controls using cone-beam computed tomography (CBCT) scans. They showed that alveoli tipped, but the teeth did not tip buccally after RME.

Also RME was reported to produce alveolar bone fenestration and/or dehiscence on the buccal aspects of the maxillary teeth.[6-8] Garib et al.[6] investigated the periodontal effects of tooth- and tooth-tissue-borne appliances and they indicated that RME treatment lead to bone dehiscence on the buccal aspects of the anchor teeth. Baysal et al.[9] evaluated root resorption after RME via CBCT and found significant root volume loss for posterior teeth.

To evaluate the osseous support of the teeth, probing of gingival tissues and radiographic methods are mostly preferred.[8] In radiographic method, bitewing and periapical radiographs are widely used.[10] However there are some limitations of radiographic method, such as superimposition of the anatomic structures and difficulty to reproduce the angles over time.[11] Also the destruction of the buccal plate cannot be distinguished from lingual defects.[12] Consequently, it may be stated that conventional radiography is a limited tool for periodontal diagnosis.[13]

Recently, CBCT was introduced for head and neck applications. The main advantage of CBCT is the ability to evaluate the real anatomy without superimposition of the neighboring structures. CBCT and conventional methods were compared by linear measurements of periodontal defects, and the methods were found to be comparable.[14] Also the observation of defects in all three dimensions also should be emphasized.[15]

Although the effects of RME on cortical bone thickness and alveolar bone height were investigated in previous studies[4,5] by means of CBCT, there is no published study that evaluated follow-up period. Therefore the aim of this study was to evaluate the effects on cortical bone thickness and alveolar bone height and to determine the incidence of dehiscence and fenestration after RME including 6-month follow up period. For the purpose of this study, the null hypothesis assumed that there were no significant changes on the cortical bone thickness, alveolar bone height and incidence of dehiscence and fenestration, after RME treatment.

SUBJECTS AND METHODS

The CBCT records of twenty subjects; 9 boys (mean age: 13.97±1.17 years) and 11 girls (mean age: 13.53±2.12 years) were obtained from the archives of the Oral and Maxillofacial Radiology Department, XXX University. All patients fulfilled the following criteria:

- Bilateral cross bite related to maxillary transverse deficiency,
- No history of previous orthodontic treatment,
- No history of systemic disease,
- All maxillary teeth exist and fully erupted except third molars.

All twenty patients had undergone RME with a Hyrax type expander as a part of their orthodontic treatment. The T1 scans were obtained before the placement of appliance, and the T2 scans were obtained right after the end of activation. Of these 20 patients: ten patients had 6-month retention records (T3).

An ethical approval had already been obtained from the Ethical Committee of the XXXX University (DUDFEK 2009/21) for the aims of another study; the patients were not exposed to extra radiation particularly for this retrospective study. Therefore, another ethical approval was not taken.

In our department, the expansion protocol using Hyrax screw is as follows: the appliance consists of an expansion screw welded on the bands on the first premolar and molar teeth. The screw is turned twice a day (one in the morning and one in the evening) until the palatal cusps of upper posterior teeth contact with the buccal cusps of lower posterior teeth. During retention period, the expansion appliance is left in the mouth for the first 3 months, and it is replaced with a transpalatal arch when the expander is removed. Fixed orthodontic treatment was initiated after retention period.

All tomographs were obtained using i-CAT® (Model 17-19, Imaging Sciences International, Hatfield, PA, USA) at the following settings by the same operator: exposures were made with 5.0 mA, 120 kV in 9.6 seconds and the axial slice thickness was 0.3 mm. The patients were positioned sitting upright in the CBCT machine, with one strap placed over the forehead to orient the Frankfort horizontal plane parallel to the floor.

The DICOM (digital imaging and communications in medicine) files were imported into Dolphin 3D (version 10.5, Dolphin Imaging, Chatsworth, CA, USA) for further analysis. With the Dolphin 3D, the orientation of each 3D volumetric data set was standardized by using the Frankfort horizontal line as the x-axis, the transporionic line as the y-axis, and the midsagittal line as the z-axis. The reference planes were defined by using the volumetric rendering view along with the multiple planar views.[16]

All of the cortical bone thickness and buccal alveolar height measurements were performed using Dolphin Imaging 11.0 Premium (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA) on hard tissue segmentation by one author who is blinded to the patient timepoints.

Cortical bone thickness of the maxillary canine, first and second premolars and first molar for left and right segments were measured using axial clipping property of the software. In order to measure these records at three different levels, cross-sections parallel to the Frankfort horizontal line were obtained at the trifurcation point, the middle of the distobuccal root and the apex of the distobuccal root of the right first molar tooth. These levels were defined as furcation, middle and apical cortical bone thickness. To identify the middle and apical thirds of this root length precisely, the length was measured using the program on the coronally clipped image.

The distances between the outer border of the cortical bone and teeth were measured both buccally and palatally; and defined as buccal and palatal cortical bone thickness (BCBT and PCBT, respectively) *(*Figure 1). In the following situations, the method was modified: If the roots of the upper premolars are shorter than the distobuccal roots of the first molars, the distances between the outer bone plate and the nearest point to the premolar apices were measured. When the maxillary sinuses span around the roots of the teeth, the distance between the apices and the sinus wall was accepted as zero. In case of tooth rotation, the thickness was evaluated using the nearest point of the root to the bone plate.

