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Alveolar Bone Thickness Before and After Periodontally Accelerated Osteogenic Orthodontics

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UCSF Division of Periodontics

Class of 2013

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Orofacial Sciences

in the

DEDICATION

To my mother, June, my father Ron, and my sister, Brittany: thank you for all of your continued love and support.

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To Dr. Paul Lee, Dr. Art Miller, Dr. Larry Chen, Dr. Alexander Kim, Dr. Marcia Wadell, Dr. Tram Hoang, Dr. Igor Roitman, Dr. Gerald Nelson: Thank you for all of your guidance, support and knowledge.

ABSTRACT

Alveolar Bone Thickness Before and After Periodontally Accelerated Osteogenic Orthodontics

Jeffrey K. Takai, DDS

Introduction: Periodontal accelerated osteogenic orthodontics (PAOO) has been proposed to decrease orthodontic treatment time as well as increase the width of the alveolar bone around roots of teeth in the direction of the intended tooth movement.

Objective: To determine whether there was a change in alveolar bone width surrounding teeth that had undergone PAOO.

Methods and Materials: Pre- and post-operative cone beam computed tomography (CBCT) scans of 4 patients who had undergone PAOO were obtained. Virtual slices of each tooth which had undergone PAOO were taken along the long axis of each tooth and measurements were made perpendicular to points at the root apex and at $2/3$ the length of the tooth measured from the incisal edge (Point X). Before and after measurements of the total width of the alveolus were compared and paired t-tests were done to determine statistical significance.

Results: There was an average increase of 1.04 mm (range: -2.3 mm – 10.73 mm) around the apices 0.98 mm (range: -2.61 mm – 3.33 mm) around point X of the measured teeth. Paired t-tests showed statistical significance for both measurements at the apex ($p < 0.01$) and at point X ($p < 0.001$).

Conclusions: This study showed an average increase in alveolar bone width around teeth that had undergone PAOO. However, while there was an average increase, there were also sites in which there was a decrease in alveolar width. While it seems that PAOO can be a safe and

effective treatment, like with any surgical procedure, there can still be complications and case selection is key to attaining predictable results. More prospective randomized control studies need to be done.

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1. INTRODUCTION

1.1 Orthodontic Movement

Orthodontic tooth movement involves the resorption and deposition of bone around teeth as they are moved through the alveolar bone. In response to mechanical forces, there are induced changes in a number of cells, mediators, and growth factors in the bone and periodontal tissue. Although there seems to be remodeling of the periodontal ligament (PDL) that leads to expression of matrix metalloproteinases (MMPS) and tissue inhibitors of metalloproteinases (TIMPs) important to this process, it has been shown that movement can still occur when the PDL is functioning abnormally.¹ Although it is not completely clear how the tissue discriminates between pressure and tension in response to mechanical stress, bone deposition occurs on the tension sites around the teeth and bone resorption on the pressure sites.¹

When mechanical forces are applied, there seems to be an inflammatory response in which a cascade of cytokines and other molecules induce bone remodeling.² Gingival crevicular fluid (GCF) found in the gingival sulcus around teeth is made up of serum and a variety of molecules and cells that may play a key role in inflammation mediation around teeth. It has been shown that during orthodontic tooth movement there is an increase in inflammatory mediators such as IL-1, IL-6, and TNF-alpha³ as well as an increased concentration of receptor activator of nuclear factor kappa ligand (RANKL).⁴ RANKL is released by osteoblasts and binds to the receptor activator of nuclear factor kappa (RANK) receptor on osteoclasts, inducing bone resorption. Osteoprotegerin (OPT), also produced by osteoblasts, competes with RANKL and suppresses osteoclastic

activity. In a review, Yamaguchi explored the importance of RANK, RANKL, and OPG in orthodontic tooth movement and suggested that in response to mechanical stress, these molecules are regulated by inflammatory cytokines in the PDL.⁵ It has also been shown that orthodontic tooth movement is inhibited by administration of non-steroidal anti-inflammatory drugs (NSAIDS) in experimental animals suggesting that the inflammatory process plays a key role in bone remodeling during orthodontic tooth movement.

1.2 Orthodontic Complications

Periodontitis is an inflammatory disease that is known to be caused by bacterial plaque. If inflammation is also a key component in orthodontic tooth movement, it is logical to suggest that orthodontic treatment can be considered a predisposing factor for the progression of periodontal disease. Also, it has been suggested that orthodontic appliances can make it more difficult to have adequate oral hygiene, leading to an increased aggregation of pathogenic bacteria.^{6, 7} Also, orthodontic patients are at an increased risk at developing white spot lesions around orthodontic appliances which may become cariogenic or esthetic problems during and after treatment.⁸ With increased inflammation due to orthodontic movement, and the possibility of increased bacterial plaque due to orthodontic appliances, there is also the risk of increased attachment loss. Also, in patients that already have thin alveolar housing, attachment loss could lead to complications such as mobility and recession. Movement of the teeth out of this thin alveolar process may be associated with a higher tendency to develop recession.⁹

It has also been shown that with orthodontic tooth movement, root resorption is an iatrogenic consequence that occurs during the course of treatment. While it has been shown that risk factors for root resorption include magnitude and distribution of force, treatment duration may be one of the most important factors contributing to root resorption.¹⁰⁻¹²

1.3 Corticotomy

Due to complications associated with longer and more extensive orthodontic treatment, procedures to shorten orthodontic treatment time have been developed. These procedures include corticotomy, low-level laser therapy, electromagnetic fields, and periodontal distraction. Based on the current literature, it seems as though corticotomy is the safest and most effective way of accelerating orthodontic tooth movement.¹³ In 1959, Kole demonstrated that interradicular corticotomies and supra-apical osteotomies would cause rapid tooth movement, and Duker, in 1975, used corticotomies to circumscribe the roots of teeth in beagle dogs to demonstrate rapid tooth movement.^{14,15} It was initially believed that the whole bony block that was outlined by corticotomy moved and retained its structural integrity during orthodontic treatment. This theory prevailed until 2001 when Wilcko *et al.*,¹⁶ believed that the rapid tooth movement was due to the regional acceleratory phenomenon (RAP) described by Frost in 1983.¹⁷ RAP occurs after the bone is “injured” by the corticotomy and increases the rapidity of bone remodeling and healing. It begins within a few days of the corticotomy/fracture, and, typically, peaks around one to two months and may take six to 24 months to complete.¹⁸ During RAP, a cascade of events occurs to increase the rate of demineralization and remineralization of

bone. Since orthodontic tooth movement requires this bone turnover to occur, by decorticating the alveolar bone around teeth, the increased rate of turnover allows more rapid tooth movement and treatment which can be accomplished in half to one third of the usual time.¹⁹ Mostafa *et al.*, in 2009,¹⁹ showed in beagle dogs that corticotomy-assisted orthodontics doubled the rate of tooth movement as compared to conventional orthodontic movement.

