Original Article

Bone dehiscence formation during orthodontic tooth movement through atrophic alveolar ridges

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ABSTRACT

Objectives: To test the null hypothesis that there is no difference in bone dehiscence formation before and after orthodontic tooth movement through an atrophic alveolar ridge.

Material and Methods: This longitudinal retrospective study evaluated pretreatment and posttreatment cone-beam computed tomography imaging of 15 adult patients. Twenty-five teeth were moved through the atrophic alveolar bone, whereas 25 teeth not subjected to translational movement were considered controls. The distances between the cementoenamel junction and the alveolar bone crest were assessed at the mesial, distal, buccal, and lingual surfaces of all of these teeth. Data were compared using the Wilcoxon test. The Spearman correlation test and multivariate linear regression analysis were also performed.

Results: In general, crestal bone height was reduced around 0.5 mm in all groups in every direction. Median buccal dehiscence increased significantly (+2.25 mm) ($P < .05$) in teeth moved through the atrophic ridge. Control teeth also had buccal crest loss (+0.83 mm), but this was not statistically different from that of the experimental teeth. Lingual dehiscence increased significantly for the experimental (+0.17 mm) and control (+0.65 mm) groups. Mesial bone height decreased more in the control group (–0.44mm) than in the experimental group (–0.14mm). There was moderate correlation between amount of tooth movement and alveolar bone loss.

Conclusions: The null hypothesis was rejected as dehiscence increased after tooth movement through an atrophic alveolar ridge, mainly in the buccal plate. (*Angle Orthod.* 2020;90:321–329.)

KEY WORDS: Alveolar bone loss; Cone-beam computed tomography

INTRODUCTION

After tooth extraction, a dimensional reduction of the alveolar bone occurs, and, 1 year later, it can be reduced by an average of 50%.[1,2] This atrophy is more pronounced on the buccal than on the lingual side and makes any future implant placement difficult.[2,3] Among the various procedures for improving the alveolar ridge bone volume, there are several types of grafting surgeries.[4] However, they can be considered invasive and/or expensive.[5–10] In addition, predictability of the vertical stability of the grafts is generally poor.[4]

Orthodontic tooth movement through an atrophic alveolar ridge (OTMAAR) is an alternative to a surgical bone graft as bone is remodeled during the orthodontic movement, thus improving bone volume at the site for implant placement.[5–10] Sometimes, such challenging orthodontic movement is also needed to completely close spaces with missing teeth and to correct occlusal discrepancies.[6,7,9]

Although there are some studies regarding marginal bone integrity after OTMAAR,[5,8,9] they were completed using two-dimensional imaging. Because of that, bone changes that may have occurred specifically on the buccal and lingual surfaces were not assessed. Hence, the present study tested the null hypothesis that there

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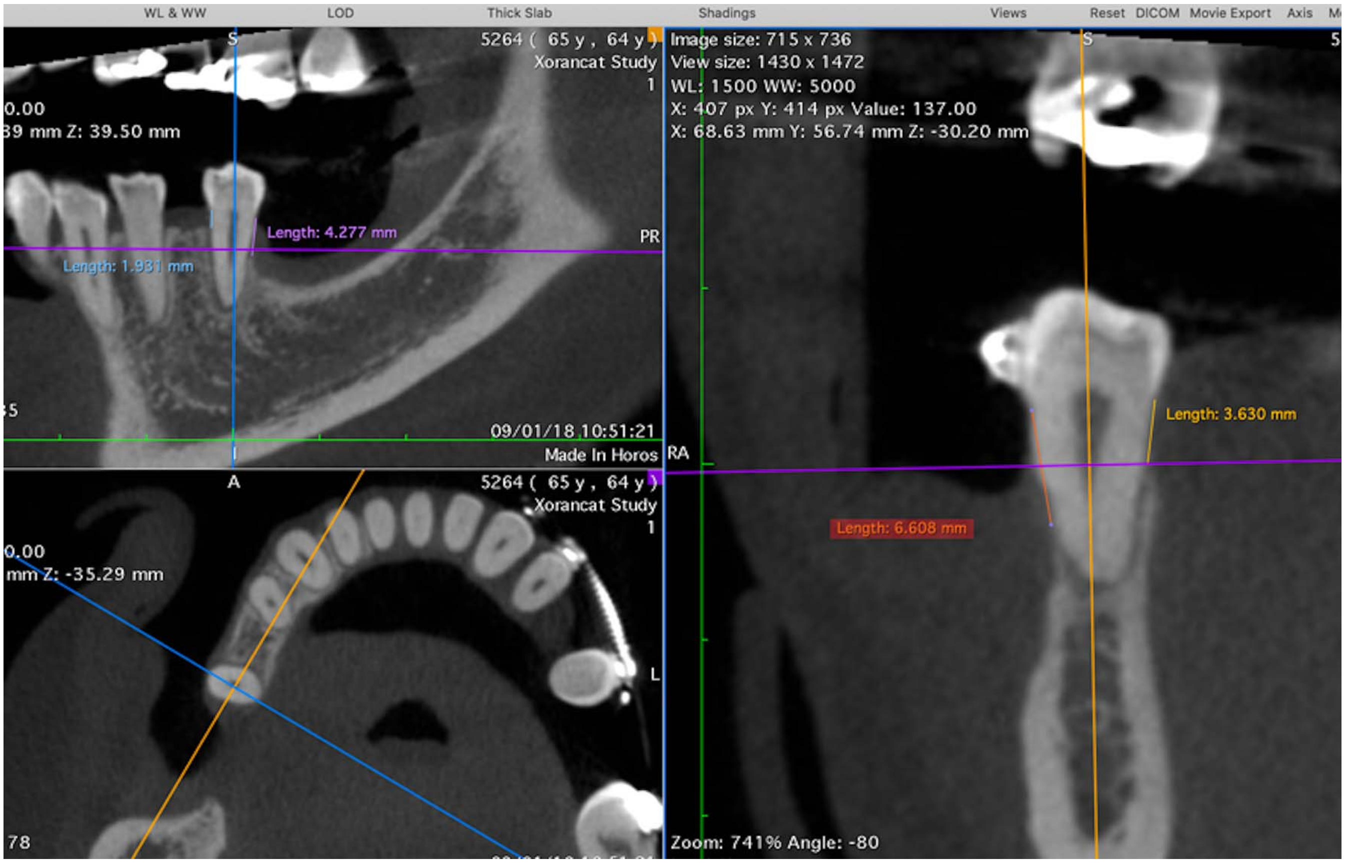