The other measurement was the buccal alveolar height (BAH) of the maxillary posterior teeth. Using the coronal clipping property of the program, the distance between the cusp tips of the posterior teeth and the buccal alveolar crest were determined separately for the right and left sides (Figure 2). For the first molar teeth, the buccal crest level was determined from the mesiobuccal, middle and distobuccal aspects of the teeth.

The presence of dehiscence and fenestration was evaluated on iCAT software program according to the method described by Evangelista et al.[17] (Figure 3 and Figure 4). Axial inclination of the tooth was placed perpendicular to the horizontal plane and the total root length was evaluated in cross-sectional slices at the buccal and palatal surfaces. Images that showed no cortical bone around the tooth at least 3 consecutive views were recorded as having dehiscence or fenestration. The defect was classified as fenestration when the defect did not involve the alveolar crest. When the alveolar crest is more than 2 mm from the cemento-enamel junction, this defect was recorded as dehiscence.[18]

Statistical Analysis

All statistical analyses were performed with the statistical package for social sciences (SPSS), 16.0 (SPSS Inc, Chicago, IL, USA). The normality test of Shapiro–Wilks and Levene's variance homogeneity test were applied to the data. When the data were normally distributed, a paired *t*-test was used. If the data were not normally distributed, a Wilcoxon Signed rank test was used to compare the mean values between the T1 and T2 measurements. Repeated measures ANOVA with Bonferroni correction was used for the data that is normally distributed and Friedman tests were used when the data were not normally distributed for the statistical evaluation of pre-expansion, post-expansion and 6-month follow up data. Statistical significance was set at $p<0.05$. Arithmetic mean and standard deviation values were calculated for all measurements.

To determine the errors associated with CBCT measurements, 15 tomographs were selected randomly and their measurements were repeated 4 weeks after the first measurements by the same examiner. Intraclass correlation coefficients were applied to the same measurements and found higher than 0.90, indicating that the reliability of all measurements was clinically acceptable.

RESULTS

Comparison of BCBT and PCBT measurements before and after RME treatment was shown in Table 1. Except the apical region of left first and second premolar, right molar's mesial apical, and right canine middle part; decrease in the BCBT was observed at three level for all investigated teeth. For the right canine and premolar teeth, the decrease in BCBT was statistically significant at the furcation level; whereas this was not statistically significant for the counterparts. For the second premolar teeth, the decrease in the middle part was statistically significant both for the left and right segments. First molar mesial and distal roots were more severely affected. For the left segment, decrease in BCBT was statistically significant for middle and apical levels; whereas for the right segment, statistically significant difference was found for the middle and furcation levels.

When the PCBT measurements were evaluated, a decrease was noted in general. But the decrease was not symmetrical for the left and right segments. For the canine and second premolar teeth, there was a decrease in the left side, but an increase at the right side for the middle and apical levels.

Comparison of BAH measurements before and after RME procedure was shown in Table 2. BAH measurements of all investigated posterior teeth were increased. These differences were found statistically significant, except for the left molar midfurcation level. This indicates that vertical alveolar height decreased immediately after expansion period.

Descriptive statistics of BCBT and PCBT measurements and statistical comparison of these values at T1, T2 and T3 time periods were shown in Table 3. Except the left canine furcation level, BCBT measurement decreased at three levels, from the baseline to the end of 6-month follow-up period. At furcation level of left and right canine, right premolar and right molar; no significant increase in BCBT was found during retention period (T2-T3). For the other levels, gradual decreases were found from T2 to T3. For the apical part of the canine tooth, a dramatic decrease in BCBT was observed which was statistically significant during T1-T3 and T2-T3 time periods. For the left premolar and molar teeth, no significant decreases were determined for the furcation level. Interestingly, for the right segment no significant difference was recorded for the first premolar teeth. The only statistically significant difference at the furcation level during T1-T3 and T2-T3 time periods was recorded for right second premolar teeth. The decrease at the furcation level of mesial and distal roots of first molar, the difference was statistically significant at T2 and recovered at T3.

The PCBT decreases were found statistically significant at the apical level for all teeth except left first premolar. The decreases were statistically significant for the right molar teeth at furcation (T1-T3), middle (T2-T3) and apical (T2-T3) levels.

Comparisons of the BAH measurements baseline to 6-month follow-up were shown in Table 4. The increase in BAH measurement during treatment period (T1-T2) was found statistically significant for the right canine tooth (p= 0.016). The changes in T1-T3 period for left second premolar and right molar distobuccal level was statistically significant (p= 0.038 and p= 0.035, respectively). No statistically significant difference was found between T2-T3 periods.

The incidence of alveolar defects in 20 patients before and after RME procedure was shown in Table 5. In Table 6, the incidence of baseline, post-treatment and post-retention alveolar defects in 10 patients were presented. In general, the incidence of dehiscence is greater than the baseline values after RME procedure. The percentage of fenestrations decreased after treatment.

Because the RME treatment has statistically significant effects on the surrounding alveolar bone, the null hypothesis of this study was rejected.

DISCUSSION

RME is a common clinical procedure to correct maxillary constriction and arch length discrepancy.[4] In adolescents, 65% of total expansion was shown to be the result of dental movement[19] and it may be thought that RME may have detrimental effects on the teeth and their supporting tissues.

CBCT scanning provides information for RME, not obtainable from other methods especially from periodontal perspective. As this study was designed as a retrospective research and by considering the As Low As Reasonably Achievable (ALARA) principle, individuals had not been exposed to extra radiation other than patients' needs for orthodontic treatment. Also an informed consent form signed by patients' parents, doctor and technician has to be obtained from every patient that goes under CBCT scanning in our university protocol.