1.4 Periodontally Accelerated Osteogenic Orthodontics (PAOO)

In 2001, Wilcko *et al.*,¹⁶ reported on a technique that combined the bone accelerating process of alveolar decortication and alveolar augmentation using particulate grafting prior to orthodontic treatment. They termed this technique accelerated osteogenic orthodontics (AOO) or periodontally accelerated osteogenic orthodontics (PAOO). The main objective of this procedure was to create a thin layer of bone ($\geq 1.5\text{mm}$) over the roots in the direction of the intended tooth movement.²⁰ The main potential advantages of PAOO are the decreased treatment time and the increased alveolar volume to possibly prevent some periodontal complications that may occur in some orthodontic patients.

1.5 Bone Grafting

By using particulate graft material to try to increase the volume of the alveolar housing during orthodontic movement, it is theorized that the teeth will be more stable following orthodontic treatment and will have less of a tendency for relapse. Wilcko *et al.*²⁰ suggest using a mixture of demineralized freeze-dried bone allograft (DFDBA) combined with either bovine particulate graft material or freeze dried bone allograft (FDBA).

Depending on the amount of movement needed, they recommend using from 0.25 to 1cc per tooth undergoing this “activation” process. They do not use any type of membrane in their case reports and claim that the graft material is contained in the desired position by the full thickness flap. However, they do suggest that the use of a resorbable membrane could be employed in this technique.

There have been several methods to augmenting the alveolar ridge. The procedure known as guided bone regeneration (GBR) involves the use of an occlusive barrier membrane with or without bone grafting material, and has been considered a successful technique for increasing alveolar bone volume. In the 1980s, guided tissue regeneration (GTR) was introduced to form new bone around teeth using a barrier membrane that would prevent soft tissue from growing into the osseous defect, and to allow osteogenic cells to create new bone^{21,22} The GBR technique was developed from the concept of GTR and initially involved the use of a non-resorbable expanded polytetrafluoroethylene (e-PTFE) membrane.²³ The ideal properties of a barrier membrane include biocompatibility, adequate space maintenance ability, and cell-occlusive properties²⁴ While the use of non-resorbable PTFE membranes is considered the “gold standard,” bioresorbable collagen membranes eliminate the need for a 2nd surgical operation to remove the membrane and have shown successful results for GBR.^{25, 26} It has been shown that mean gains in horizontal ridge width have varied anywhere from 1.5 - 5.5 mm of new bone. Geurs *et al.*, performed a GBR procedure with a bioabsorbable synthetic membrane with particulate bone allograft and found an average increase of 2.4 - 5.2 mm of new bone at the ridge crest and 4.4 - 7.5 mm of new bone 4 mm apical to the crest.²⁷

1.6 Cone Beam Computed Tomography (CBCT)

Cone beam computed tomography (CBCT) is a variation of traditional computed tomography that allows three-dimensional imaging of the maxillofacial region and is becoming increasingly popular in dentistry. While traditional CTs generate a fan-beam, CBCT scanners generate a cone-shaped beam. One of the most significant advantages of CBCT over traditional CT is the reduced amount of radiation the patient is exposed to during a scan. While a CT of the head can expose the patient to an effective dose of ionizing radiation varying from 1202 - 3324 uSv, CBCT scans only expose the patient to a range of 19.9-42.1 uSv.²⁸ Along with the reduced radiation dose and reduced cost of equipment, one of the other advantages of CBCT compared to traditional CT is that due to the cone-shaped beam, the total scan time is decreased, and, therefore, there is less of a chance for the patient to move around and cause artifacts or distortion in the final image.²⁹

Along with the advantages of CBCT, there are some disadvantages as well. One of the main disadvantages of CBCTs is the inability to clearly distinguish bone and soft tissue boundaries.²⁹ While CBCT is able to accurately depict the shape and dimensions of alveolar bone in edentulous areas, it may be more difficult to accurately show alveolar bone around teeth due to the thinness (especially on the buccal) as well as root proximity and periodontal ligament space. While many studies have shown an accuracy level of under a millimeter, some have shown that CBCTs may underestimate alveolar bone width up to 1-2 mm.

In a study by Kobayashi *et al.*, the alveolar bone of cadaver mandibles was measured by hand with calipers as well as with CBCT. The accuracy of CBCT to measure the alveolar bone was determined to be within 0.01 to 0.65 mm (0.1% to 5.2%).³⁰ Timock, *et al.*, agreed that CBCT measurements showed a high degree of accuracy and precision with a mean absolute difference of 0.30 mm in alveolar bone height and 0.13 mm in width.³¹

In a study with 13 human skulls and 334 teeth, Leung *et al.*, showed that the CBCT measurements showed mean deviations of 0.1 +/- 0.5 mm for measurements from the cusp or incisal edge to the cemento-enamel junction and 0.2 +/- 1.0 mm to the bone margin.³² They also looked at the accuracy of CBCT in detecting fenestrations and dehiscence and found that the sensitivity and specificity for fenestrations were both about 0.80, whereas the specificity for dehiscence was higher (0.95) and the sensitivity lower (0.40). Therefore, it was concluded that fenestrations could be detected with greater accuracy than dehiscence.

Patcas *et al.*, showed that bony measures obtained with CBCT were fairly precise and only differed from physical findings about 0.13 mm.³³ However, there were discrepancies that were ranged up to 2.10 mm, depending on measurement and resolution. They concluded that although CBCT can accurately depict linear measurements, it may not depict thin buccal alveolar housing reliably, and there is risk of overestimating fenestrations and dehiscence.

