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Clinical and Radiographic Evaluation of Bone Grafting in Corticotomy-facilitated Orthodontics in Adults

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Abstract

Aim: To evaluate the effect of bone grafting in corticotomy-facilitated orthodontics in adults, using a further modified conventional corticotomy technique. **Methods:** Twenty adult orthodontic patients with moderate crowding of the lower anterior teeth were equally divided into two groups and treated with either a modified corticotomy-facilitated orthodontic tooth movement alone (Group I) or modified corticotomy-facilitated orthodontic tooth movement combined with bone grafting (Group II). Total treatment time was calculated in weeks from the time of activation of the orthodontic appliance immediately following the corticotomy procedure to the time of debracketing. Clinical periodontal parameters and standardized periapical radiographs were recorded at baseline, post-orthodontic treatment (debracketing time) and six months post-operatively. The primary radiographic variables were root length and bone density. **Results:** Treatment duration for patients in both groups ranged from 14-20 weeks. There was no statistically significant difference between the two groups in clinical parameters at each time interval. The net percentage of change that occurred to bone density from baseline to six months post-orthodontic treatment was statistically significantly different between the two groups. Group I demonstrated a net decrease in bone density of -17.59%, while Group II demonstrated a net increase in bone density of 25.85%. Group I demonstrated an average net decrease in root length of -0.056 mm ± 0.025, while Group II demonstrated an average net decrease in root length of -0.050 mm ± 0.026, which was not statistically significantly different.

Conclusion: The results of the current study suggest that corticotomy-facilitated orthodontic tooth movement significantly reduces the total time of treatment. In addition, the incidence of apical root resorption and periodontal problems associated with orthodontic tooth movement were reduced. The incorporation of bone graft material significantly increased the alveolar bone density in adult patients.

Key words: Corticotomy- facilitated orthodontics, bone grafts, alloplasts, root resorption, alveolar bone density, follow-up studies.

Introduction

Conventional orthodontic treatment in adults usually results in problems such as marginal bone loss, gingival recession, root resorption, and prolonged treatment time (Newman, 1973; Midgeer *et al.*, 1981; Sharpe *et al.*, 1987; Behrents, 1988; Melsen, 1991). In addition, the characteristics of the anterior alveolar bone have an adverse effect on efforts to remodel bone, particularly in adult maxillary protrusion cases. The anatomic limits set by the cortical plates of the alveolus at the level of the apices act as orthodontic walls (Handelman, 1996). Post-treatment results show less remodeling than desired, in addition to severe resorption, when conventional orthodontic treatment is performed alone (Handelman, 1996).

To avoid these complications, and meet the patient's demand for a short treatment time, corticotomy-facilitated orthodontics is considered. Corticotomy-facilitated orthodontics is a physiologically driven process, and an uninterrupted

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vascular supply to the areas operated upon is critical in maintaining the vitality of the hard and soft tissues. "Mobilization" of any outlined single-tooth blocks of bone (luxation) is absolutely contraindicated. It can lead to intrapulpal and intraosseous morbidity and will not increase the distance that the tooth can be moved. The luxation can also jeopardize the integrity of the neurovascular bundle exiting the apex of the teeth and result in devitalization (Wilcko *et al.*, 2008). The alveolar corticotomy technique has been revised and changed over the years to eliminate possible risks of the procedure, such as periodontal damage and devitalization of the teeth and osseous segments because of inadequate blood supply (Köle, 1959; Generson 1978; Suya, 1991).

Orthopedist Harold Frost recognized that surgical wounding of osseous hard tissue results in striking reorganizing activity adjacent to the site of injury in osseous and/or soft tissue surgery. He collectively termed this cascade of physiologic healing events the "regional acceleratory phenomenon" (RAP; Frost, 1989). Following surgical wounding of cortical bone, RAP potentiates tissue reorganization and healing by way of a transient burst of localized hard and soft tissue remodeling leading to a transient catabolic condition (Shih and Norrdin, 1985). For bone, this transient osteoporosis means increased mobilization of calcium, decreased bone density, and increased bone turnover, all of which facilitate more rapid tooth movement (Wilcko *et al.*, 2001). The tissues formed in the alveolus surrounding the area of desired tooth movement respond efficiently to biomechanical forces, and teeth move rapidly. Medullary bone osteopenia is highest nearest the decortication sites, and as long as the teeth continue to move, complete alveolar recalcification is possible (Ferguson *et al.*, 2006). It has been demonstrated that the residual soft tissue matrix has the ability to induce remineralization after the cessation of tooth movement (Nyman *et al.*, 1985).