According to the study of Ekström et al.[20] the mineralization of midpalatal suture completed 3 months after the RME treatment. They advocate a retention period of 3 to 6 months for a good long-term stability. In the current study, 6-month retention records were obtained from the archive and used, as this period was thought to be enough for the adaptation of hard and soft tissues.

The force generated by the activation of the appliance initially leads to compression of the periodontal ligament, bending of the alveolar bone and tipping of the anchor teeth. Then, gradual opening of the midpalatal suture occurs.[21] Hicks[22] found that the angulation between the right and left molars was increased from 1° to 24° during expansion. These changes are due to the alveolar bending and tipping of the posterior teeth in alveolar bone. Conversely, Kartalian et al.[5] showed no statistically significant dental tipping after RME. Hence it may be stated that RME results in tipping of maxillary posterior teeth. In this study, buccal alveolar crest level lowered in all investigated teeth immediately after RME. These changes may be attributed to the tipping of maxillary posterior teeth and tipping movement may lead to resorption of the crestal alveolar bone. This finding is in accordance with previous studies.[23,24]

After retention period, the alveolar bone heights did not change but the buccal cortical bone continued to decrease, in general. According to Barber and Sims,[25] the residual loads may cause the alveolar bone to be compressed toward the buccal aspect of anchor teeth which held rigidly by the expansion devices used as retainers. Cotton[26] stated that post-expansion angular changes of the maxillary molars might be due to stretched fibers of the attached palatal mucosa. Thus, the roots of the posterior teeth may move towards buccally and the thickness of the buccal cortical bone may continue to decrease.

In the palatal portion of the tooth, there was a trend toward increase in PCBT measurements after active phase of RME. This finding is attributed to the buccal tipping of the posterior teeth, which increases the distance between palatal cortical plate and the root surfaces. On the other hand, the decreases in PCBT in retention period may show the compensatory resorption under periosteum. By this way, the thickness of the bone kept. Sarikaya et al.[27] showed compensatory resorption under buccal periosteum when the maxillary incisors were retracted.

Because of the considerable force needed to break the median palatine suture during RME, an evaluation of the periodontal structures, including alveolar bone and gingival biotype, is an important approach for the procedure.[17] Evangelista et al.[17] compared the presence of alveolar defects (dehiscence and fenestration) in patients with different malocclusions. They found that the maxillary canines and first premolars showed high prevalence of dehiscences. This offers an important sign to the treatments involving RME, since the first premolars, and sometimes the canines, are the supporting teeth for orthopedic devices. In the current study, the incidence of dehiscences on buccal surface of posterior teeth varied between 2.5% and 55%. Additionally, this incidence increased during the use of tooth-borne RME appliance (range: 10%-72.5%). We think that the effects of dental inclination and decrease in alveolar bone height are associated with these alveolar defects.

Wainwright [7] showed that when the apex of a tooth is moved facially, cortical bone penetration occurs. This penetration is closed with bone deposition on the buccal surface if the apex of the tooth is moved to the opposite direction and retained in that position. Also a fenestration may turn to a dehiscence. [28] In this study, the number of dehiscence increased and fenestration decreased after RME. The fact that a fenestration turns to a dehiscence may explain the increases. Although a general increase was shown in the percentages of these alveolar defects for the buccal surface of the first molar teeth, the alveolar defect percentage decreased. This decrease is attributed to the horizontal bone loss.

The least amount of alveolar defects was found in the second premolars. It is logical to find greater alveolar defects in the first premolar and molar teeth, as they were anchor teeth. Although the canines were not anchor tooth, initial supra-alveolar position of these teeth might cause dehiscence at the buccal surfaces and these might not recover.

In the present study, CBCT scans were used to evaluate the alveolar defects. As we can measure the bone around the teeth accurately by means of axial and cross-sectional sections, alveolar bone measurements and bone defects may be judged by CBCT. Leung et al.[29] evaluated the accuracy and reliability of CBCT for measuring alveolar bone height and alveolar defects. They correlated direct and indirect (CBCT) measurements. The correlation coefficient with direct and CBCT measurements was 0.870 for bone margin measurements. On the other hand, detection of fenestrations and dehiscence was more prone to error. For dehiscence, both sensitivity and specificity were about 0.80. The diagnosis of alveolar defects using CT, such as dehiscence and fenestration, depends on length, thickness of the alveolar cortical plate, and visualization of the periodontal ligament space.[17] Fuhrmann et al.[30] observed that, when cortical thickness is less than 0.5 mm, the CBCT scan is relatively accurate. Because these are so small measurements and the scoring of these thicknesses as defect could be a limitation of our study.

Another limitation of this study is the small sample size. To overcome this limitation, the same author performed all measurements and the high accuracy of quantitative measurements on CBCT images enhances the reliability of the outcomes and makes the small sample size acceptable. Furthermore, in order to prevent the underestimation of p-values, repeated measures ANOVA which is, much more powerful than independent ANOVA, was used. Future studies with large sample size are needed for further evaluation.

CONCLUSION

Within the limitation of this study following conclusion can be drawn:

- RME may have detrimental effects on the supporting alveolar bone as thickness and height of buccal alveolar bone were decreased.
- The greater dehiscence formation may support these findings.

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Figure Legends

Figure 1. Buccal cortical bone thickness (BCBT) and palatal cortical bone thickness (PCBT) at the level of the trifurcation of the first molar.