1.7 Problems with measuring alveolar bone after PAOO

There is inherent difficulty in accurately depicting linear and volumetric measurements before and after periodontally accelerated osteogenic orthodontics. Since the teeth have been moved orthodontically, it is possible that they have been moved into a region with a thicker alveolar housing regardless of the grafting procedure. Also, the mandibular plane is often used as a reference line to evaluate the inclination of the mandibular incisors as compared to the alveolar housing. However, if the patients are adolescents who are still growing, there will be some discrepancies in the before and after CBCTs regarding various reference points, and superimposition of the images will be slightly inaccurate.³⁴

Ahn *et al.*, chose to measure alveolar thickness from the apex of the tooth as well as from the “B-point” which was the shallowest point of the buccal plate as visualized on lateral cephalograms.³⁴ By keeping the tooth as the reference when measuring alveolar bone, one must consider the possibility of root resorption on the post-operative image as well as mesial-distal tilting of the tooth causing foreshortening. Also, the B-point pre-operatively may have been grafted over during PAOO and may also undergo remodeling during growth and orthodontic movement.

2. OBJECTIVE

The objective of this paper is to develop accurate and reproducible methods for measuring alveolar bone thickness and volume before and after PAOO in order to determine if there really is a significant increase in the alveolar housing to support the teeth following orthodontic treatment.

3. MATERIALS AND METHODS

CBCTs were obtained from four patients aged 17-28 years old (three females and one male) who had undergone the PAOO procedure. Patients signed informed consent forms regarding the surgery and orthodontic treatment. All patients were deemed healthy with no history of smoking, systemic disease or developmental disorders, and they denied any use of prescription or recreational drugs.

3.1 Surgical Procedure

Each patient received either sulcular or papilla sparing incisions on the buccal and/or lingual surfaces from 1st bicuspid to 1st bicuspid, on the maxilla, mandible, or both (Figure 1). Vertical corticotomies were performed using either a tapered bur in a high-speed handpiece, or with a piezoelectric surgical saw just past the cortical plate (Figure 2). Two - three cc of freeze-dried bone allograft was used to pack at least 2 mm thickness of graft material over the roots of the involved teeth (Figure 3).



Figure 1: Full thickness flap reflected from premolar to premolar



Figure 2: Vertical selective decortication between roots of teeth undergoing PAOO



Figure 3: Grafting particulate freeze dried bone allograft of about 1.5-2mm thickness over buccal plate.

Graft material was covered with Biogide collagen membranes (Geistlich, Switzerland), and flaps were sutured back into place to achieve primary wound closure with 5.0 vicryl sutures (Figure 4). In all cases first bicuspids were extracted, and extraction sockets were grafted with freeze-dried bone allograft during the surgical procedure. Patients were

given hydrocodone/acetaminophen 5-mg/500 mg to take as needed for pain as well as 500 mg tablets of amoxicillin to take three times a day for seven days. Patients were also advised to rinse with 0.2% chlorhexidine gluconate rinse twice daily for two weeks. Oral hygiene instruction was administered at one week (Figure 5) and two weeks following surgery. Patients were seen for suture removal at two weeks post-surgery, and orthodontic tooth movement was activated within two to four weeks following the surgical procedure.



Figure 4: Closure of surgical site with 5.0 vicryl sutures.



Figure 5: 1 week post-operative healing

3.2 Orthodontic Treatment

Three of the four patients had received orthodontic treatment prior to the PAOO procedure that had left the patient unsatisfied with the final result. All cases involved retracting and aligning crowded anterior teeth. Orthodontic treatment time ranged from 7 to 16 months after the corticotomy and bone graft procedures were completed.

3.3 CBCT

Pre-treatment and post-treatment cone beam CT scans were obtained for the four patients who underwent orthodontic treatment as well as the corticotomy and bone graft procedure (PAOO). All CBCT scans were obtained from Bay Area Advanced Imaging, (Sunnyvale, CA) and were taken by a Board Certified radiologist. All CBCTs were taken using the Imaging Sciences i-CAT Platinum (Imaging Sciences International, LLC, Hatfield, PA) using the 0.25 mm setting at 26 seconds. The field of view was custom collimated to the individual patient to cover only from the top of the TMJ to the bottom of the mandible.

Scans were uploaded into the Anatomage Invivo software (Anatomage, San Jose, CA), and measurements were taken along the long axis of all teeth that underwent the PAOO procedure measuring the tooth length from incisal edge to root apex. Linear measurements were taken 90 degrees to the long axis of the tooth from the buccal and lingual plates to the root apex, as well as to a point 2/3 the length of the tooth measured from the incisal edge (Point X). Linear measurements taken on the post-treatment CBCTs were taken from the same root apex and Point X measured from the pre-treatment

CBCTs to account for root resorption and/or mesial and distal tipping of the root. All measurements were initially recorded by a postgraduate periodontology resident, and the measurement method was duplicated for all teeth by a third year dental student in order to verify reproducibility of the measuring technique.

3.4 Measuring and Statistical Analysis

Linear measurements were taken from the apex of each involved tooth, as well as from Point X, to the buccal and lingual alveolus (Figure 6). The sum of the measured buccal and lingual distances to each point equaled the total width of alveolar housing around the involved teeth at those specific points. The total width as well as the amount of buccal and lingual bone were compared between the before and after CBCTs for each involved tooth, and the differences in bone width for each site was calculated. The average difference in bone width was calculated for the apex of the tooth (Table 1), as well as from point X (Table 2). Paired t-tests were done using STATA statistical software (StataCorp, College Station, TX) to determine statistical significance in the differences between before and after measurements at the apex and point X at each site .