In 2001, Wilcko *et al.* described selective alveolar decortication with augmentation grafting combined with orthodontic treatment. They trademarked their technique as accelerated osteogenic orthodontics (AOO), or periodontally accelerated osteogenic orthodontics (PAOO). Although bone tissue shows a good regenerative capacity that results in restoration of its structural and mechanical properties, this capacity for repair may be impaired by poor blood supply, mechanical instability, and the presence of other tissues with higher proliferative activity (AboElsad *et al.*, 2009). PAOO has contributed to greater stability of orthodontic clinical outcomes and less relapse. Nazarov (2003), using the objective grading system (OGS) sanctioned by the American Board of Orthodontics (ABO), observed no differences in non-extraction therapies immediately after treatment between PAOO and non- PAOO groups. At six months post-treatment, three of the nine OGS variables (alignment, marginal ridges, and total score) were significantly better in the PAOO group, and no relapse was demonstrated. Ferguson *et al.* (2006) suggested that the limits of orthodontic treatment can be expanded 2- to 3-fold in all dimensions except retraction following PAOO, and that the stability of these positions is probably due to loss of tissue memory from high turnover of the periodontium as well as increased thickness of the alveolar cortices from the augmentation grafting.

This new orthodontic method includes the advantages of corticotomy surgery and alveolar augmentation. Very frequently there are preexisting alveolar inadequacies such as fenestration and dehiscence over the root surfaces. As long as the root surfaces in these defects are vital and there has been no apical epithelial migration, these alveolar deficiencies can be corrected with alveolar augmentation. In addition, after opening the gingival flap, a larger than expected amount of fenestration and dehiscence may be noted. Because the tooth movement is "buccal to the alveolar bone," grafts of lyophilized material would minimize the risks associated with such movement. Moreover, different authors suggest that the bone grafts are aimed at increasing alveolar volume so that even if very large expansions were implemented to resolve severe crowding, the roots would still have sufficient support (Wilcko, 2001, Wilcko *et al.*, 2009, Ferguson *et al.*, 2007).

Biocompatible tissue-bonding bioactive glasses (BAGs) were first introduced as bone graft materials in the early 1970s (Wilson *et al.*, 1993). Glasses with SiO_2 content between 53 and 56 mol% form a hydroxycarbonated apatite layer and bond to bone but not to soft tissues; the apatite gel layer on the surface of the bioactive glass particles attracts osteoprogenitor cells and osteoblasts, thus stimulating bone formation (Hench *et al.*, 1991). The success of BAGs is due to the bioactivity of the material, which is the result of its composition. An increase of SiO_2, a decrease of alkali, or the addition of Al_2O_3 can control the durability or water resistance of the glass and influence its long-term reliability (Pereira *et al.*, 1994).

The aim of the present study was to evaluate the effect of bone grafting in corticotomy-facilitated orthodontics (CFO) in adults using a further modified corticotomy technique.

Materials and methods

A total of 20 adult orthodontic patients (16 females and 4 males) with an average age range of 24 years and six months, with moderate crowding of the lower anterior teeth were selected from patients seeking orthodontic treatment in the outpatient clinic of the Orthodontic Department, Faculty of Dental Medicine for Girls, Al-Azhar University-Girls' Branch.

The participants were equally and randomly divided into two groups. Group I was treated with a modified technique of corticotomy-facilitated orthodontic tooth movement only, while Group II was treated with a modified technique of corticotomy-facilitated orthodontic tooth movement and bone grafting material. The criteria needed for inclusion in the study were as follows: 1) crowding of the lower anterior teeth, ranging from 3-5 mm (skeletal class I); 2) good oral hygiene; 3) adequate gingival thickness (evaluated using a periodontal probe; De Rouck *et al.*, 2009); 4) no acute periodontal involvement; 5) no previous orthodontic treatment; 6) no previous periodontal surgeries; 7) no regular administration of any medication.