Figure 2. Buccal alveolar height (BAH: distance between the cusp tip and the buccal alveolar crest) of the maxillary first molar.

Figure 3. The presence of dehiscence at 3 consecutive views.

Figure 4. The presence of fenestration at 3 consecutive views.

Figure 5. An example of decrease in BCBT measurement of maxillary right molar.

Figure 6. An example of increase in BAH measurement of maxillary left molar.

Figure 7. An example of treatment changes; palatal cortical bone thickness increased after active expansion and decreased at the end of retention.

Table 1: Buccal and palatal cortical bone thickness measurements before and after rapid maxillary expansion procedure (20 patients)

		Left Segment								Right Segment						
Measurement Region	**n**	**Before expansion (T1)**		**After expansion (T2)**		**Change (T1-T2)**		***p-value***	**n**	**Before expansion (T1)**		**After expansion (T2)**		**Change (T1-T2)**		***p-value***
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
BCBT																
Canine																
Furcation	**20**	0,24	0,43	0,00	0,00	0,24	0,43	0,018	**20**	0,21	0,35	0,08	0,27	0,13	0,33	NS
Middle	**20**	0,68	0,60	0,71	0,72	0,03	0,56	NS	**20**	0,37	0,41	0,41	0,61	-0.04	0,62	NS
Apical	**20**	1,86	0,85	1,90	1,21	0,04	1,09	NS	**20**	1,77	0,8	1,47	0,88	0,30	0,82	NS
First premolar																
Furcation	**20**	0,96	0,44	0,51	0,68	0,45	0,76	0,016	**20**	0,61	0,48	0,49	0,59	0,13	0,81	NS
Middle	**20**	0,88	0,46	0,77	0,82	0,11	0,65	NS	**20**	1,00	0,59	0,64	0,57	0,35	0,71	NS
Apical	**20**	0,85	0,74	0,88	0,84	-0.03	0,72	NS	**20**	0,69	0,47	0,7	0,74	0,00	0,58	NS
Second premolar																
Furcation	**20**	1,52	0,45	1,19	0,70	0,33	0,83	NS	**20**	1,65	0,51	1,35	0,64	0,31	0,74	NS
Middle	**20**	1,93	0,54	1,50	0,58	0,42	0,44	p<0.001	**20**	1,95	0,54	1,24	0,72	0,71	0,71	p<0.001
Apical	**20**	1,65	0,55	1,95	0,75	-0.30	0,83	NS	**20**	1,93	0,81	1,57	0,51	0,36	1,09	NS
First molar-mesial																
Furcation	**20**	0,77	0,50	0,45	0,69	0,31	0,78	NS	**20**	1,14	0,49	0,56	0,54	0,57	0,61	p<0.001
Middle	**20**	1,31	0,90	0,67	0,83	0,65	0,85	0,002	**20**	1,41	0,65	0,79	0,66	0,62	0,68	0,003
Apical	**20**	1,91	1,27	1,33	1,27	0,59	0,77	0,002	**20**	2,03	1,19	2,05	1,29	-0.20	0,85	NS
First molar-distal																
Furcation	**20**	1,27	0,35	1,13	0,78	0,14	0,80	NS	**20**	1,62	0,45	1,01	1,01	0,61	0,38	p<0.001
Middle	**20**	1,83	0,86	1,28	1,01	0,55	0,89	0,009	**20**	1,95	1	1,21	0,98	0,74	0,37	p<0.001
Apical	**20**	2,96	1,72	2,37	1,54	0,59	1,08	0,030	**20**	2,71	1,63	2,4	1,77	0,31	1,18	NS

Table 1: Buccal and palatal cortical bone thickness measurements before and after rapid maxillary expansion procedure (20 patients) **(cont.)**

	Left Segment								Right Segment							
Measurement Region	**n**	**Before expansion (T1)**		**After expansion (T2)**		**Change (T1-T2)**		***p-value***	**n**	**Before expansion (T1)**		**After expansion (T2)**		**Change (T1-T2)**		***p-value***
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**			**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
PCBT																
Canine																
Furcation	**20**	1,99	0,91	1,81	0,88	0,18	0,69	NS	**20**	2,19	0,99	2,38	0,9	-0.19	0,99	NS
Middle	**20**	2,12	0,90	2,18	0,95	-0.06	0,79	NS	**20**	2,70	0,93	2,2	0,79	0,49	0,66	0,001
Apical	**20**	4,19	1,31	4,44	1,25	-0.25	1,28	NS	**20**	5,22	1,89	4,66	1,65	0,56	1,75	NS
First premolar																
Furcation	**20**	1,32	0,95	1,59	1,11	-0.28	1,03	NS	**20**	1,22	0,47	1,76	0,85	-0.54	0,85	0,013
Middle	**20**	1,64	1,01	1,78	1,25	-0.13	1,00	NS	**20**	1,68	0,68	2,02	0,88	-0.34	0,75	NS
Apical	**20**	3,84	1,92	2,73	1,55	1,11	1,42	0,002	**20**	3,76	1,63	4,28	1,69	-0.52	1,39	NS
Second premolar																
Furcation	**20**	1,87	0,60	1,91	0,67	-0.04	0,53	NS	**20**	1,67	0,47	1,81	0,58	-0.14	0,58	NS
Middle	**20**	1,92	0,64	2,26	0,67	-0.34	0,73	0,043	**20**	2,06	0,49	2,06	0,81	0,00	0,65	NS
Apical	**20**	3,78	1,89	4,47	1,96	-0.69	1,83	NS	**20**	5,31	1,12	4,5	1,85	0,81	2,09	NS
First molar																
Furcation	**20**	1,19	0,40	1,64	0,54	-0.45	0,51	0,002	**20**	1,58	0,58	1,5	0,7	0,75	0,6	NS
Middle	**20**	1,35	0,39	1,53	0,47	-0.17	0,52	NS	**20**	1,20	0,44	1,65	0,56	-0.44	0,51	0,001
Apical	**20**	2,01	1,07	1,34	0,60	0,67	1,23	0,025	**20**	1,60	0,6	1,89	0,87	-0.29	0,77	NS