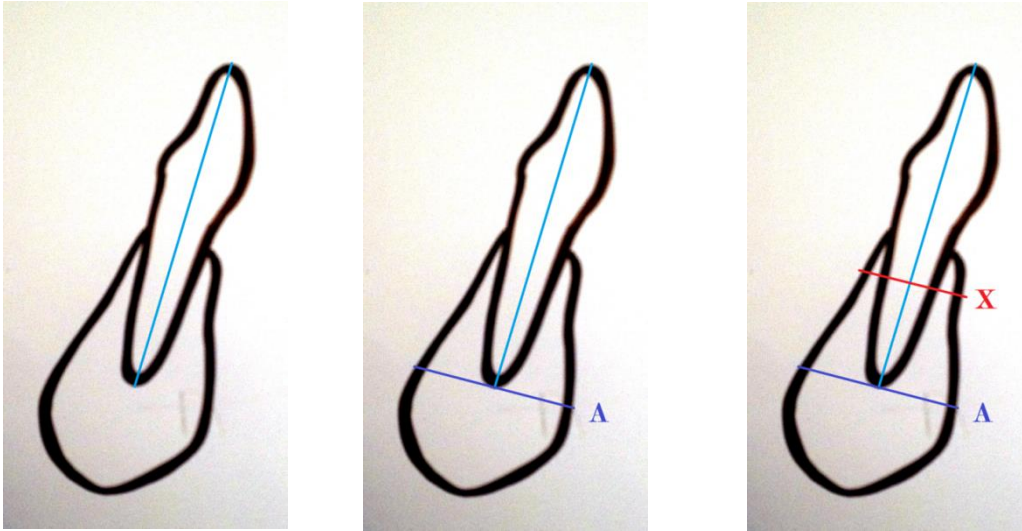


Figure 6: Measurements were taken from point A (apex along the long axis of the tooth) and from point X (2/3 the length of the tooth measured from the incisal edge).

4. RESULTS

Each patient completed treatment and were satisfied with the outcome. All healing was uneventful, and there were no reports of any complications such as post-operative infection.

Some of the sites had to be excluded because an adequate sagittal slice of the long axis of the tooth could not be visualized on the Anatomage Invivo software or because the measurement at the apical aspect of the tooth extended into the hard palate. However, there were visible changes in the width of the alveolar housing surrounding treated teeth as seen on the CBCTs (Figures 7, 8, 9). All values for the measurements of alveolar bone width before and after PAOO are shown in Tables 1 and 2.

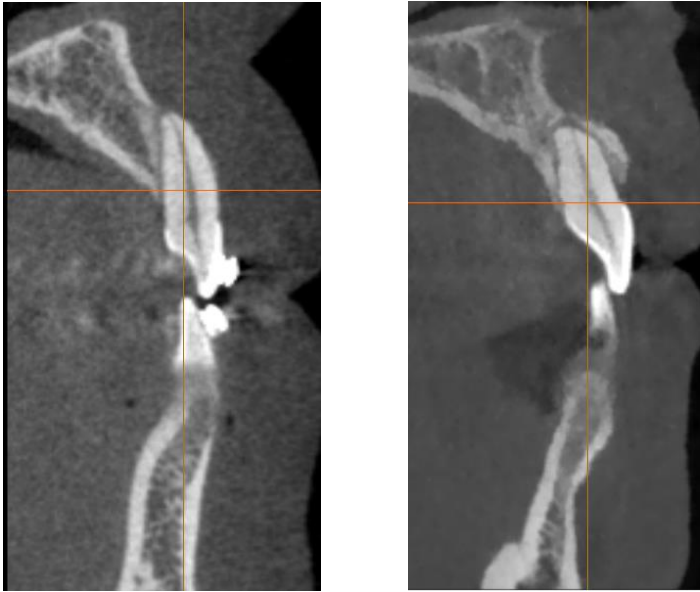


Figure 7: CBCT sagittal planar image of a tooth before and after grafting in one patient.

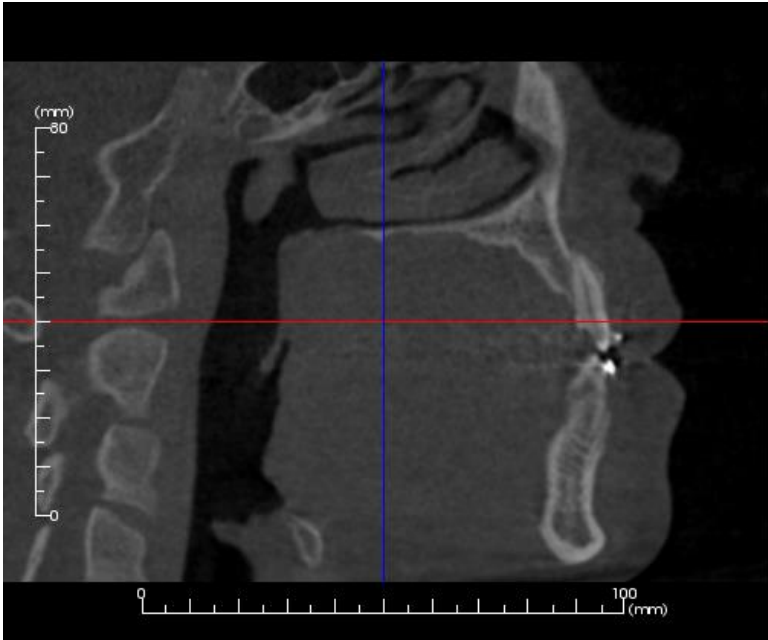


Figure 8: Sagittal CBCT views before and after PAOO

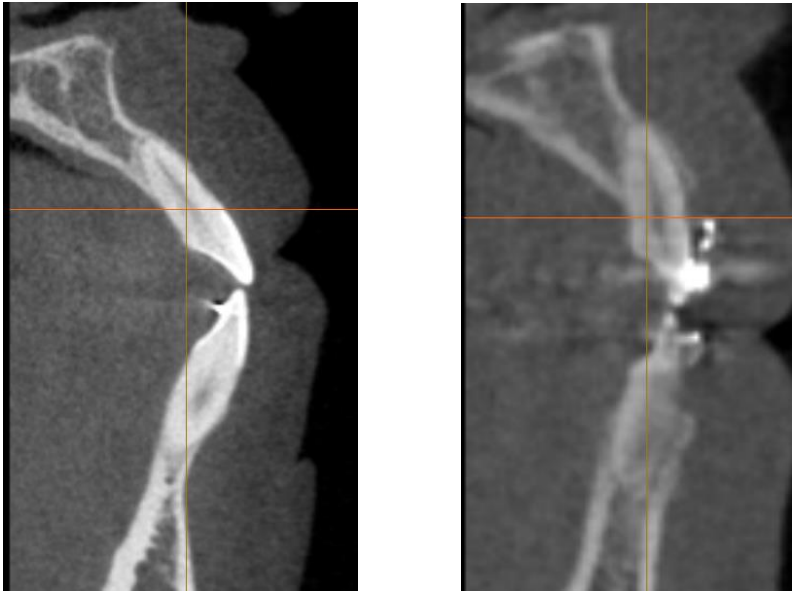


Figure 9: Visible increase in alveolar width around mandibular lateral incisor.

