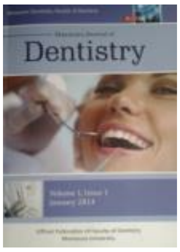

Maxillary Buccal Alveolar Bone Assessment Following Orthodontic Alignment Without Extractions (Cone beam study)

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Abstract:

Objective: Assessment of maxillary buccal alveolar bone following orthodontic alignment without extractions.(Cone beam study).

Materials and Methods: Twenty adolescents with crowded permanent dentitions were treated without extractions with EASY SMILE (USA) Orthodontic self-ligating bracket brackets & conventional brackets. Cone beam computed tomographic scans were taken before treatment (T0) and after alignment (T1). Alveolar bone thickness (BT) was evaluated at the maxillary central incisor (I), second premolar (2PM), and first molar mesiobuccal (mb1M) and distobuccal (db1M) roots. Correlations between alveolar width changes and initial arch width, initial crowding, amount of expansion, amount of tipping, and amount of molar rotation were calculated were calculated. All data collected will be tabulated and statistically analyzed.

Results: BT decreased and BH increased significantly for the incisors and mesiobuccal(mb1M) root of the first molars. Also, arch dimensions generally increased together with tipping. Bone loss was correlated with crowding and amount of expansion in the premolar region.

Conclusion: Nonextraction alignment resulted in arch expansion associated with tipping of teeth for both self-ligating brackets & conventional brackets. Alignment with expansion led to horizontal and vertical bone loss at the incisors and mesiobuccal root of the first molars. Thinner BTs and more severe crowding before treatment led to increase the risk for buccal bone loss.

Keywords: Alveolar bone,CuNiTi wire,CBCT,Self-ligating

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Introduction

Orthodontic tooth movement is a process whereby the application of a force induces bone resorption on the pressure side and bone apposition on the tension side.[1]

Moving teeth beyond anatomical limits with orthodontic treatment increases the risk of bone loss and formation of anatomical defects such as dehiscence or fenestration.[2]

The search for improved efficiency in orthodontic treatment has afforded new designs of brackets.[3] One such evolution occurred with the use of self-ligating brackets, which were introduced in the early 1930s but have been gaining popularity only in recent years.[4]

Relief of crowding without extractions and reduction of tooth material can be achieved by distal movement of posterior teeth, expansion of the dental arch, and incisor proclination.[5]

Rapid palatal expansion provokes horizontal and vertical reductions in the buccal alveolar bone of premolars and molars according to three-dimensional (3D) studies,[6-7] whereas the combination of self-ligating brackets with heat-activated super elastic arch wires has been alleged to produce a low-force, low friction environment in which the bone follows tooth movement. Thus, orthodontic treatment with self-ligating appliances would allow for greater dental expansion, provoke less incisor proclination, and require fewer extractions than would treatment with conventional appliances.[8]

Self-ligating brackets first introduced in the 1930s. In 1970s, self-ligating brackets have been recommended to decrease friction between wires and brackets, deliver forces in more biological levels, decrease overall treatment period, better plaque control, and increase patient comfort.[9,10] Nevertheless, many of these allegations are still controversial.[9,11]

Nonextraction alignment with self-ligating appliances generated dental arch expansion associated with tipping of teeth. Significant bone loss (in terms of both thickness and height) was observed at the maxillary central incisors and the mesiobuccal root of the first molars.[12]

Tooth movement degree of can be studied and evaluated using a conventional two-dimensional (2D)[13,14] cephalogram that has been used for long time to evaluate the skeletal and dental changes during orthodontic treatment course. Unfortunately, two dimentional imaging (including cephalogram and panoramic x-ray) major drawback is superimposition that makes it difficult to accurately assess the right and left side dental changes separately.

Cone-beam computed tomography (CBCT) given the ability to evaluate the length and thickness of the root and height and thickness of the alveolar bone quantitatively and qualitatively.[15,16]

Few studies have investigated changes in maxillary alveolar bone during alignment. Therefore, the purpose of this study was to assess changes in the maxillary buccal alveolar bone during the alignment phase of orthodontic treatment using a two system, a self-ligating and a conventional preadjusted edgewise appliance system.

Patients and Methods:

This study was carried out upon 20 patients with an age range from 16 to 30 years, selected from the outpatient orthodontic clinic, Faculty of Dental medicine, Al-azher University, Assiut branch.

Based on a preliminary power analysis, a minimum sample size of 20 participants was needed to achieve an 80% power of the study with a significance level of .05, aiming to demonstrate a true difference of arch width before and after alignment.