All patients were given information about the proposed treatment and were asked to sign a consent form approved by the local ethics committee. Initial periodontal therapy consisted of full mouth scaling under local anesthesia utilizing both hand and ultrasonic instruments. Four to six weeks following the initial phase of treatment, a reevaluation was performed to assess the periodontal condition. The following data were recorded for all patients: extra-oral and intra-oral photographs, an orthodontic study model, a digital panoramic radiograph and a standardized digital lateral cephalometric radiograph.

Clinical and radiographic parameters were recorded the day of surgery, immediately post-treatment (at the time of debracketing) and six months post-treatment. Clinical measurements were made with a William's probe and recorded to the nearest millimeter. Radiographic measurements were assessed as follows: bone density (BD) was assessed using the DBSWIN software, which is a part of the recently introduced Vistascan system. The mean gray value in each region of interest was calculated (256 gray levels of color resolution) by assigning the gray value 0 to black, and the value 256 to white (Yokota *et al.*, 1994). To measure bone density, linear density measurements were performed by drawing a line parallel to the root surface. The line extended from the apex of the alveolar crest to the level of the apex of the root. A line was drawn midway between every two lower anterior teeth. The grey level along each line was recorded at the beginning of the line, at the middle, and at the end. The average of the three readings was calculated to obtain the mean average density (grey level) along this line. The measurement of the root length was done by measuring the distance between the cemento-enamel junction (as a reference point) to the apex of the root. A comparison between the linear measurements prior to treatment, post-treatment, and after six months of retention was done to determine the extent of apical root resorption after the corticotomy-facilitated orthodontic tooth movement for both study groups (Rennington *et al.*, 1989).

Passive installation of an orthodontic appliance was performed, including direct bond pre-adjusted brackets (Roth prescription; 0.022 x 0.028 inches) from the right mandibular second premolar to the left mandibular second premolar, using chemical cure orthodontic adhesive and banding of the mandibular first molars. The appliance was not activated pre-surgically.

The corticotomy technique used in this study is a modification of the corticotomy technique described by Wilcko *et al.* (2009), and it was performed under local anesthesia. For the two study groups: intracrevicular full thickness flaps were reflected labially from the distal surface of the lower right canine to the distal surface of the lower left canine. The labial flap was reflected beyond the apices of the lower anterior teeth (*Figure 1*). The lingual flap was not elevated and the lingual bone was left intact. Selective alveolar decortication was performed in the form of vertical grooves through the labial cortical plate of bone, using a small round stainless steel surgical bur (*Figure 2*). The vertical grooves started 1-2 mm below the alveolar crest, and extended 1-2 mm below the apices of the teeth, Decortication grooves barely reached the medullary bone; horizontal subapical cuts were not performed. After the completion of the corticotomy procedure, bioactive glass was mixed with blood from the surgical site in a sterile dappen dish until a sandy consistency was obtained (*Figure 3*). The resultant coagulum was transferred in increments and applied directly over the bleeding bone (*Figure 4*). Flaps were repositioned at their original pre-surgical site and sutured.

Orthodontic tooth movement was initiated immediately after the surgical procedure by installation of a nickel-titanium archwire 0.012". Orthodontic adjustments were performed every 2 weeks. Nickel-titanium archwires 0.012", 0.014", 0.016", and 0.018" were used for leveling and alignment. Stainless steel archwires up to size 0.019" x 0.025" were used for finishing.

Post-operative care consisted of a prescription for a systemic antibiotic, an antiedematous drug, and analgesic for seven days (Dziak, 1993; Wilcko *et al.*, 2001; Wilcko *et al.*, 2003). Patients were instructed to rinse twice daily for two minutes for a period of two weeks using 0.12% chlorhexidine gluconate.