Table 2. Buccal alveolar height measurements before and after rapid maxillary expansion

Measurement Region	Left Segment								Right Segment							
	n	Before Expansion		After Expansion		Change (T1-T2)		*p*	n	Before Expansion		After Expansion		Change (T1-T2)		*p*
		Mean	SD	Mean	SD	Mean	SD			Mean	SD	Mean	SD	Mean	SD	
Canine	**20**	11.96	0.94	12.89	1.29	-0.93	0.99	0.001	**20**	11.53	1.24	12.35	1.51	-0.82	1.01	0.002
First premolar	**20**	9.48	0.74	10.81	1.61	-1.32	1.64	0.002	**20**	9.32	1.18	10.46	1.32	-1.13	1.51	0.003
Second premolar	**20**	8.8	1.23	9.94	1.67	-1.14	1.45	0.002	**20**	8.51	0.91	9.49	1.17	-0.97	1.15	0.001
First molar																
Distobuccal	**20**	8.78	0.74	9.18	0.81	-0.4	0.83	0.045	**20**	9.24	0.68	10.15	0.86	-0.91	0.85	p<0.001
Midfurcation	**20**	8.84	0.8	9.06	0.79	-0.22	0.8	NS	**20**	8.71	0.70	9.44	0.88	-0.73	0.61	p<0.001
Mesiobuccal	**20**	9.02	1.07	10.45	1.55	-1.42	1.7	0.001	**20**	9.28	0.72	10.11	0.86	-0.82	0.73	p<0.001

Table 3. Comparison of buccal and palatal cortical bone thickness measurements before, after rapid maxillary expansion procedure and following 6-month retention period.

Left Segment

Measurement Region	n	Before expansion (T1)		After expansion (T2)		After Retention (T3)			*p-value (T1-T2)*	*p-value (T1-T3)*	*p-value (T2-T3)*
		Mean	SD	Mean	SD	Mean	SD				
BCBT											
Canine											
Furcation	10	0.140	0.290	p<0.001	p<0.001	0.240	0.510	NS			
Middle	10	0.600	0.630	0.700	0.760	0.140	0.440	NS			
Apical	10	1.930	1.040	1.920	1.400	0.520	0.750	0.004	NS	0.034	0.037
First premolar											
Furcation	10	0.950	0.410	0.790	0.750	0.630	0.650	NS			
Middle	10	1.080	0.510	1.110	0.840	0.200	0.290	0.001	NS	0.005	0.020
Apical	10	0.960	0.690	1.250	0.860	0.410	0.470	NS			
Second premolar											
Furcation	10	1.530	0.420	1.530	0.690	0.970	0.670	NS			
Middle	10	2.190	0.560	1.770	0.490	1.040	0.770	0.008	0.024	0.020	NS
Apical	10	1.630	0.650	2.150	0.610	0.900	0.840	0.001	NS	NS	0.004
First molar-mesial											
Furcation	10	0.800	0.410	0.500	0.760	0.450	0.490	NS			
Middle	10	1.230	0.860	0.870	0.880	0.550	0.490	0.018	NS	0.011	NS
Apical	10	1.880	1.390	1.420	1.410	0.950	1.070	NS			
First molar-distal											
Furcation	10.1	1.290	0.320	1.190	0.670	1.100	0.580	NS			
Middle	10	1.830	0.860	1.430	1.120	1.180	0.830	0.008	NS	0.015	NS
Apical	10	3.100	1.850	2.380	1.810	1.290	1.010	0.000	NS	0.002	NS
PCBT											
Canine											
Furcation	10	2.250	0.840	2.110	1.010	1.740	0.810	NS			
Middle	10	2.130	1.060	2.620	0.900	1.880	0.960	NS			
Apical	10	4.250	1.100	4.690	1.470	2.120	0.950	p<0.001	NS	p<0.001	0.001
First premolar											
Furcation	10	1.130	0.950	1.730	1.320	1.450	0.760	NS			
Middle	10	1.780	1.390	1.790	1.450	1.740	0.990	NS			
Apical	10	3.400	2.270	2.340	1.830	1.550	1.180	NS			
Second premolar											
Furcation	10	1.750	0.550	1.870	0.790	1.260	1.200	NS			
Middle	10	2.030	0.490	2.220	0.790	1.290	0.970	NS			
Apical	10	3.370	2.010	3.870	1.830	1.570	1.440	0.004	NS	NS	0.018
First molar											
Furcation	10	1.150	0.460	1.500	0.610	1.010	0.750	NS			
Middle	10	1.230	0.450	1.500	0.360	1.020	0.660	NS			
Apical	10	2.170	1.180	1.440	0.500	0.720	0.520	0.013	NS	0.039	0.045