Figure 1. Three-dimensional multiplane reconstruction (3D MPR) screen showing regions measured.

is no difference in crestal bone heights before and after OTMAAR.

MATERIALS AND METHODS

This retrospective cohort study was approved by the Human Research and Ethics Committee of the State University of Maringa, Brazil. The sample size was calculated considering a power of 0.8, an alpha 0.05, and a clinically meaningful alveolar bone crest level difference of 0.5 mm (standard deviation [SD] = 1.6 mm; data from a pilot study). The required sample size was 20 teeth for each group.

Records were obtained from 15 patients (6 males and 9 females) who had at least one region of atrophic alveolar ridge from a tooth extraction that had taken place more than 1 year from the start of the study. The records were selected after a prior evaluation of 530 records of adult patients treated at the orthodontic clinic of the State University of Maringa from 2010 to 2016. Mean age of the sample was 46.8 years old (SD = 7.3; range = 36.8 to 63.1). Patients with systemic diseases, active periodontal disease and/or smoking habit, previous orthodontic treatment, or graft surgery were excluded.

Prettreatment and posttreatment orthodontic movement cone-beam computed tomography (CBCT) images from 50 teeth, most of them premolars, were evaluated. Twenty-five teeth (group 1) were moved through atrophic alveolar bone, while the control group (group 2) consisted of 25 adjacent teeth that were not subjected to translational movement.

The CBCT images were acquired using the i-CAT Next Generation equipment (Imaging Sciences International, Hatfield, Pa, USA) up to 1 month before (T1) and up to 1 month after orthodontic movement was completed (T2). The volumes were reconstructed with an isometric voxel size of 0.2 mm, field of view measuring 16 $\times$ 13 cm, tube tension of 120 kVp, and tube current of 3-8 mA. DICOM (Digital Imaging and Communications in Medicine) files were imported into Horos 3.3.2 software (Nimble Co LLC Purview, Annapolis, Md, USA). Images were analyzed under tridimensional multiplanar reconstruction mode (3D MPR, Horos 3.3.2). Mesial, distal, buccal, and lingual crestal bone heights were evaluated by measuring the distance between the cementoenamel junction (CEJ) and the alveolar bone crest. Using the 3D MPR tool, reference lines were positioned over the long axis (for sagittal and coronal views) and over the mean