Statistical analysis

The collected data were tabulated and statistically analyzed using SPSS analytic software (SPSS, IBM Company). Student's *t*-test was used to test the effect of group on different measurements within each interval. Paired *t*-tests were run to test the effect of intervals on different measurements within each group.

Results

Total treatment time was calculated in weeks from the time of activation of the orthodontic appliance immediately following the corticotomy procedure to

Figure 1. Reflection of labial alveolar flap.

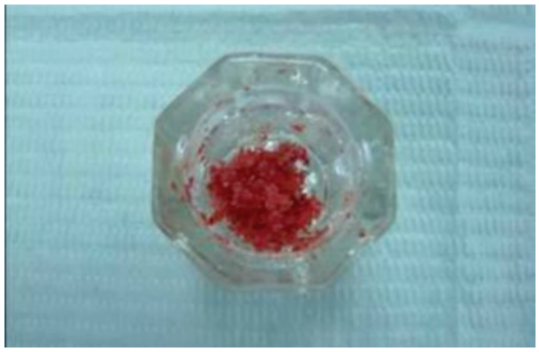

Figure 3. Bioglass mixed with blood from the surgical site to obtain a sandy consistency.

Figure 2. Interradicular alveolar decortication grooves.

Figure 4. Bone graft material application.

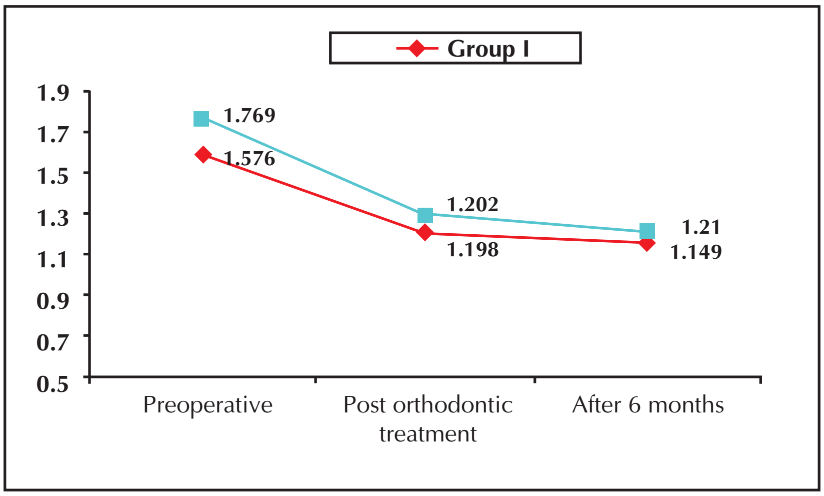

Figure 5. Mean probing depth at different intervals within each group.

the time of debracketing. Treatment durations for patients in both groups ranged from 14-20 weeks with a mean of 17 weeks for Group I and 16.67 weeks for Group II. There was no statistically significant difference regarding the total treatment time between the two groups.

Probing depth

Within each group, there was a significant difference in probing depths at different times (*Figure 5*). In Group I, there was no significant difference in probing depth during the retention period (immediately post-treatment to six months post-treatment). Within both groups there was a significant difference between the participants regarding the net amount of change in probing depth that occurred from the beginning of treatment until six months post-treatment. (*Table 1* and *Figure 6*)

There was no statistically significant difference between the two groups regarding the change that occurred in probing depth in each time interval. Six months post-treatment, Group I demonstrated a mean net decrease in probing depth of -1.427 ± 0.237 mm, while Group II demonstrated a mean net decrease in probing depth of -1.559 ± 0.164 mm (*Figure 6*).

Table 1. Descriptive statistics (mean ± SD) and test of significance for the change in probing depth during each interval of time within each group (paired *t*-test).