Right Segment

Measurement Region	n	Before expansion (T1)		After expansion (T2)		After Retention (T3)			*p-value (T1-T2)*	*p-value (T1-T3)*	*p-value (T2-T3)*
		Mean	SD	Mean	SD	Mean	SD				
BCBT											
Canine											
Furcation	10	0.300	0.480	0.000	p<0.001	0.100	0.310	NS			
Middle	10	0.400	0.510	0.380	0.640	0.100	0.310	NS			
Apical	10	2.200	0.630	1.670	0.960	0.150	0.330	p<0.001	NS	p<0.001	0.001
First premolar											
Furcation	10	0.690	0.510	0.330	0.350	0.380	0.470	NS			
Middle	10	1.040	0.530	0.650	0.510	0.590	0.920	NS			
Apical	10	0.700	0.360	0.700	0.740	0.480	0.680	NS			
Second premolar											
Furcation	10	1.750	0.490	1.620	0.690	0.620	0.580	0.001	NS	0.004	0.008
Middle	10	2.040	0.470	1.550	0.730	0.710	0.740	p<0.001	NS	0.003	0.013
Apical	10	1.550	0.790	1.720	0.320	0.910	0.790	0.015	NS	NS	0.018
First molar-mesial											
Furcation	10	1.900	0.480	0.380	0.530	0.460	0.570	0.003	0.002	NS	NS
Middle	10	1.450	0.550	0.750	0.760	0.450	0.500	p<0.001	0.008	0.001	NS
Apical	10	1.900	1.170	1.760	1.150	0.690	0.700	0.002	NS	0.036	0.033
First molar-distal											
Furcation	10	1.540	0.520	0.860	0.620	1.160	0.670	0.013	0.002	NS	NS
Middle	10	2.020	1.320	1.240	1.210	1.060	0.680	0.019	p<0001	NS	NS
Apical	10	2.580	1.810	2.560	2.300	1.360	1.040	0.020	NS	0.024	NS
PCBT											
Canine											
Furcation	10	1.900	1.100	2.430	1.100	2.330	1.060	NS			
Middle	10	2.400	0.960	2.020	0.870	1.710	0.980	NS			
Apical	10	4.400	1.430	4.530	1.560	2.120	0.910	p<0.001	NS	0.002	0.002
First premolar											
Furcation	10	1.020	0.460	1.440	0.810	1.680	0.960	NS			
Middle	10	1.320	0.590	1.730	0.970	1.450	1.100	NS			
Apical	10	3.440	1.720	4.170	1.750	1.540	1.370	0.005	NS	NS	0.032
Second premolar											
Furcation	10	1.370	0.470	1.690	0.390	1.400	0.810	NS			
Middle	10	1.760	0.410	1.800	0.700	1.190	0.890	NS			
Apical	10	5.140	1.050	4.830	1.480	1.860	1.070	p<0.001	NS	0.001	0.010
First molar											
Furcation	10	1.480	0.340	1.580	0.650	0.920	0.340	0.020	NS	0.047	NS
Middle	10	1.000	0.420	1.490	0.700	0.750	0.240	0.010	NS	NS	0.070
Apical	10	1.390	0.600	2.010	1.070	0.770	0.490	0.002	NS	NS	0.023

Table 4. Comparison of buccal alveolar height measurements before and after rapid maxillary expansion and following 6 months observation period.

Measurement Region	Left Segment n	Before Expansion		After Expansion		After Retention			*p*-value			Right Segment n	Before Expansion		After Expansion		After Retention			*p*-value		
		Mean	SD	Mean	SD	Mean	SD		*T1-T2*	*T1-T3*	*T2-T3*		Mean	SD	Mean	SD	Mean	SD		*T1-T2*	*T1-T3*	*T2-T3*
Canine	10	11.850	1.040	12.940	1.590	13.070	2.100	NS				10	11.700	1.220	12.720	1.660	12.640	1.740	0.008	0.016	NS	NS
First premolar	10	9.480	0.520	11.070	2.020	10.830	2.010	NS				10	9.260	1.050	10.540	1.530	10.310	1.910	NS			
Second premolar	10	8.300	1.230	9.480	2.010	10.260	2.010	0.020	NS	0.038	NS	10	8.260	1.060	9.270	1.460	9.560	1.170	NS			
First molar																						
Distobuccal	10	9.020	0.860	9.150	1.080	9.360	0.870	NS				10	9.250	0.730	9.800	1.010	9.970	0.990	0.012	NS	0.035	NS
Midfurcation	10	9.000	1.040	8.820	0.780	9.270	1.050	NS				10	8.580	0.790	9.220	1.140	9.140	0.870	NS			
Mesiobuccal	10	9.110	0.950	9.890	1.260	9.690	0.970	NS				10	9.340	0.870	10.100	1.070	10.250	1.120	NS			

Table 5. Incidence of alveolar defects in 20 patients before and after rapid maxillary expansion procedure.

Measurement Region	Total Surface Number	Before Treatment				After Treatment			
		Dehisence		Fenestration		Dehisence		Fenestration	
		n	%	n	%	n	%	n	%
Canine									
Buccal	40	22	55.0	3	7.5	29	72.5	2	5.0
Palatal	40	1	2.5	0	0.0	3	7.5	0	0.0
First premolar									
Buccal	40	1	2.5	11	27.5	23	57.5	8	20.0
Palatal	40	1	2.5	1	2.5	0	0.0	0	0.0
Second premolar									
Buccal	40	1	2.5	1	2.5	4	10.0	2	5.0
Palatal	40	0	0.0	0	0.0	5	12.5	0	0.0
First molar									
Buccal	40	2	5.0	9	22.5	26	65.0	6	15.0
Palatal	40	5	12.5	8	20.0	9	22.5	1	2.5

Table 6. Incidence of alveolar defects in 10 patients before and after rapid maxillary expansion procedure and following observation period.