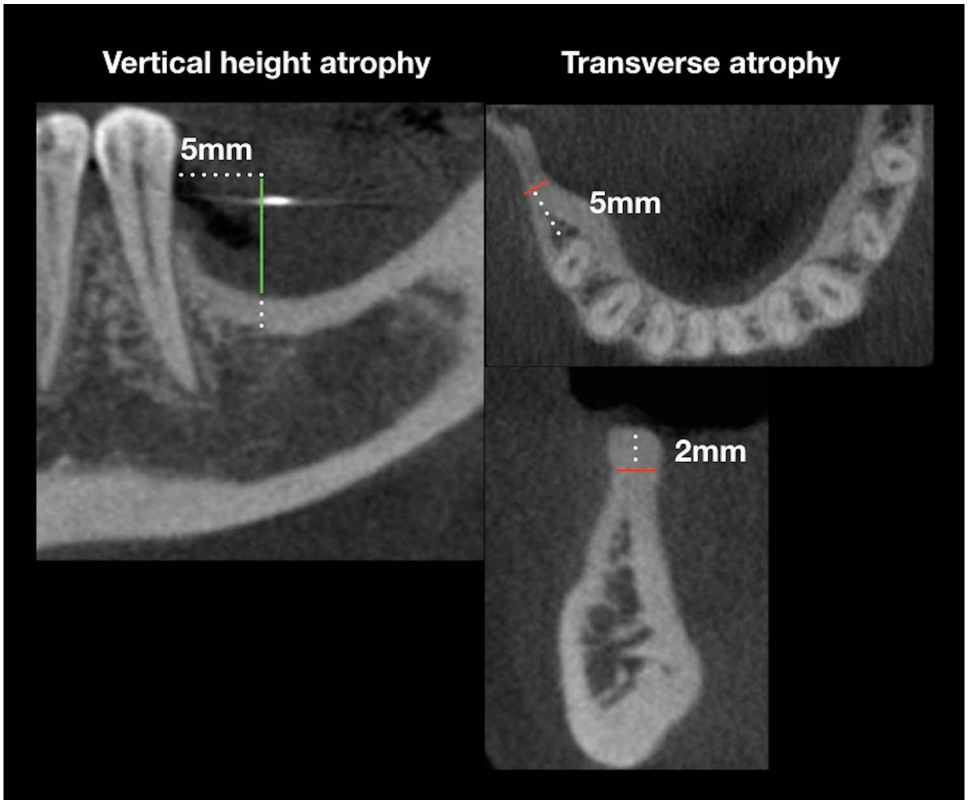

Figure 2. Vertical (green) and transverse (red) bone atrophy measurements taken 5 mm from the cementoenamel junction line, perpendicular to the occlusal plane. Transverse measurement was taken 2 mm below bone margin.

buccolingual axis (axial view) of each tooth studied (Figure 1).

The atrophic bone area was evaluated 5 mm away from the closest CEJ of the tooth to be moved into the area. The transverse atrophic bone dimension was measured 2 mm below the bone margin, and alveolar atrophy height was measured from a 5-mm CEJ line to the bone margin, perpendicular to the occlusal plane (Figure 2).

All patients received orthodontic treatment starting with 0.014″ NiTi wire, followed by 0.016″and 0.018″ and 0.020″ stainless steel (SS) wires (Morelli, São Paulo, Brazil). OTMAAR was carried out with NiTi open coil springs inserted over 019 × 025″ SS in 0.022″ slot brackets (Morelli, São Paulo, Brazil) (Figure 3). Mean orthodontic movement time was 10.1 months (SD = 2.6; range = 6 to 14 months). The mean movement through the atrophic area was 5.58 mm (SD = 1.33; range = 3.3 to 7.5 mm), obtained from the difference between CEJ locations pre- and post-movement on CBCT 3D MPR slices.

Measurements were made by one calibrated examiner and were repeated 1 month later. Intraclass coefficient (IC) and Student's *t*-test were performed to evaluate intrarater reliability. Data distribution was checked with the Shapiro-Wilk test. As data were not normally distributed, intragroup and intergroup comparisons were performed using the Wilcoxon test at 0.05% significance. Correlation test and multivariate linear regression analysis were also performed among variables. Past 3.23 statistical software (Oslo, Norway) was used.

RESULTS

IC showed good concordance both for control and experimental groups (0.80; 95% IC 0.630, 0.914, and 0.82, 95% IC 0.631, 0.923, respectively). Student's *t*-test revealed no statistical differences between the first and second measurements ($P > .05$), with mean differences of 0.131 mm for the control, group and 0.034 mm for the experimental group.

The mean pretreatment transverse and vertical atrophic bone dimensions were 4.17 mm (SD = 1.61) and 5.68 mm (SD = 1.52), respectively.

Crestal bone height comparisons are shown in Table 1 and Figure 4. When all surfaces were compared, both groups experienced significant bone loss (+0.57, control group; +0.23, experimental group). Mesial bone height decreased slightly more in the control group (–0.44 mm) than in the experimental group (–0.14 mm) ($P < .05$). No statistical differences were found for the distal aspect. Median buccal dehiscence increased