Group	Treatment time	Mean	SD	*p*
Group I	Preoperative – Post-orthodontic treatment	-1.378	0.152	0.001**
	Post-orthodontic treatment – After 6 months	-1.049	0.157	0.410
	Preoperative – After 6 months	-1.427	0.237	0.001**
Group II	Preoperative – Post-orthodontic treatment	-1.477	0.148	0.001
	Post-orthodontic treatment – After 6 months	-1.082	0.061	0.004*
	Preoperative – After 6 months	-1.559	0.164	0.001**

Group I, corticotomy-facilitated orthodontic tooth movement; Group II, corticotomy-facilitated orthodontic tooth movement and bone grafting material. *$p < 0.01$, **$p < 0.001$

Table 2. Descriptive statistics (mean ± SD) and test of significance for the percentage changes in bone density between the two groups

	Group I		Group II		*p*
	Mean	SD	Mean	SD	
Preoperative – post-orthodontic treatment	-41.501	14.157	-42.580	12.543	0.870
Post-orthodontic treatment – After 6 months	47.632	35.082	128.311	56.485	0.003*
Preoperative – After 6 months	-17.596	5.774	25.849	15.644	0.001**

Group I, corticotomy-facilitated orthodontic tooth movement; Group II, corticotomy-facilitated orthodontic tooth movement and bone grafting material. *$p < 0.01$, **$p < 0.001$.

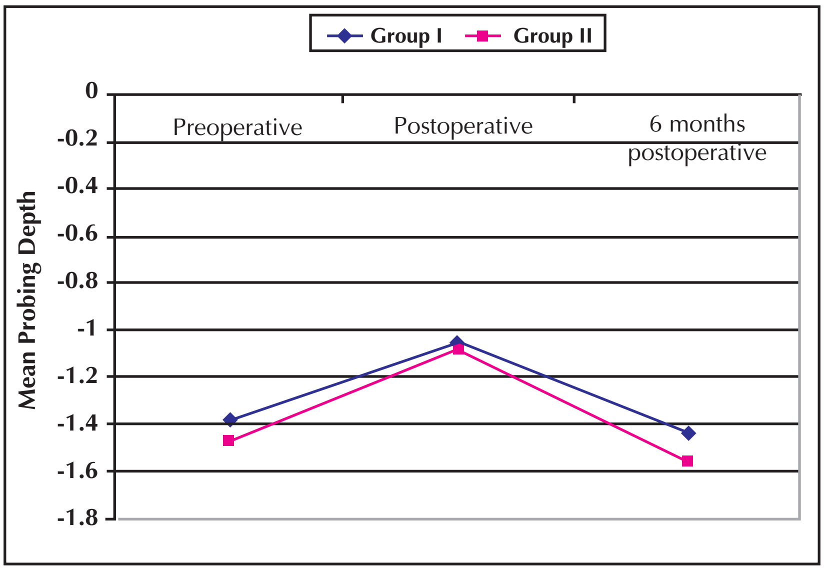

Figure 6. Mean changes in probing depth in the two groups.

Bone density

Within the two groups, there were significant differences in the change in bone density during different intervals of time. During the period of active tooth movement (from pre- to post-treatment) both groups demonstrated similar percentages of decrease in bone density. The mean decrease in bone density for Group I was -41.50% while it was -42.58 % for Group II. The difference between the two groups regarding the increase in bone density from immediately post-treatment to six months post-treatment was statistically significant. The mean increase in bone density for Group I was 47.6% while it was 128.3% for Group II. The net percentage change in bone density from the beginning of treatment to six months post-treatment was statistically significantly different between the two groups. Six months post-treatment, bone density values in Group I were -17.59% less than pre-treatment values, while bone density values of Group II were 25.85% more than pre-treatment values (*Table 2* and *Figure 7*).

Table 3. Descriptive statistics (mean ± SD) and test of significance for the changes in root length between the two groups. There were no significant differences between time intervals in either group

	Group I		Group II		p
	Mean	SD	Mean	SD	
Preoperative – post orthodontic treatment	-0.040	0.025	-0.035	0.024	0.718
Post orthodontic treatment – After 6 months	-0.017	0.009	-0.015	0.010	0.694
Preoperative – After 6 months	-0.056	0.025	-0.050	0.026	0.625

Group I, corticotomy-facilitated orthodontic tooth movement; Group II, corticotomy-facilitated orthodontic tooth movement and bone grafting material.