Measurement Region	Total Surface Number	Before Treatment				After Treatment				After Observation			
		Dehisence		Fenestration		Dehisence		Fenestration		Dehisence		Fenestration	
		n	%	n	%	n	%	n	%	n	%	n	%
Canine													
Buccal	20	14	70.0	1	5.0	15	75.0	1	5.0	19	95.0	0	0.0
Palatal	20	1	5.0	0	0.0	2	10.0	0	0.0	8	40.0	0	0.0
First premolar													
Buccal	20	1	5.0	3	15.0	11	55.0	4	20.0	13	65.0	3	15.0
Palatal	20	1	5.0	0	0.0	0	0.0	0	0.0	3	15.0	0	0.0
Second premolar													
Buccal	20	0	0.0	0	0.0	0	0.0	0	0.0	1	5.0	1	5.0
Palatal	20	0	0.0	0	0.0	4	20.0	0	0.0	0	0.0	0	0.0
First molar													
Buccal	20	2	10.0	6	30.0	12	60.0	3	15.0	8	40.0	2	10.0
Palatal	20	3	15.0	6	30.0	7	35.0	0	0.0	8	40.0	1	5.0

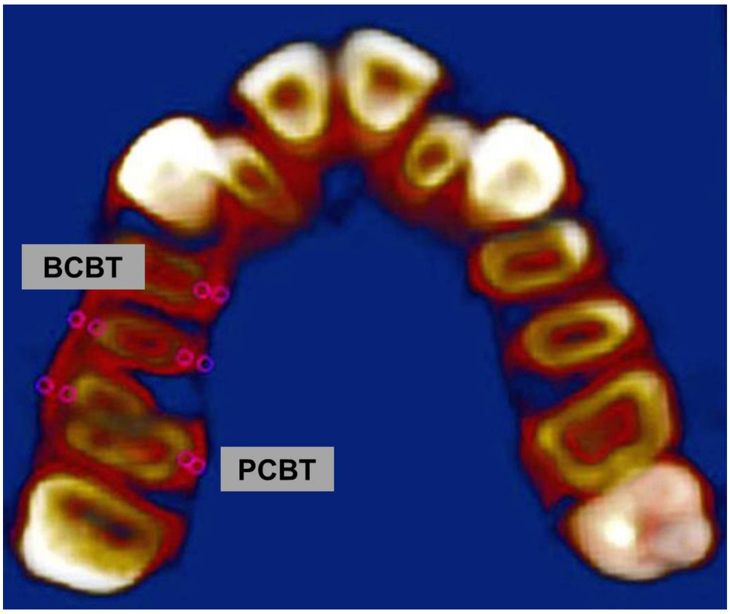

Figure 1. Buccal cortical bone thickness (BCBT) and palatal cortical bone thickness (PCBT) at the level of the trifurcation of the first molar.

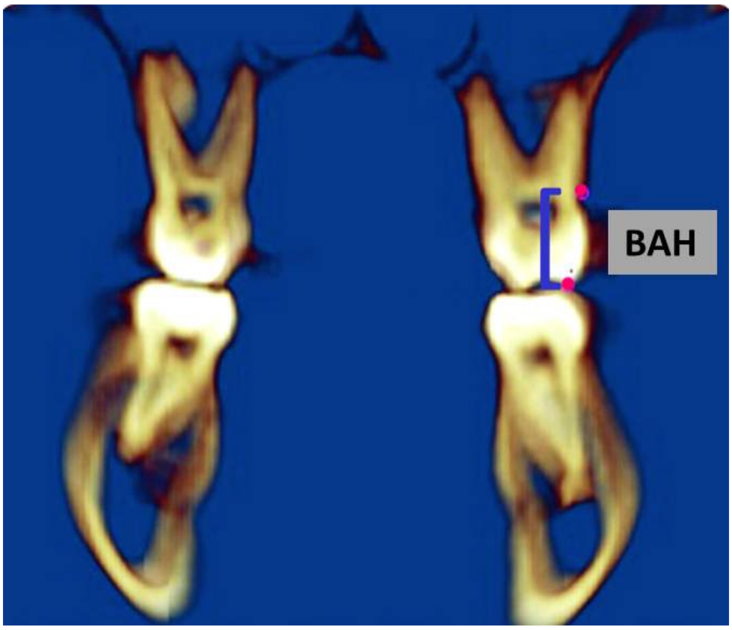

Figure 2. Buccal alveolar height (BAH: distance between the cusp tip and the buccal alveolar crest) of the maxillary first molar.