In some sites there was evidence of tooth resorption (Figure 10) showing that regardless of the shortened treatment time, there may still be some root resorption that occurs as a result of the orthodontic tooth movement.

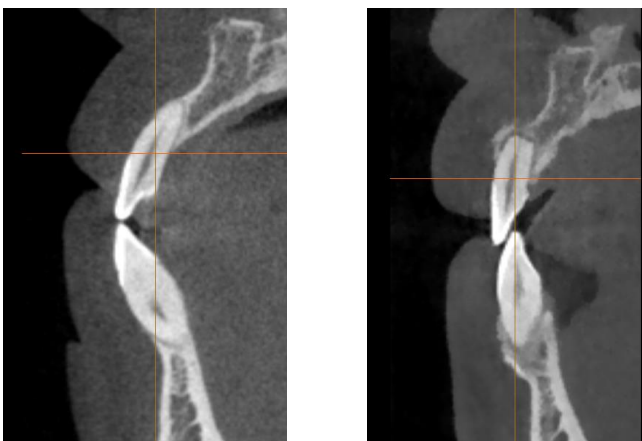


Figure 10: Example of root resorption in maxillary lateral incisor

Table 1: Measurements of alveolar bone width before and after PAOO at apex.

Total Width of Alveolus at Apex (mm)			
Site	Before	After	Difference
1	could not be measured	9.62	n/a
2	16.29	13.99	-2.3
3	9.53	11.71	2.18
4	9.33	11.88	2.55
5	13.5	13.19	-0.31
6	could not be measured	12.59	n/a
7	9.78	8.99	-0.79
8	9.06	10.16	1.1
9	8.73	8.76	0.03
10	8.73	8.87	0.14
11	8.4	9.25	0.85
12	10.19	9.71	-0.48
13	10.98	10.58	-0.4
14	6.37	6.35	-0.02
15	8.84	9.21	0.37
16	8.27	7.15	-1.12
17	6.42	5.59	-0.83
18	10.27	9.03	-1.24
19	6.27	7.11	0.84
20	5.01	5.13	0.12
21	4.18	4.87	0.69
22	5.38	6.13	0.75
23	4.99	7.49	2.5
24	7.48	8	0.52
25	10.26	20.99	10.73
26	4.92	9.85	4.93
27	6.34	6.99	0.65
28	9.24	8.4	-0.84
29	5.08	7.79	2.71
30	11.77	15.48	3.71
31	5.28	5.64	0.36
32	5.14	4.93	-0.21
33	5.36	5.12	-0.24
34	6.85	6.42	-0.43
35	9.07	10.25	1.18
36	7.55	10.43	2.88
37	6.59	8.37	1.78
38	7.17	9.49	2.32
39	6.35	7.55	1.2
40	9.31	11.91	2.6
41	6.03	7.74	1.71
42	3.8	6.93	3.13
43	5.26	5.19	-0.07
44	4.51	5.63	1.12
45	6.51	7.02	0.51
		Average Difference:	1.0437

Table 2: Measurements of alveolar bone width before and after PAOO at Point X

Total Width of Alveolus at Point X (mm)			
Site	Before	After	Difference
1	8.32	11.4	3.08
2	10.55	10.57	0.02
3	8.23	8.76	0.53
4	7.87	10.19	2.32
5	8.43	10.19	1.76
6	13	10.39	-2.61
7	10.64	9.12	-1.52
8	6.52	8.13	1.61
9	6.29	7.45	1.16
10	6.07	8.65	2.58
11	6.63	9.65	3.02
12	9.97	10.23	0.26
13	9.76	9.89	0.13
14	7.84	6.78	-1.06
15	8.37	7.21	-1.16
16	7.8	7.63	-0.17
17	7.21	7.26	0.05
18	9.27	9.09	-0.18
19	8.48	7.92	-0.56
20	6.59	6.78	0.19
21	5.35	5.82	0.47
22	6.68	6.67	-0.01
23	6.26	8.46	2.2
24	7.53	7.78	0.25
25	9.58	12.69	3.11
26	5.99	8.17	2.18
27	6.99	6.85	-0.14
28	9.07	8.55	-0.52
29	6.24	7.47	1.23
30	10.27	11.01	0.74
31	6.62	6.85	0.23
32	5.63	5.48	-0.15
33	5.98	5.68	-0.3
34	6.12	6.27	0.15
35	9.12	10.8	1.68
36	6.52	7.71	1.19
37	6.97	10.11	3.14
38	6.75	10.08	3.33
39	5.32	9.42	4.1
40	9.11	11.28	2.17
41	7.99	10.35	2.36
42	6.16	8.27	2.11
43	5.99	6.88	0.89
44	6.92	8.01	1.09
45	7.3	10.34	3.04
		Average Difference:	0.97755556

It was found that the average increase occurred of 1.04 mm at the apices of the teeth and of 0.98 mm at point X. The ranges for the differences around the apices were -2.30 mm to 10.73 mm (Figures 11 and 12) and around point X was -2.61 mm to 3.33 mm (Figures 13 and 14). Paired t-tests revealed that there was a statistical significance in the differences between the before and after measurements both at the apices of the sites ($p < 0.01$) and at point X ($p < 0.001$; Tables 3 and 4).