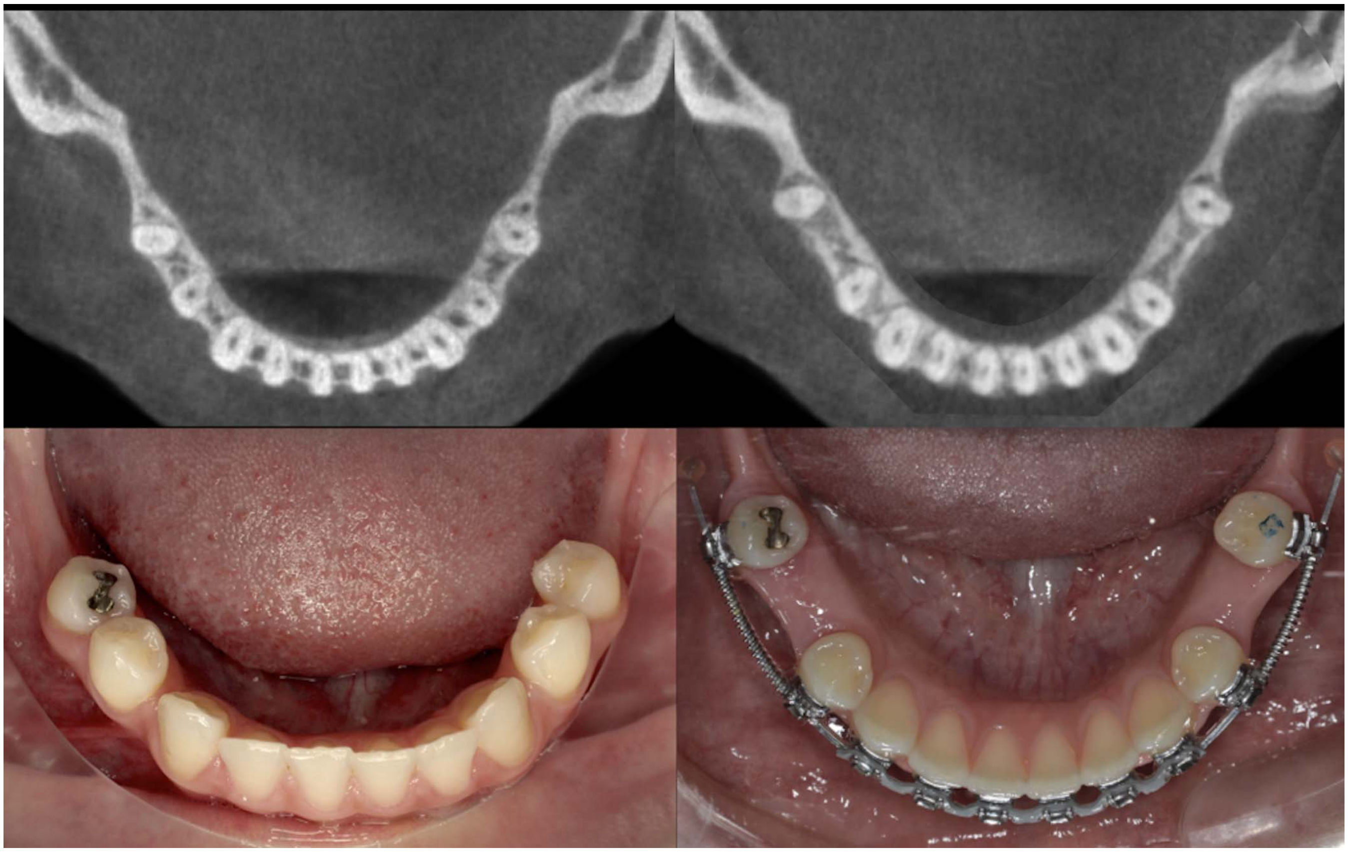

Figure 3. Bilateral second premolar distalization through atrophic ridges. Note the alveolar bone thickness recovery.

significantly (+2.25 mm) ($P < .05$) in the experimental group, although that was not statistically different compared with controls (+0.83 mm) ($P > .05$). Lingual dehiscence increased significantly for experimental (+0.17 mm) and control (+0.65 mm) groups, although without a statistically significant difference.

Spearman's correlation tests showed significant correlation between the amount of movement (mm) and treatment time ($r = 0.75$) and between the amount of movement and lingual bone loss ($r = 0.60$) (Table 2). Multivariate regression analysis (MRA) for buccal and lingual dehiscence showed that the amount of OTMAAR (in mm) was the most significant variable influencing crestal bone height loss, followed by treatment time ($P < .05$) (Tables 3 and 4; Figures 5 and 6). MRA also confirmed that vertical and transverse bone status before treatment did not influence bone height loss after tooth movement (Tables 3 and 4). Table 5 presents mean values of buccal and lingual measurements by tooth type.

DISCUSSION

Bone dehiscence is defined as the increase in the distance between the CEJ and alveolar bone crest from normal values in one cervical point of the tooth.[11] In clinically normal conditions, this space is, on average, 1.5 to 2 mm as the alveolar bone must be protected by supracrestal fibers.[12] Many authors[11,13,14] consider a bone dehiscence to be when the CEJ to crestal bone distance is greater than 2 mm. Davies et al.[15] considered a bone defect to be present with at least 4 mm of bone loss, while Leung et al.[16] considered 3 mm of bone loss to be a dehiscence. Prevalence of dehiscence has varied significantly among studies[13,17–20] due to variability in methods and samples (8.19%,[19] 40.4%,[20] 50%,[11,18] and 71.61%[21]). Nevertheless, there is consensus that the prevalence of dehiscence increases with age.[13,22,23] Orthodontic treatment is also a factor affecting dehiscence prevalence.[11,13,18] Jäger et al.[13] observed that, before treatment, 20% exhibited such bone defects, increasing to 90% of the patients with at least one tooth with dehiscence after orthodontic intervention.