A Complete case history was taken for each patient. Then, the patients were examined for conformity with criteria for inclusion in this study. They were orthodontically diagnosed and a treatment plane was set.

For each patient, the following records were taken before and after levelling & alignment: -

1. Extraoral and intraoral photographs.

Extraoral views include:

- Frontal view. - Frontal view with a smile. - Profile view.

Intraoral views include:

- Frontal view in centric occlusion - Right and left side views in centric occlusion.
- Upper and lower occlusal views.

2- Impression for study model analysis

3- Upper arch CBCT for each patient.

Written consent to undergo CBCT radiographic examinations and to participate in this investigation was obtained from all patients and from their parents or guardians. The following inclusion criteria were applied: (1) Class I or Class II molar relationship; (2) more than 2 mm of crowding in the maxillary arch; (3) full permanent dentition anterior to the first molars; (4) healthy periodontium; and (5) no previous orthodontic treatment. Patients were divided randomly into two groups (conventional group and self-ligating group).

Group 1: - Conventional bracket group.

Ten patients were treated with EASYINSMILE dental orthodontic metal Conventional Bracket standard torque brackets with the following archwire sequence: - 0.014 - .016” NiTi (nickel titanium) each wire for 4-6 weeks or until the teeth were passively engaged in all bracket slots, 0.018” SS (stainless steel) for 4 weeks, 0.016 x .022” NiTi for 4-6 weeks, 0.018 x .025” SS or .019 x .025” SS for 6-8 weeks. Oral hygiene was monitored during this period. Appointment intervals were approximately 5 weeks. No additional interventions, such as interproximal reduction, intermaxillary elastics, or any orthopedic mechanics, were used.

Group 2: - Self ligating group

Ten patient treated with Easy Smile self-ligating bracket standard torque brackets with the following archwire sequence: (1) 0.014-inch copper-nickel-titanium (CuNiTi) archwires for at least 10 weeks or until the teeth were passively engaged in all bracket slots, (2) 0.014 x 0.025-inch CuNiTiarchwires kept until tooth alignment allowed the complete insertion of the archwire in the slots with passive closure of the bracket lid, and (3) 0.019 3 0.025-inch stainless-steel (SS) archwire contoured for maintenance of the arch form developed in the first two phases. Oral hygiene was monitored during this period. Appointment intervals were approximately 6 weeks. Additional interventions, such as interproximal reduction, intermaxillary elastics, or any orthopedic mechanics, were not used.

deviation (SD) if normally distributed or median and interquartile range (IQR), or range if not. IQR is the difference between 75th percentile and 25th percentile, while range is the difference between maximum and minimum values. Also, standard error (SE) was reported which equals SD divided by square root of sample size (N).

CBCT scans (Sidexis 4 software from Dentsply Sirona 2) were taken before treatment (T0) and a minimum of 5 weeks after insertion of the 0.019 x 0.025-inch SS archwire (T1). The following imaging acquisition parameters were used: 5 mA, 120 kV, field of view (FOV) of 13 cm height 3 16 cm diameter, and either 20-second or 40-second exposure time.For each patient, the identical scanning protocol was used at T0 and T1 and no additional CBCT scan was taken at the end of treatment according to the approved protocol.

Each CBCT scan was imported into Mimics software (version 14.01, Materialise, Leuven, Belgium) using the DICOM file format. A prior pilot study was carried out to analyze the sites at which the buccal bone thickness allowed for reliable measurements. Thus, buccal alveolar bone morphology relative to the maxillary central incisor (I), second premolar (2PM), and first molar mesiobuccal (mb1M) and distobuccal (db1M) roots was assessed.All measurements and their respective abbreviations are described in Table 1.

Results:

Data were entered and analyzed using IBM-SPSS software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.)

Qualitative data were expressed as absolute frequency (N) and relative frequency (%, percentage).