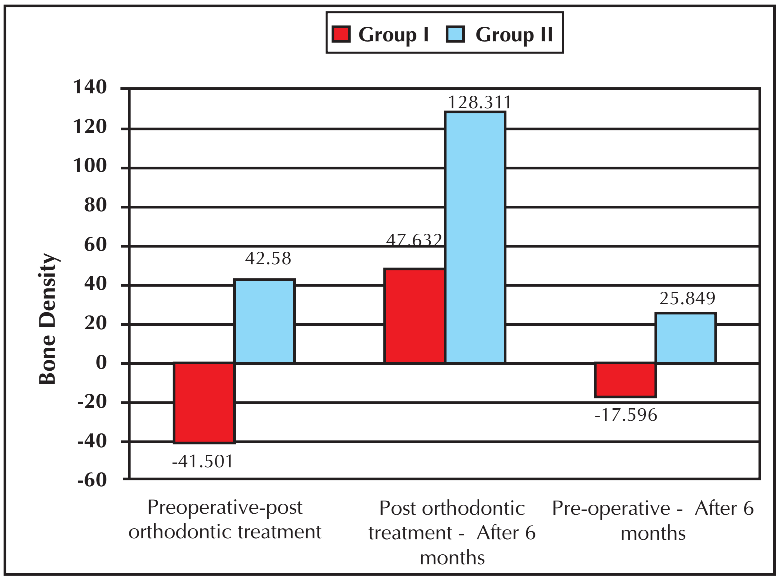

Figure 7. Mean percentage changes in bone density in the two groups.

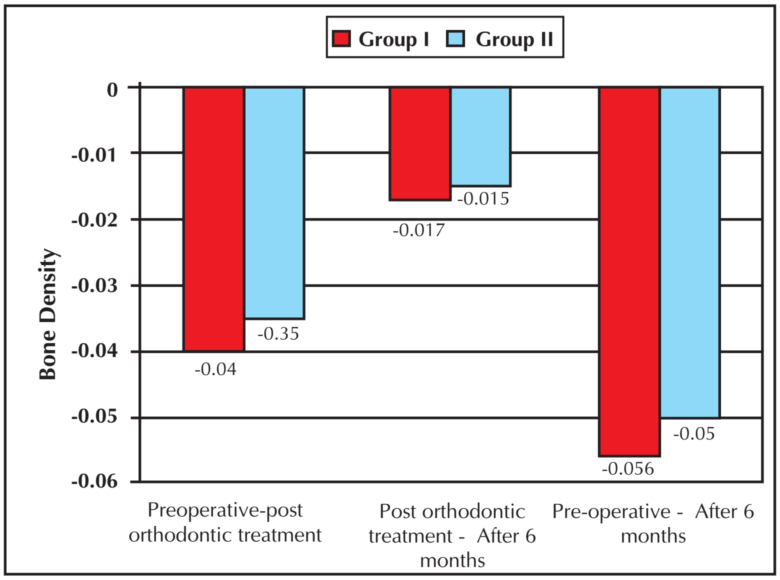

Figure 8. Mean changes in root length in the two groups

There was no significant difference between the two groups regarding average root length values obtained pre-treatment, post-orthodontic treatment, and six months post-treatment. The difference between the two groups regarding the net amount of root resorption was also statistically insignificant. Group I demonstrated an average net decrease in root length of -0.056 mm ± 0.025, while Group II demonstrated an average net decrease in root length of -0.050 mm ± 0.026 (*Table 3* and *Figure 8*).