In the present study, before orthodontic intervention, 96% of teeth exhibited some level of dehiscence on the buccal aspect (median = 3.68 mm for control group, median = 3.8 mm for experimental group). Among lingual surfaces, 88% of the control teeth and 96% of the experimental teeth already displayed dehiscence (median = 3.2 mm for control group, median = 3.13 mm for the experimental group). These results may reflect

Table 1. Intragroup and Intergroup Comparisons (Wilcoxon Test) Among Distances Between Cementoenamel Junction and Alveolar Bone Crest

	Group 1 (control) T1 (n = 25)	Group 1 (control) T2 (n = 25)	Group 2 (atrophic) T1 (n = 25)	Group 2 (atrophic) T2 (n = 25)
All surfaces				
Minimum-maximum	1.17–7.63	1.25–10.15	1.33–8.28	1.14–9.5
Mean (SD)	3.08 (1.28)	3.55 (1.58)	3.14 (1.34)	3.64 (1.80)
Standard error	0.128	0.158	0.134	0.180
Variance	1.661	2.497	1.812	3.245
Median (25–75 percentile)	2.66 (2.24–3.68)	3.23 (2.43–4.46)*	2.77 (2.26–3.70)	3.00 (2.34–4.48)*
Mesial				
Minimum-maximum	1.31–4.94	1.27–5.14	1,33–4.27	1.19–3.43
Mean (SD)	2.54 (0.89)	2.93 (1.04)	2.19 (0.61)	2.32 (0.65)
Standard error	0.178	0.210	0,122	0.130
Variance	0.794	1.111	0,377	0.426
Median (25–75 percentile)	2.31 (1.93–3.06)	2.75 (2.41–3.5)*[a]	2.12 (1.79 –2.47)	2.26 (1.92–2.93)
Distal				
Minimum-maximum	1.17–5.84	1.25–5.67	1.59–4.27	1.14–7.34
Mean (SD)	2.58 (1.08)	2.74 (0.99)	2.85 (0.86)	3.08 (1.33)
Standard error	0.216	0.199	0.172	0.266
Variance	1.170	0.999	0.740	1.771
Median (25–75 percentile)	2.39 (1.97–3.06)	2.63 (2.01–3.50)	2.93 (1.90–3.43)	2.87 (2.32–4)
Buccal				
Minimum-maximum	1.72–7.63	2.25–10.15	2.12–8.28	2.48–9.5
Mean (SD)	4.08 (1.61)	4.93 (1.93)	4.31 (1.75)	5.44 (1.98)
Standard error	0.323	0.386	0.351	0.396
Variance	2.609	3.729	3.096	3.938
Median (25–75 percentile)	3.68 (2.63–5.39)	4.51 (3.47–6.32)	3.8 (2.74–6.04)	6.05 (3.46–7.06)*
Lingual				
Minimum-maximum	1.57–4.62	1.72–5.62	1.81–5.6	2.06–6.99
Mean (SD)	3.11 (0.81)	3.61 (1.17)	3.21 (0.8)	3.73 (1.30)
Standard error	0.163	0.235	0.179	0.261
Variance	0.664	1.390	0.803	1.713
Median (25–75 percentile)	3.2 (2.63–3.83)	3.37 (2.55–4.78)*	3,13 (2.54–3.79)	3.78 (2.43–4.53)*

* tatistically significant for intragroup comparison ($P < .05$).
[a] Statistically significant for intergroup comparison ($P < .05$).

not only the age of the sample (46.86 years) but also the oral hygiene status and periodontal response of the participants (uncontrolled variables). Although they did not present active periodontal disease during the study interval, subjects may have had periodontal problems in the past. Additionally, all of the patients had had at least one tooth extraction with subsequent alveolar ridge atrophy. This fact may be suggestive of lack of proper oral hygiene in the past. Patients in the present sample were seeking care for implant placement, but the alveolar bone atrophy did not allow immediate rehabilitation. Those patients were then referred for orthodontic treatment as an alternative to the surgical bone graft.

OTMAAR is one alternative for improving bone conditions and preparing a new site for implant placement.[5–10] However, OTMAAR might lead to some additional marginal bone loss.[5,9] Radiographic studies[5,9] of such movement reported a mean crestal bone loss of 0.4 to 0.5 mm in the mesial area and 0.1 to 0.4

Table 2. Spearman‘s Correlation Matrix Among Age, Movement Quantity, Transverse and Vertical Atrophy, Buccal and Lingual Bone Height Loss

	Age	Millimeters of Movement	Treatment Time	Transverse Atrophy	Vertical Atrophy	Buccal Bone Loss	Lingual Bone Loss
Age		0.33016	0.48256	0.25405	0.20258	0.2883	0.32254
Millimeters of movement	0.33016		0.75734*	-0.17751	–0.11367	0.47678	0.60545*
Treatment time	0.48256	0.75734*		0.0641	–0.066049	0.28713	0.47607
Transverse atrophy	0.25405	–0.17751	0.0641		–0.12466	–0.092325	0.054262
Vertical atrophy	0.20258	–0.11367	–0.066049	–0.12466		–0.047317	–0.11372
Buccal bone loss	0.2883	0.47678	0.28713	–0.092325	–0.047317		–0.029242
Lingual bone loss	0.32254	0.60545*	0.47607	0.054262	–0.11372	–0.029242	

* Statistically significant ($P < .05$).