Quantitative data were initially tested for normality using Shapiro-Wilk’s test with data being normally distributed if $p>0.050$. Presence of significant outliers (extreme values) was tested for by inspecting boxplots. Quantitative data were expressed as mean ± standard

Measurements	Abbreviation	Descriptions
Buccal bone thickness at 3 mm	Tooth-3	Buccal bone thickness measured between the facial aspect of the root to the facial aspect of the alveolar bone, at 3 mm from the cementoenamel junction (CEJ). *
Buccal bone thickness at 6 mm	Tooth-6	Buccal bone thickness measured between the facial aspect of the root to the facial aspect of the alveolar bone, at 6 mm from the (CEJ). *
Bone area	Tooth-area	Alveolar bone area delimited apically at 3/4 of the root length from the CEJ, lingually by the tooth root, and buccally by the facial contour of the bone plate. The root length was determined on the post alignment scans. **
Bone height	BH-tooth	Vertical distance between the facial CEJ and the buccal alveolar bone crest. **
Arch widths	Tooth-W	Distance between contralateral teeth. ***
Arch length	AL	Distance from the interincisor point and the mean distance between the mesial contact points of the first molars. ****
Buccolingual inclinations	Tooth-inclination	Angles between the mesiodistal plane of each tooth and the occlusal plane. *
First molar rotations	Rotation-1M	Angle between molar buccal surface at the CEJ level and a line perpendicular to the palatal raphe, measured on a 3-mm-thick axial section. ****
Tooth (root)	I	Central incisors
	C	Canines
	1PM	First premolars
	2PM	Second premolars
	1M	First molars
	mb1M	Mesiobuccal root of first molars
	db1M	Distobuccal root of first molars

Table (1): All measurements and their respective

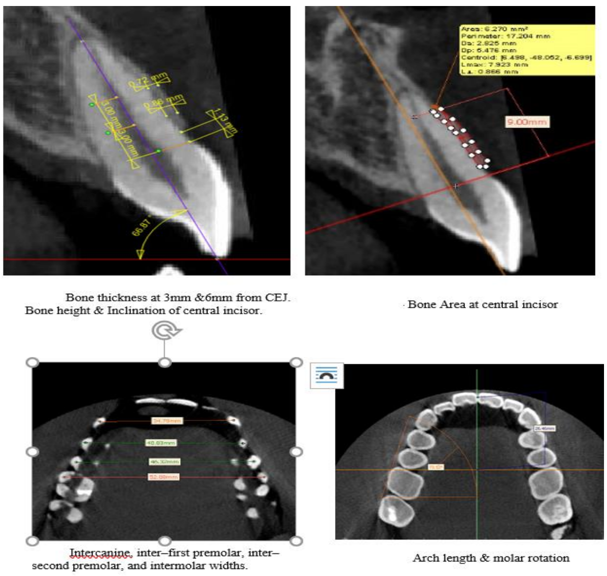


Figure (1):-Actual measurement on CBCT slices which represent :- Buccal bone thickness , angulation of incisor, bone area, alveolar width at canine-1st premoar-2nd premolar- 1st molar, arch length, and molar rotation

Initial features	Mean	SD
Age, years	14.7	1.2
Little Index–maxillary arch, mm	11.3	5.2
Space analysis–maxillary arch, mm	_6.6	3.0
Gender	9 Female & 11 males	
Molar relationship	14 Class I, 6 Class II subdivision	
Treatment times by weeks for conventional group		
0.014-inch NiTi	4.5	5.0
0.016-inch NiTi	6	4
0.018- inch NiTi	6	4.5
0.016 x 0.022-inch NiTi wire	8.5	5.0
0.017 x 0.025 StSt wire	8.5	6.5
Treatment times by weeks for self-ligating group		
0.014-inch CuNiTi	12.0	9.6
0.014 3 0.025-inch CuNiTi	8.6	8
0.019 x 0.025-inch StSt	10.6	4.1

Table (2): Demographics and Clinical Characteristics of the Sample (N = 20)

All Measurements: -This study involved 20 units divided into two groups:
Group 1: Conventional bracket group: N = 10
Group 2: Self-ligating bracket group: N = 10

Irregularity index:

There was no statistically significant difference between (Conventional) and (Self) where (p=0.221). The highest mean value was found in (Self), while the least mean value was found in (Conventional) group.

The results of One-Way ANCOVA which was run to determine the effect of conventional bracket and self-ligating bracket trials on post-intervention measurements of alveolar buccal bone thicknesses and heights after controlling for pre-intervention .

Variables	Total irregularity index	
	Mean	SD
Conventional group	9.15	0.86
Self-ligating group	10.52	0.79
p-value	0.221ns	

Table (3): The mean, standard deviation (SD) values of total irregularity index of different groups.

measurements. After adjustment for pre-intervention measurements, there was no statistically significant difference in post-intervention measurements between the two interventions as presented in table.