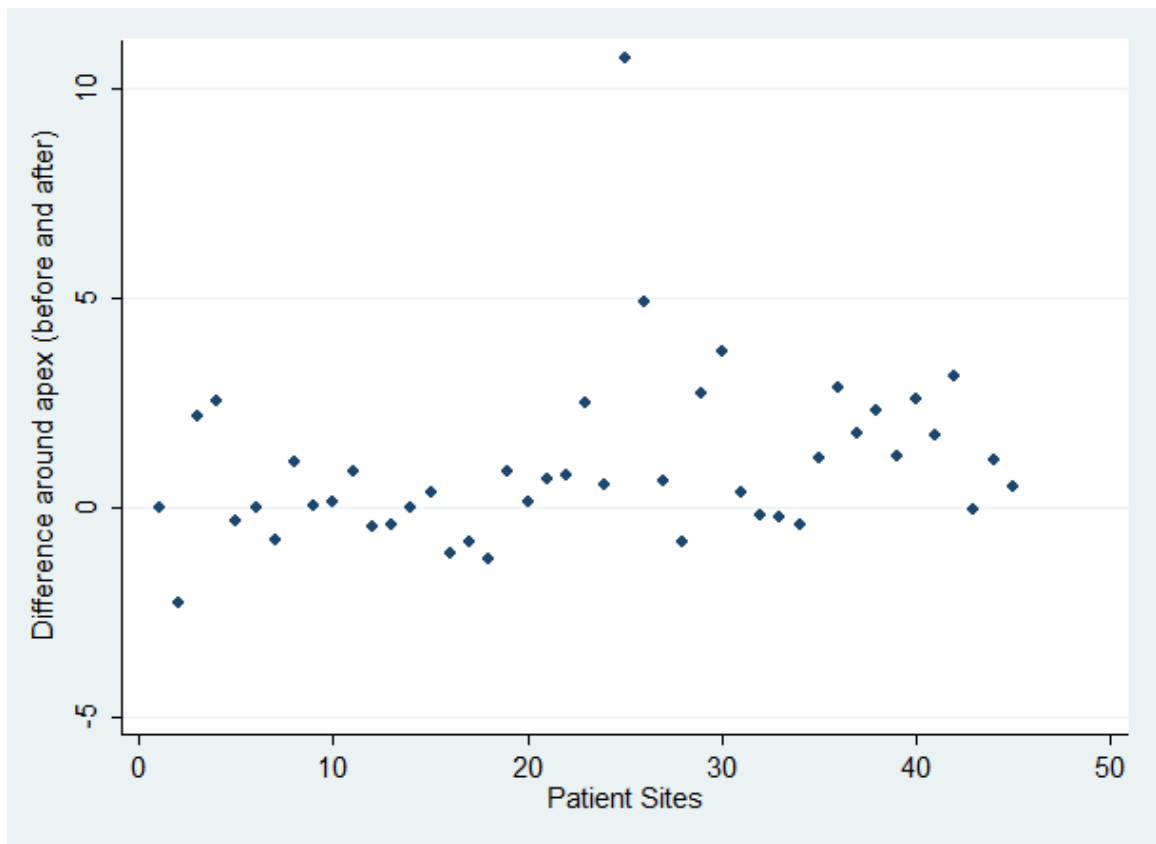


Figure 11: Differences in alveolar bone width before and after PAOO at apex at each patient site

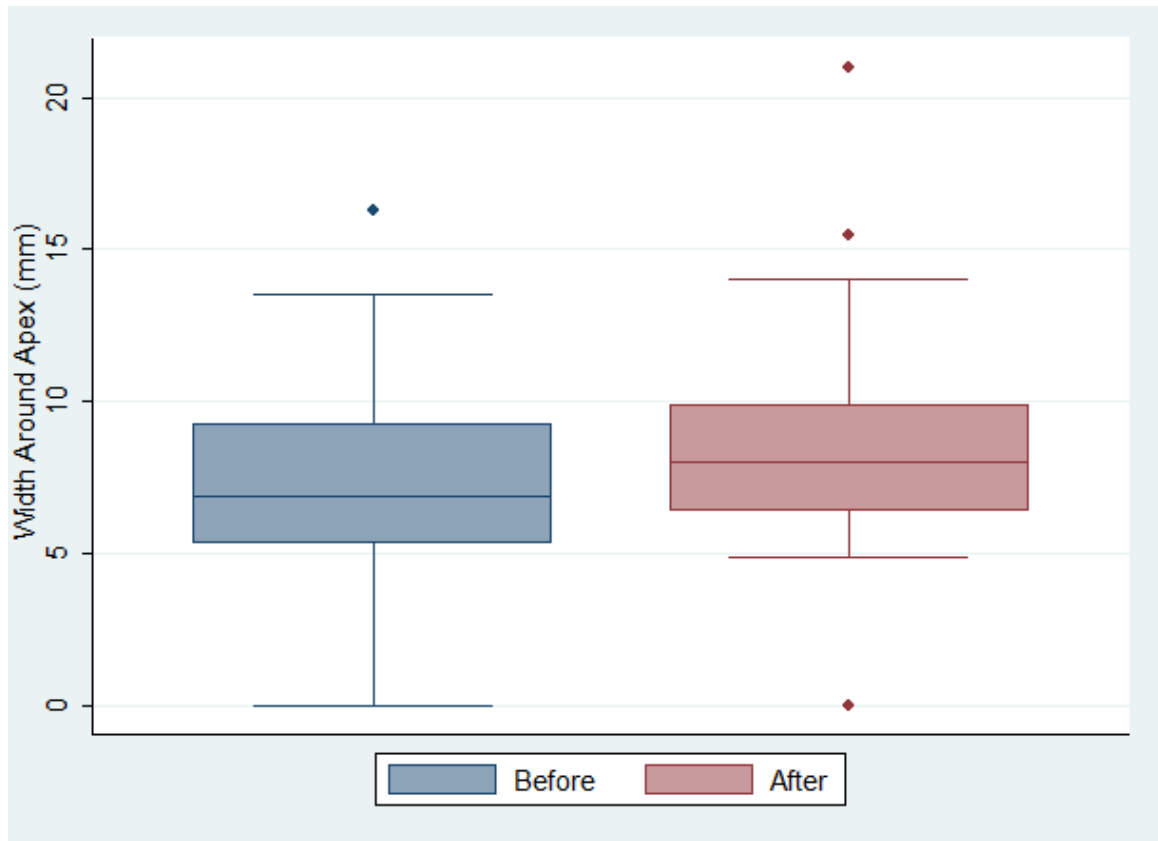


Figure 12: Box plot showing difference of alveolar bone width at the apex before and after PAOO in which the median, 25 and 75% quartiles, and ranges are depicted.