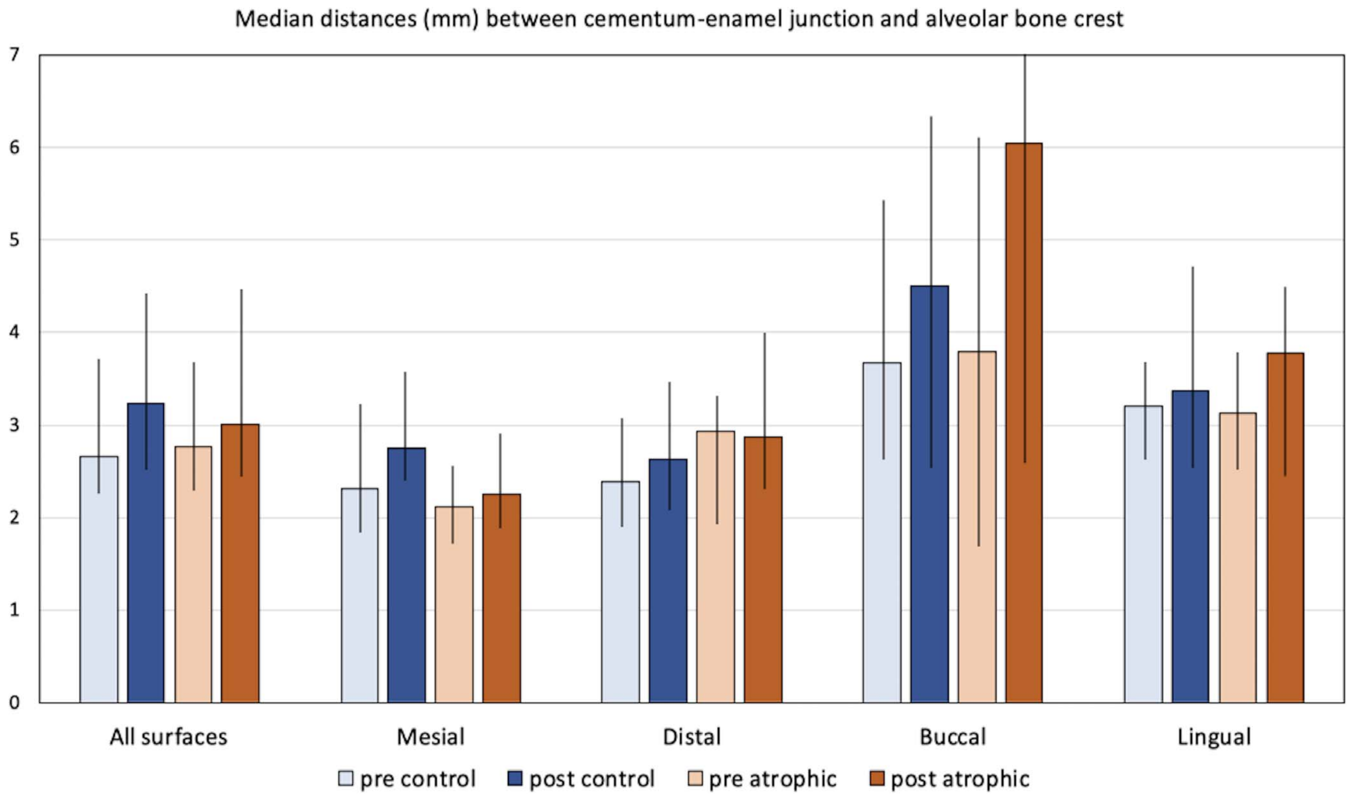

Figure 4. Median distances (bars) and percentiles (vertical lines) between the cementoenamel junction and alveolar bone crest for Group 1 in T1 (pre control), Group 1 in T2 (post control), Group 2 in T1 (pre atrophic) and Group 2 in T2 (post atrophic).

mm in the distal area. In the present study, there was more bone loss among the control teeth (–0.44 mm) on the mesial compared with the experimental teeth (–0.14 mm), but this difference can be considered clinically irrelevant.[5,9] There was no significant bone loss on the distal aspect. However, the buccal plate showed significant loss after OTMAAR (+2.25 mm). (Table 1; Figure 4) Buccal bone loss from 0.2 to 0.8 mm was reported in the orthodontic treatment of adults not involving atrophic areas.[13,18,22]

Although the present study evaluated mainly lower first and second premolars, descriptive and dispersion graphs indicated a variable response of buccal and lingual bone loss in all types of tooth movement (Table 5; Figures 5 and 6). Isolated statistical comparisons per tooth type were limited in the study due to the sample characteristics and size.