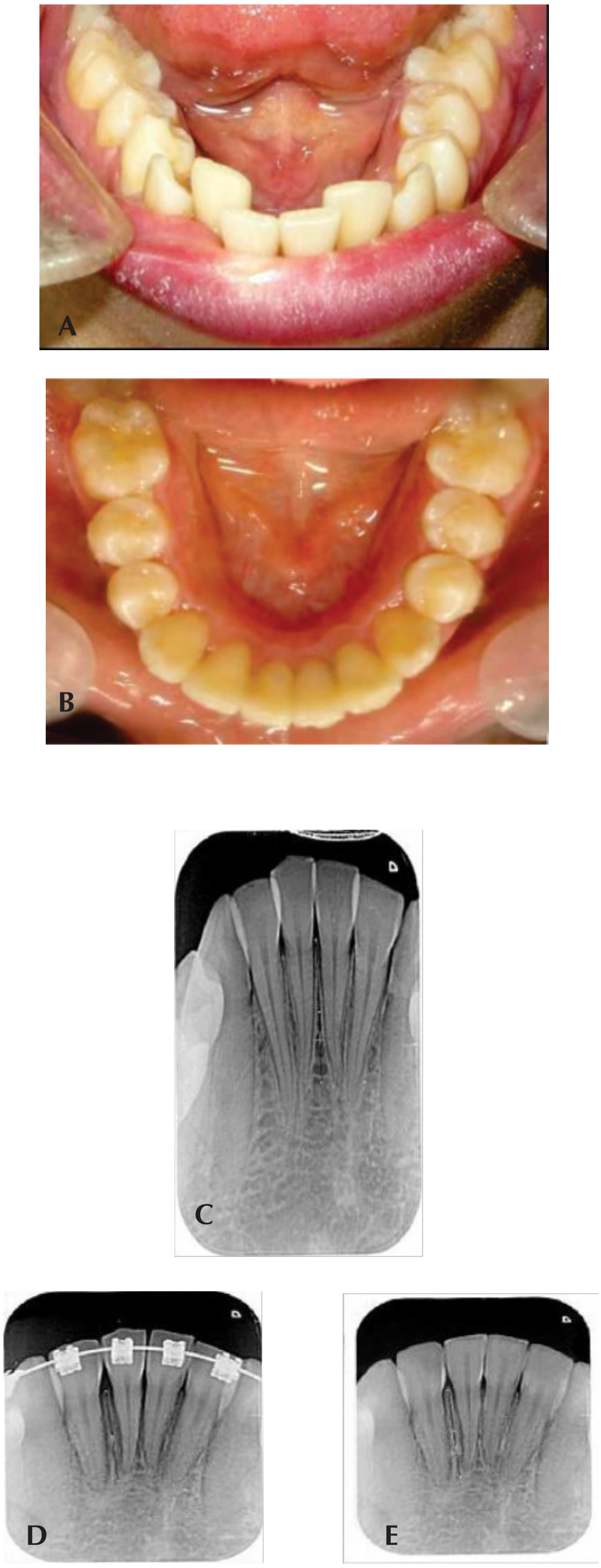

Figure 9. Case presentation. A) Pre-treatment intra-oral photographs; B) Post-treatment intra-oral photographs; C) Pre-treatment bone density analysis using DBSWIN software; D): Post-treatment bone density analysis using DBSWIN software and six months post-treatment, demonstrating a net increase in bone density.

Discussion

Some complications have been reported after extensive corticotomies (Gantes *et al.*, 1993). Some adverse effects were caused by reduced blood flow or thermal damage during the surgical procedures (Oliveira *et al.*, 2008; Akay *et al.*, 2009). Thus, in this study, a further modified corticotomy technique was proposed.

In conventional corticotomy techniques, corticotomy cuts were performed labially and lingually in the form of dots, grooves, or both (Generson *et al.*, 1978; Ferguson *et al.*, 2007; Wilcko *et al.*, 2001; Wilcko *et al.*, 2009). In some studies the grooves did not include the alveolar crest (Duker, 1975; Suya, 1991; Germec *et al.*, 2006). The further modified technique proposed in our study minimized the possible risks of the corticotomy procedures. To secure the advantages of maintaining the lingual mucosa and lingual bone intact, corticotomy was performed on the labial side only of the lower anterior region.

The modifications that were done in the current study reduced both the amount of removed bone and the operation time. Participants in this study presented with crowding of the lower anterior teeth that ranged from 3-5 mm. Crowding was resolved and orthodontic treatment was completed by dental expansion only, without using any other means of gaining space, in 14-20 weeks. This result is equivalent to results from previous studies in which moderate and severe crowding were treated without extraction and in shorter periods of time by corticotomy/osteotomy-assisted orthodontics (Hajji, 2000; Wilcko *et al.*, 2001). This finding could be explained by the expansion of the envelope of tooth movement following corticotomy, which was suggested in a study by Ferguson *et al.* (2006).