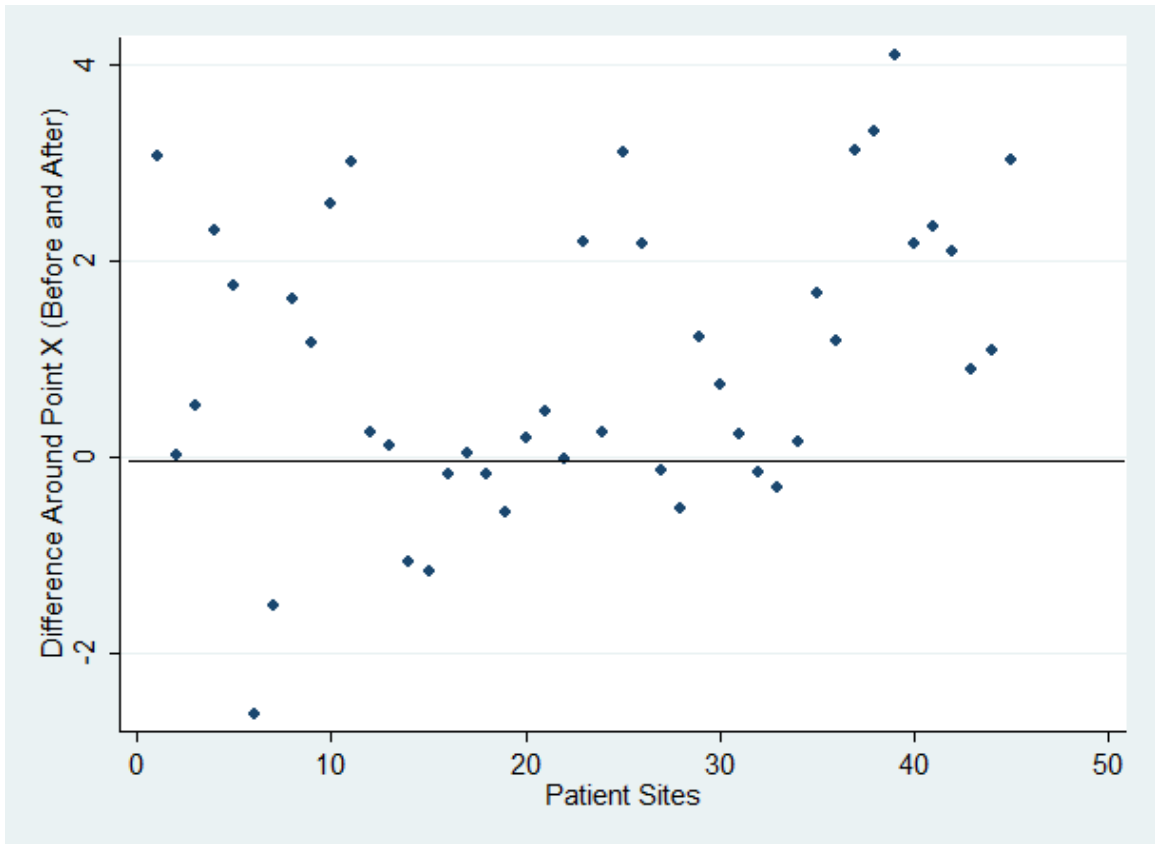


Figure 13 – Differences in alveolar bone width before and after PAOO at Point X at each patient site

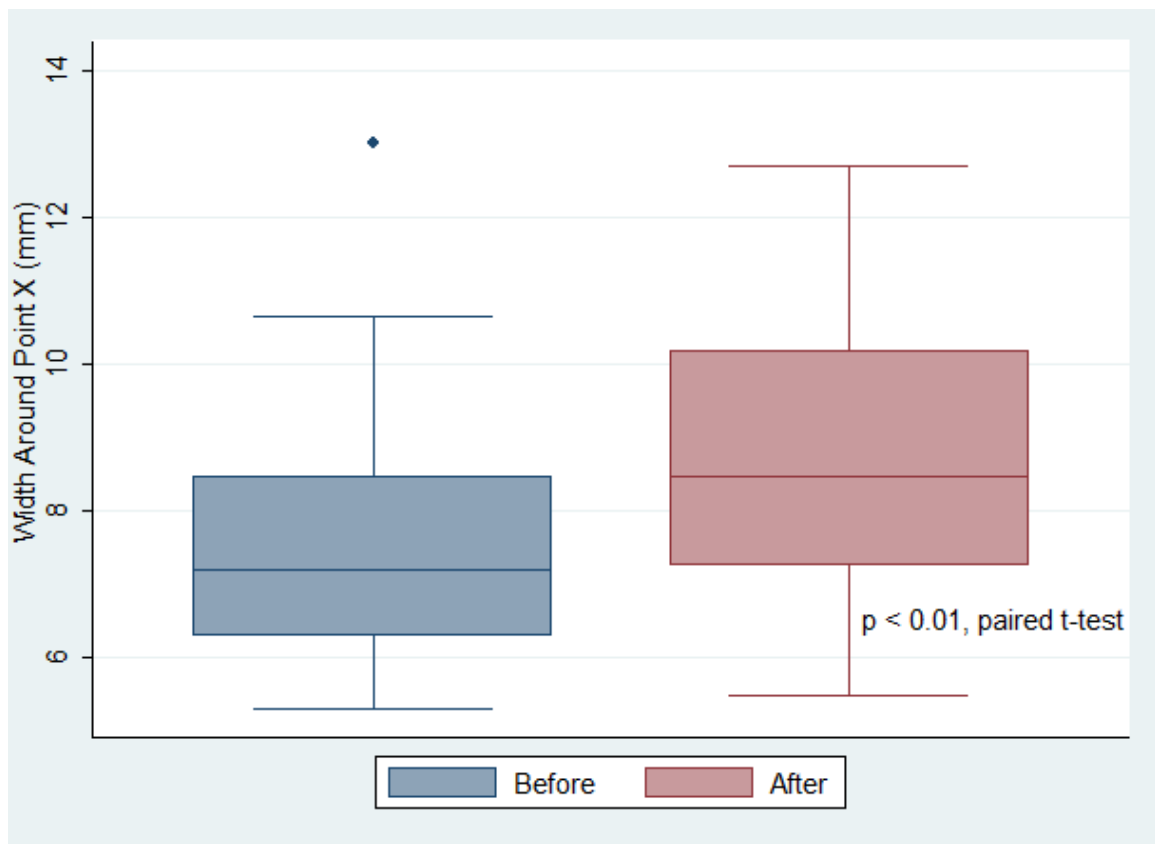


Figure 14: Box plot showing difference of alveolar bone width at the point X before and after PAOO

Table 3: Paired t-test for measurements taken at apex

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
widtha..	45	7.342	.4505822	3.022597	6.433911	8.250089
~exafter	45	8.339333	.5349222	3.588367	7.261268	9.417398
diff	45	-.9973332	.3093768	2.075362	-1.620841	-.3738254

mean(diff) = mean(widtharoundape~e - widtharoundape~r) t = -3.2237
 Ho: mean(diff) = 0 degrees of freedom = 44