Periapical x-rays have limited diagnostic acumen as they are two-dimensional and do not allow visualization for buccal and lingual crestal bone height measurements.[6] On the contrary, CBCT reconstructions allow three-dimensional evaluation of both crestal height and thickness.[6,11,13,16–18] It has been reported that when the cortical plate is thinner than 0.5 mm, a false-positive diagnosis for dehiscence might be generated.[24] CBCT reconstruction was reported to only have about 70% accuracy for distinguishing between the presence and absence of this condition.[25] It is well known that the smaller the voxel size, the richer the imaging details.[16–18,25,26] Menezes et al.[26] suggested that there was adequate precision for crestal bone measurements only when the voxel size was 0.3 mm or smaller. Also it is well known that the smaller the voxel size, the higher the ionizing radiation. Hence, a reasonable balance between voxel size and diagnostic needs

Table 3. Multivariate Linear Regression Analysis for Buccal Dehiscence

Variable	Slope	Error	Intercept	Error	r	P
Age	0.4708	0.9292	47.216	1.9685	0.1050	.6172
Movement (mm)	0.3996	0.1395	5.064	0.2956	0.5126	.0087*
Time	0.5029	0.3089	9.4705	0.6544	0.3214	.1171
Transverse atrophy	–0.0279	0.1952	4.2074	0.4136	–0.0298	.8872
Vertical atrophy	–0.0996	0.1836	5.8115	0.3889	–0.1124	.5925

* Statistically significant ($P < .05$).

Table 4. Multivariate Linear Regression Analysis for Lingual Dehiscence

Variable	Slope	Error	Intercept	Error	r	*P*
Age	1.8654	1.4293	46.844	1.6901	0.2625	.2047
Movement (mm)	0.6777	0.2154	5.2241	0.2547	0.5484	.0045*
Time	1.2027	0.45237	9.4883	0.5348	0.4848	.0140*
Transverse atrophy	0.0260	0.3096	4.1575	0.3660	0.0175	.9335
Vertical atrophy	–0.2241	0.2891	5.8005	0.3419	–0.1595	.4462

* Statistically significant ($P < .05$).

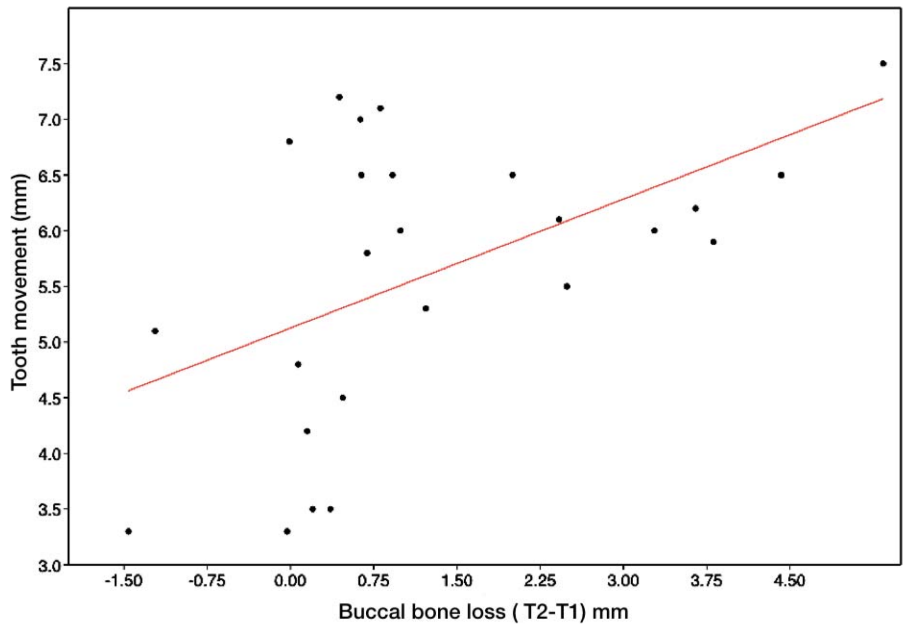

Figure 5. Dispersion plot between tooth movement (mm) and buccal bone loss.