Parameter	Conventional bracket		Self-ligating bracket		Test of significance		
	Adj. Mean	SE	Adj. Mean	SE	F value	P value	Partial η^2
I-3 (mm)	1.190	0.053	1.102	0.053	1.379	0.256	0.075
I-6 (mm)	1.395	0.097	1.311	0.097	0.370	0.551	0.021
I-area (Sq. mm)	7.168	0.222	6.732	0.222	1.904	0.186	0.101
BH-I (mm)	1.761	0.067	1.882	0.067	1.628	0.219	0.087
2PM-3 (mm)	2.376	0.129	2.231	0.129	0.628	0.439	0.036
2PM-6 (mm)	2.572	0.075	2.654	0.075	0.593	0.452	0.034
2PM-area (Sq. mm)	21.375	0.984	21.192	0.984	0.016	0.900	0.001
BH-2PM (mm)	.719	0.041	0.803	0.041	2.106	0.165	0.110
mb1M-3 (mm)	1.362	0.111	1.394	0.111	0.038	0.847	0.002
mb1M-6 (mm)	1.365	0.125	1.419	0.125	0.090	0.768	0.005
mb1M-area(Sq. mm)	7.531	0.292	7.732	0.292	0.236	0.633	0.014
BH-mb1M (mm)	1.409	0.041	1.351	0.041	0.991	0.334	0.055
db1M-3 (mm)	2.125	0.051	2.058	0.051	0.821	0.378	0.046
db1M-6 (mm)	2.331	0.070	2.278	0.070	0.278	0.605	0.016
db1M-area (Sq.mm)	13.102	0.141	13.129	0.141	0.019	0.892	0.001
BH-db1M (mm)	1.247	0.057	1.209	0.057	0.208	0.654	0.012

Table (4): Alveolar buccal bone thicknesses and heights between the two groups.
Notes: Adj. mean=Postintervention mean adjusted for preintervention measurement. SE=standard error. Test of significance is One-Way analysis of covariance (One-Way ANCOVA). Partial η^2 is a measure of effect size.

Also, the results of One-Way ANCOVA which was run to determine the effect of conventional bracket and self-ligating bracket trials on post-intervention measurements of arch dimensions and buccolingual inclinations after controlling for pre-intervention measurements. After adjustment for pre-intervention measurements, there was no statistically significant difference in post-intervention measurements between the two interventions as presented in table.

Parameter	Conventional bracket		Self-ligating bracket		Test of significance		
	Adj. Mean	SE	Adj. Mean	SE	F value	P value	Partial η^2
C-W (mm)	35.333	0.323	35.980	0.323	1.964	0.179	0.104
1PM-W (mm)	44.664	0.201	44.976	0.201	1.193	0.290	0.066
2PM-W (mm)	48.795	0.154	49.123	0.154	2.249	0.152	0.117
1M-W (mm)	52.235	0.320	51.856	0.320	0.678	0.422	0.038
Arch length (mm)	33.930	1.475	33.524	1.475	0.038	0.849	0.002
I-inclination ()	58.063	1.108	57.196	1.108	0.289	0.598	0.017
C-inclination ()	67.362	0.527	66.801	0.527	0.561	0.464	0.032
1PM-inclination ()	76.163	0.682	75.883	0.682	0.081	0.780	0.005
2PM-inclination ()	80.850	1.189	80.149	1.189	0.171	0.684	0.010
1M-inclination ()	86.297	0.539	86.237	0.539	0.006	0.940	0.000
Rotation-1M ()	85.063	0.757	84.039	0.757	0.855	0.368	0.048

Table (5): Arch dimensions and buccolingual inclinations between the two groups.
Notes: Adj. mean=Postintervention mean adjusted for preintervention measurement. SE=standard error.
Test of significance is One-Way analysis of covariance (One-Way ANCOVA). Partial η^2 is a measure of effect size.