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0
 Pr(T < t) = 0.0012 Pr(|T| > |t|) = 0.0024 Pr(T > t) = 0.9988

Table 4: Paired t-test for measurements taken at point X

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
widtha..	45	7.651111	.2496167	1.67448	7.148042	8.154181
~dxafter	45	8.628667	.2588132	1.736172	8.107063	9.15027
diff	45	-.9775556	.2214336	1.485422	-1.423826	-.5312855

mean(diff) = mean(widtharoundxbe~e - widtharoundxaf~r) t = -4.4147
 Ho: mean(diff) = 0 degrees of freedom = 44

Ha: mean(diff) < 0 Ha: mean(diff) != 0 Ha: mean(diff) > 0
 Pr(T < t) = 0.0000 Pr(|T| > |t|) = 0.0001 Pr(T > t) = 1.0000

5. DISCUSSION

In trying to determine an appropriate measurement technique, there were many variables that were difficult to manage. First of all, it was challenging to find points of reference that would be constant throughout orthodontic treatment. Especially in the patients who were in their late teenage years, it is possible that they are not completely finished with their growth, and some reference points may shift as they develop. Also, by using the tooth as a reference, the software was only able to measure straight sagittal slices through the CBCT, and any mesial or distal tipping of the root of the tooth would cause the slice to be skewed along the long axis of the tooth. Therefore, any measurements taken along the length of the tooth would have to keep this in consideration. It was also difficult to determine what increase in buccal or lingual plate thickness around the tooth could be attributed to the graft material, itself, and what was just a result of the teeth being brought into the alveolar housing by orthodontic tooth movement. A method of using the mandibular angle and the menton line as reference points to superimpose pre- and post-operative images was suggested, however, in the still growing patients, this would not be accurate as those reference points may shift.

One drawback to this study is that it was a retrospective study to look at only those patients who had the PAOO procedure done. There were no matched controls who had similar alveolar widths and orthodontic treatment done without the use of the corticotomy and bone grafting procedure. Therefore, we cannot compare what would have been the net gain or loss in alveolar bone width had there been no grafting procedure done.

While the results show that the average alveolar bone width increased by about a millimeter overall, there were some sites that showed a loss of alveolar width. Nonetheless, according to many of the sagittal slices along the long axis of the teeth, it is shown that many of the teeth have a greater thickness of alveolar bone around the teeth, even if the overall width may be less at certain sites. Whether the alveolar bone shown around the teeth post-operatively is new bone, graft material, or a combination of both cannot be determined without histologic sampling from these patients. Wilcko *et al.*, re-entered a patient 15 months after the decortication and graft procedure, and found that there were still graft particles that did not incorporate into the alveolar housing.¹⁶ Regardless of un-integrated graft particles, they did find an overall increase in the alveolar width in the bucco-lingual dimension as well as covered previously dehiscenced roots. Also, depending on how the teeth were moved orthodontically, the angle of the long axis of the tooth compared to the measurements to the buccal and lingual plate could vary between pre- and post-operative scans.

Yaffe *et al.*, in 1994, showed that just by elevating a mucoperiosteal flap in rats, the regional acceleratory phenomenon occurred, and there was an initial rapid resorption of alveolar bone.³⁵ The alveolar bone width recovered to near control levels 120 days following surgery, but the authors noted that in cases where the alveolar plate was thin, this initial resorption which occurs in RAP may lead to dehiscence and fenestrations that may not fully recover. Donnenfeld *et al.*, in 1964, showed that there was a mean crestal bone loss of 0.6 mm after elevation of full thickness flap³⁶ and Tavtigian estimated a mean loss of 0.47 mm of crestal bone after flap elevation.³⁷ Fickl *et al.*, showed that

when elevating a full thickness flap during tooth extraction in beagle dogs, an additional 0.7 mm of alveolar bone loss can be expected.³⁸ It can be concluded from this evidence that by reflecting a full thickness flap, there will inevitably be some loss of alveolar bone due to activation of the regional acceleratory phenomenon. Therefore, if decortication had been the only treatment performed on these patients with already thin alveolar bone, they may have experienced dehiscence or fenestrations that may have resulted in further complications such as attachment loss and/or mobility. Therefore, the results of this study as well as other previous case studies validate the use of graft material in combination with selective decortication to provide additional stability during and after orthodontic treatment.

CBCTs were obtained within a few months of debanding these patients, and no long-term data has been collected. Although the teeth seem stable within the alveolar housing initially after orthodontic treatment, we cannot predict long term what will happen to the graft material around these teeth.

6. CONCLUSION

These results show that within this small sample size, there was an overall increase in alveolar width both at the apices and mid-root of the teeth involved with the PAOO procedure. Whether the increase in measurement is due to the graft material, itself, the orthodontic tooth movement, or a combination of both is difficult to determine. Also, whether the increased bone shown radiographically is histologically new bone could not be determined in this study. Although treatment may have been shorter than traditional orthodontic movement, there were no matched controls to compare overall treatment time for similar treatment modalities. By comparing pre and post-operative CBCTs there may still have been some root-end resorption in some cases. However, it is difficult to assess if this was true resorption or mesial-distal tipping of the teeth making it difficult to obtain an accurate sagittal slice through the entirety of the tooth.

Overall, PAOO seems to be a safe procedure that can shorten treatment time and potentially provide for better post-operative stability by slightly increasing the width of the alveolar housing. While the methodology for measuring pre- and post-operative alveolar width was reproducible and able to provide general knowledge of the width of the alveolus in relation to the teeth being moved orthodontically, it was not able to account for root resorption or mesial/distal tipping of the teeth. Also, the amount and type of orthodontic tooth movement has an effect on the bone surrounding the tooth, which was not quantified in this study. In patients with thin buccal or lingual alveolar bone looking to undergo orthodontic treatment, PAOO may be a valuable procedure to reduce treatment time and possible periodontal complications such as attachment loss,

dehiscence, fenestration, mobility and recession. However, case selection is extremely important, and disadvantages such as cost and complications of an additional surgical procedure must be considered and discussed with the patient. Further studies need to be done to determine long-term outcomes on patients undergoing this PAOO procedure, and if there are differences in outcomes compared to patients who have similar pre-treatment characteristics that do not have the procedure done.

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