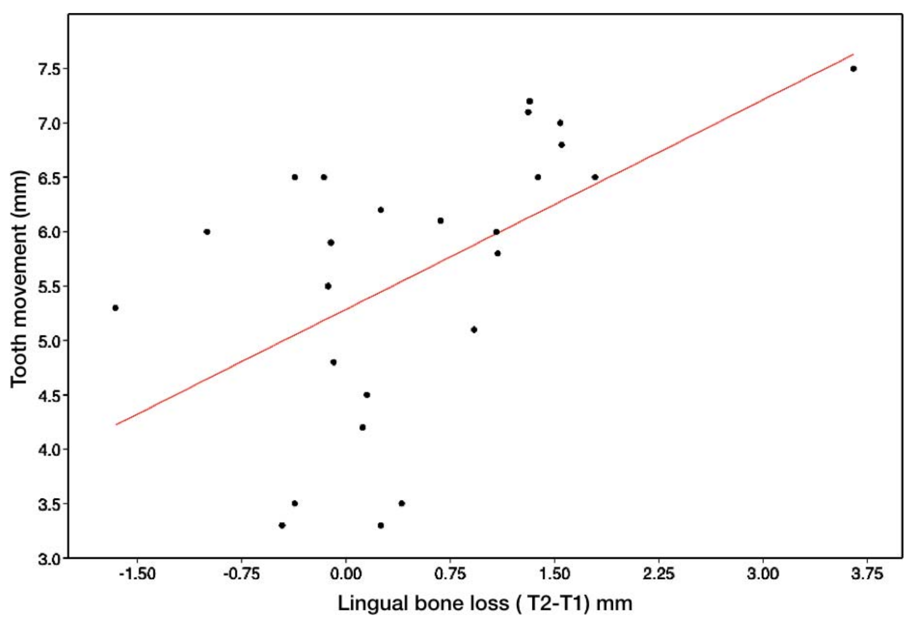

Figure 6. Dispersion plot between tooth movement (mm) and lingual bone loss.

Table 5. Mean Values of Buccal and Lingual Measurements by Tooth Type

Tooth Type (n)	Control Group (*x*)		Experimental Group (*x*)	
	Preintervention	Postintervention	Preintervention	Postintervention
Buccal				
Second lower premolars (20)			3.93	6.07
First lower premolars (21)	3.16	4.16	5.63	5.65
Second upper premolar (2)			3.54	3.44
First upper premolar (2)	2.36	4.12		
Upper canines (2)			5.26	7.51
Lower canine (1)			5.6	6.24
Upper incisors (2)	3.55	4.35		
Lingual				
Second lower premolars (20)			2.94	3.52
First lower premolars (21)	2.96	3.28	5.6	5.62
Second upper premolar (2)			2.81	4.04
First upper premolar (2)	4	4.13		
Upper canines (2)			5.08	4.99
Lower canine (1)			3.01	4.06
Upper incisors (2)	3.59	5.01		

should be sought.[27] Ising et al.[17] compared CBCT reconstructions using a voxel size less than 0.2 mm and concluded that dehiscence could be evaluated with good accuracy even by measuring the rendered images. In the present study, a three-dimensional multiplanar reconstruction tool was used and both IC and Student's *t*-tests demonstrated good reliability. This was in agreement with the literature indicating high precision for CBCT image quantitative measurements.[16–18,25–27] The actual accuracy of the technique is unknown as no gold standard measurement was available (ie, direct measurement after opening a flap). Also, it must be considered that newly formed bone might be underestimated as CBCT images were taken up to 1 month after treatment and the buccal plate in particular may not have been completely mineralized at that point. Additionally, due to possible false-negative findings in plates thinner than 0.5 mm, such measurements can fail to detect real dimensions.

Although etiology of the dehiscence is unclear, it seems that it is influenced by the thickness of the alveolar bone.[18,28] Thinner bones pose a greater risk of bone loss. It also seems that excessive inclination toward the buccal or lingual plates may negatively influence bone integrity.[28,29] Force direction and intensity influence bone remodeling during orthodontic movement and careless mechanics can move any tooth away from the mid-alveolus, leading to thinner bone on one side.[28,29] In the present study, NiTi coil springs were used when the .019 $\times$ .025 SS wire was passive. In spite of low forces used (around 70 g), it likely caused a slight buccal inclination and rotation of the crown as side effects. This may explain the poorer results for the buccal plate. It should also be considered that almost all teeth exhibited more than a 2 mm distance between the CEJ and crestal bone before orthodontic intervention, indicating already-reduced alveolar bone support.

OTMAAR may take time, therefore exposing periodontal tissues to more stress caused by orthodontic movement and plaque accumulation.[5,8,9] A correlation was found between the amount of movement and treatment time with more tooth translation requiring more time. The results also revealed that the amount of movement was significant and moderately correlated to the lingual crestal bone loss ($r = 0.60$) and moderately correlated to the buccal bone loss ($r = 0.47$), but it was not statistically significant (Table 2). Regression analysis showed that the amount of OTMAAR was the most significant variable influencing crestal bone loss, followed by treatment time ($P < .05$) (Table 3 and 4). Surprisingly, the results did not show correlation between the level of atrophy and bone loss during the study. It seemed that the tooth moved with its surrounding bone, bringing new bone to the atrophic area, despite some crestal bone loss.

In summary, OTMAAR is an alternative to surgical bone grafting, potentially remodeling the atrophic bone area and preparing an adequate site for implant placement, as previously suggested.[5–10] However, the crestal bone should be checked before orthodontic movement, especially the buccal aspect, as it is the area most likely to suffer bone loss. This should provide guidance for carefully planned orthodontic mechanics to minimize buccal inclination during tooth movement. It is expected that with good oral hygiene supervision associated with careful orthodontic mechanics, marginal bone loss may be minimized during this type of orthodontic movement. Further studies are needed in this area.

CONCLUSION

The null hypothesis was rejected since dehiscence increased after tooth movement through an atrophic alveolar ridge, mainly in the buccal plate.

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