Discussion

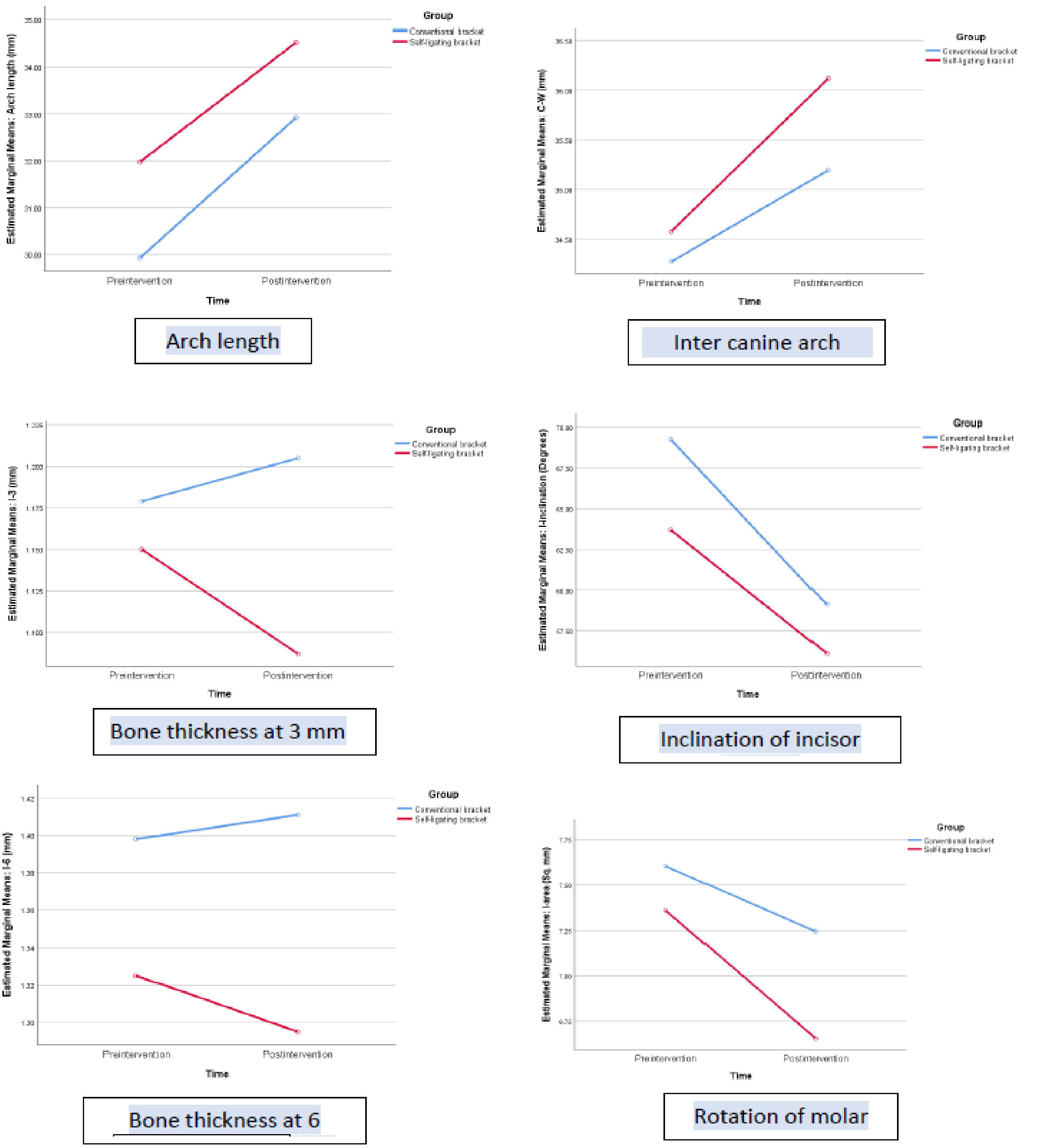
The aim of this study was to be assess the effects of alignment by non-extraction approach with two a preadjusted fixed appliances on buccal alveolar bone in the maxillary anterior and posterior areas.

CBCT was chosen due to a 3D imaging method, it enables evaluation of the buccal bone, yet exposes the patients to a lower level of ionizing radiation (as compared to medical CT). [17.]

The accuracy of linear measurements of thin objects in CBCT shows limitations related to the image resolution. This means that it is difficult to detect the presence of bone on the images in sites in which the bone has the same thickness or less than the voxel size. [18]

The use of smaller FOV and voxel size could offer better image resolution. However, the patients would have been exposed to a higher dose of ionizing radiation. Indeed, a FOV of 13 cm [19] 16 cm was used; thus, no other radiographs (i.e., panoramic, or cephalometric) were needed for treatment planning. Additionally, the 0.3-mm voxel size used in this study was considered acceptable for this purpose. [18]

Assessment of effects on the maxillary buccal alveolar bone of using conventional appliance and a passive self-ligating appliance to relief crowding with a non-extraction approach. Overall, crowding was resolved by transverse expansion and dental tipping, as previously reported. [19-23]



Figure(2): - Profile plots were used to graphically present the results between conventional group (Blue line) and self-ligating group (Red line).