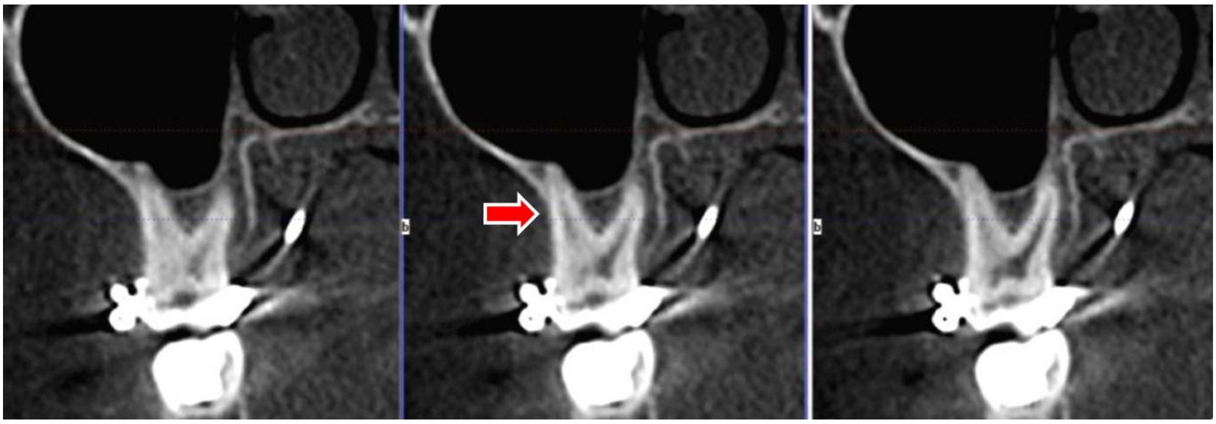

Figure 3. The presence of dehiscence at 3 consecutive views.

Figure 4. The presence of fenestration at 3 consecutive views.

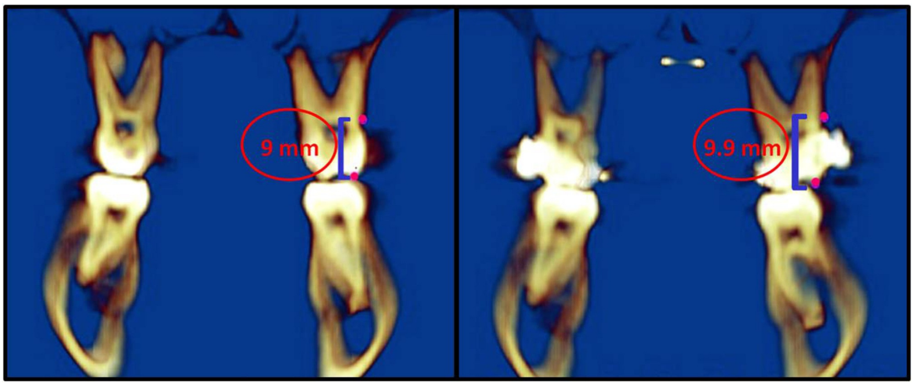

Figure 5. An example of decrease in BCBT measurement of maxillary right molar.

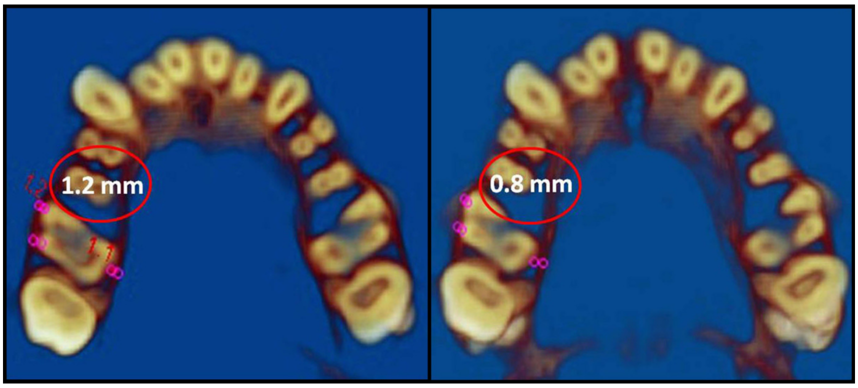

Figure 6. An example of increase in BAH measurement of maxillary left molar.

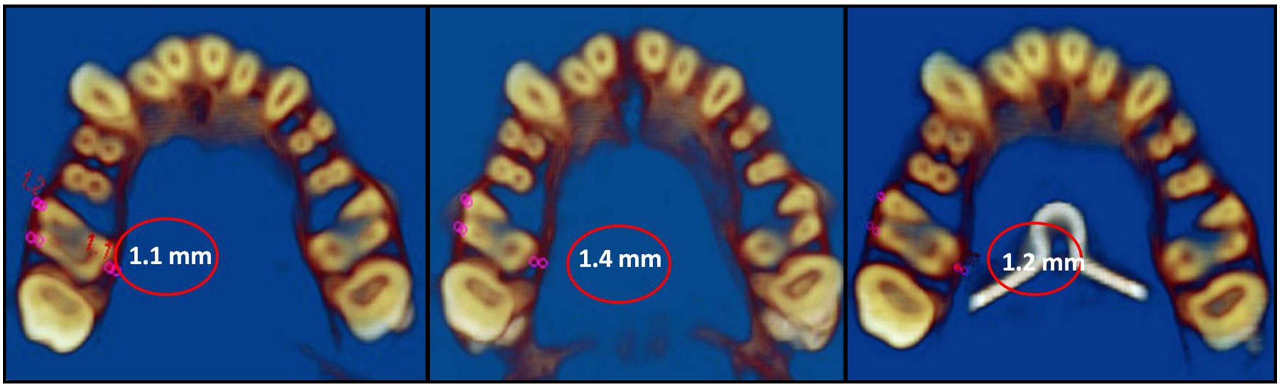

Figure 7. An example of treatment changes; palatal cortical bone thickness increased after active expansion and decreased at the end of retention.