In the present study, three of 20 patients were excluded because of their failure to maintain several consecutive appointments. The remaining patients showed extreme cooperation and compliance in respecting the scheduled appointments, maintaining good oral hygiene, and complying with the instructions given to them. The high internal motivation the patients had mostly resulted from their high expectations of a much shorter treatment time than conventional orthodontic treatment had to offer. This assumption is supported by previous studies that reported that better patient cooperation and acceptance were possible advantages when lengthy orthodontic treatment was avoided (Machado *et al.*, 2002; Hassan *et al.*, 2010).

Another study states that the increase in the distance that the teeth can be moved translates to a dramatic reduction in the need for extractions and perhaps some orthognathic surgery (Wilcko *et al.*, 2008).

Following the corticotomy procedure, and during the period of active tooth movement, both groups demonstrated a significant decrease in bone density as a consequence of the corticotomy procedure.

Corticotomy invokes an RAP, where a transitional condition of increased calcium mobilization, decreased bone density, and increased bone turnover are observed (Frost, 1989; Bogoch *et al.*, 1993). Such findings are in accordance with previous studies that reported a significant decrease in bone density following corticotomy-facilitated tooth movement (Wilcko *et al.*, 2003; Pham-Nguyen *et al.*, 2006; Ferguson *et al.*, 2006; Lei Wang *et al.*, 2009).

There was a significant difference between the two groups regarding the increase in bone density recorded six months after the cessation of tooth movement; the greater increase was recorded for Group II. The use of a bone graft with the further modified corticotomy demonstrated a net increase in bone density of around 25.8%. This could be because of the incorporation of bone graft material into the corticotomized bone in Group II. This assumption is supported by the findings of previous studies stating that bone graft materials have a beneficial effect during bone formation because of alkalinization, increase in collagen synthesis and crosslinking, and hydroxyapatite formation (Samachson, 1969; Silver *et al.*, 2001). Previous studies on corticotomy-facilitated orthodontics with augmentation grafting reported the incorporation of bone graft material into the new layer of bone and its beneficial effect on repair of bone deficiencies, increasing the volume of the alveolar bone (Ferguson *et al.*, 2007; Wilcko *et al.*, 2001; Wilcko *et al.*, 2008), expanding the limits of tooth movement (Ferguson *et al.*, 2006), and long-term stability (Ferguson *et al.*, 2006; Ferguson *et al.*, 2007; Wilcko *et al.*, 2008).

Apical root resorption detected in some of the participants in both study groups was negligible and statistically insignificant. The absence of any significant apical root resorption has been reported in previous studies as an advantage of CFO in comparison to traditional orthodontics (McFadden *et al.*, 1989; Machado *et al.*, 2002; Wilcko *et al.*, 2003; Ren *et al.*, 2007; Moon *et al.*, 2007 and Hassan *et al.*, 2010) and results from two factors. The first factor is the short treatment duration that results from the corticotomy procedure. This assumption is supported by previous studies on CFO that reported decreased incidence of root resorption with decreased duration of treatment (Machado *et al.*, 2002; Ren *et al.*, 2007; Moon *et al.*, 2007; Hassan *et al.*, 2010). The second factor is the decreased bone density during tooth movement that also results from the corticotomy procedure. This assumption is supported by previous studies that reported that the corticotomy-induced decrease in bone density was responsible for the decreased incidence of root resorption (Machado *et al.*, 2002).

In the present study, not only was there no deterioration of periodontal health, participants in both groups demonstrated an improvement in probing depths. These results are in accordance with a previous study on CFO that reported that the shortened treatment time is advantageous to the patient's periodontal health (Wilcko *et al.*, 2008).

In conclusion, the further modified corticotomy-facilitated orthodontic technique with bone grafting resulted in favorable clinical and radiographic outcomes (*Figure 9*). Within the limits of this study, the modified technique with bone grafting resulted in a significant reduction in total treatment time, increased the alveolar bone density, and reduced the incidence of root resorption and periodontal problems associated with orthodontic tooth movement.

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