In this study, buccal alveolar bone showed significant reduction in thickness and height at the central incisors and mb1M, even though a large variation among patients was noted. Buccal alveolar bone reduction following orthodontic treatment corroborates results reported in previous CT and CBCT studies. [24-29]

Based on recent study, reported on average 1.12 mm of buccal bone recession at the mandibular central incisor, with high variability after non extraction treatment with a self-ligating appliance. [24]

In another study, Cattaneo et al. [21] found 12–23% reduction of buccal bone thickness relative to 2PM following non extraction orthodontic treatment with self-ligating appliances.

Similarly, an animal study [25] demonstrated buccal expansion with a self-ligating appliance occurring with uncontrolled tipping and apical migration of bone. Other methods of maxillary expansion, slow or rapid, have also been shown to result in dehiscence at posterior teeth. [26,28]

On the other side, treating patients with extractions does not seem to assure that bone loss will be avoided.

Lund et al. [30] found remarkable vertical bone loss in patients treated with premolar extractions, especially on the lingual surfaces of the maxillary incisors (1.0– 1.3 mm), while on the buccal surfaces of central incisors, premolars, and molars, the mean bone loss was 0.2 mm.

In contrast to the findings of our study, the bone reduction at 2PM was not significant. Among various explanations, the large variation in initial BT, the smaller amount of expansion, the short treatment duration, and the different methods of measurement may account for this variability. The largest decrease in BT was found in lingually positioned premolars and was due to initial crowding.

The average increase in arch dimensions was mainly accompanied by tipping in both conventional & self-ligating systems, in agreement with previous clinical studies [20-23] analyzing the effect of non-extraction treatment with self-ligating appliances.

Crowding has been cited [31] as a risk factor for bone loss and dehiscence. This was confirmed in this study, as patients with severe initial crowding and thin bone presented more reduction of BT at the 2PM area.

In this study the irregularity index was used for measurement of crowding, the Irregularity Index is simple, clinically reliable, and valid but is not without error. [32]

Expansion and tipping have been reported [21,25,31] to cause apical migration of marginal buccal bone and decrease in buccal bone thickness. The results showed a relation between the amount of expansion and the degree of bone reduction at 2PMs and mb1Ms. The degree of tipping was, adversely, not significantly correlated to changes in the buccal bone thicknesses. This agrees with another study [28] in which no correlation between proclination of incisor and gingival recession in adults was found.

Pandis et al. [33] performed a study in order to compare copper-nickel titanium vs nickel-titanium archwires in resolving crowding of the mandibular anterior dentition. Sixty patients were bonded with the same brackets and randomly split into either the copper-nickel-titanium archwire group or the nickel-titanium archwire group. The results of the study showed that the type of wire (copper-nickel-titanium or nickel-titanium) had no significant effect on crowding alleviation.

Pretreatment thinner BTs increased the risk for bone reduction at the central incisors. Similar correlations were found previously for molars and premolars when evaluating rapid maxillary expansion. [26]

The opposite tendency was found at db1Ms, where thinner initial bone thickness was weakly, though significantly, correlated to vertical bone gain. This can be explained by the increase in bone thickness produced by the mesiobuccal rotation caused by the preadjusted molar tube.

As a consequence of large variations in both bone morphology and changes in molar rotation among the subjects, this correlation was not significant.

Expansion and tipping occurred as a result of archwire expansion with continuous forces. Since the force used can be considered light to moderate. [34]The experimental second premolars were expanded by about 3.5 mm. Approximately 1 mm of tooth movement occurred during the first 4 weeks of expansion; this was like previous studies of mesiodistal movements of single isolated teeth in dogs ranging from 0.75 mm [29] to approximately 1 mm [25,35] per month.

Even with light continuous forces, archwire expansion has previously been shown to produce tipping (7^0-13.5^0) with both round [22] and edgewise [21-23] wires. The tipping that occurred produced significant dehiscences and reduced bone thickness on the buccal surfaces of both premolar roots.

Finally, in a cone-beam computed tomography evaluation of patients treated with archwire expansion, significant decrease in facial bone thickness and height were also found in both the maxilla and the mandible. [30]

Conclusion:

There was a change (reduction) in alveolar bone thickness and height after orthodontic leveling with both Conventional and self-ligating brackets. However, these changes do not appear to be statistically significant when comparing the two treatment groups.

Also, initial bone thickness, crowding severity, and the amount of expansion during treatment had a weak, though significant, impact on the buccal bone reduction.

Finally, when treating patients with crowding with any bracket system nonextraction, the anterior maxilla is the site of most susceptible to develop decreases in alveolar bone thickness and height in this study.

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