PERIODONTALLY ACCELERATED OSTEOGENIC ORTHODONTICS VERSUS CONVENTIONAL EXTRACTION-BASED ORTHODONTICS IN DENTAL DECROWDING: A RANDOMIZED CONTROLLED TRIAL

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Abstract

The objectives of this randomized controlled trial study were 1) to evaluate the efficacy of periodontally accelerated osteogenic orthodontics (PAOO) when treating severe crowding in patients with Class I malocclusion; 2) to compare orthodontic treatment by modified PAOO approach for crowded cases without extraction versus traditional extraction orthodontic treatment regarding the duration of treatment and changes in the inclination of upper and lower incisors and 3) to study the short-term stability of the results for PAOO technique. Thirty patients participated in the study. 15 patients were randomly selected to undergo conventional treatment for decrowding (extraction of upper and lower first premolars); after first premolars extraction, decrowding and space closure were accomplished.

The measured outcomes for the two groups included: duration of the orthodontic treatment, canine to canine width and inter-2nd premolars-width, upper and lower incisor axial inclination, distance between Is-point to the E Line, distance between Ii-point to the E Line, SNA and SNB angles, maxillary and mandibular arch length analysis and maxillary and mandibular incisors irregularity.

The orthodontic treatment in the PAOO group was faster than that in the extraction group throughout the experiment ($p<0.001$). At the end of treatment, there were no statistically significant differences in inter-canines width, but the inter-2nd premolars width was statistically higher in PAOO group than in the extraction group.

Compared with traditional orthodontic treatment, the PAOO procedure provides a safe alternative for patients with moderate to severe crowding who desire the benefits of orthodontic treatment in a relatively short duration.

Keywords: Accelerated tooth movement - periodontally accelerated osteogenic orthodontics - corticotomy - dental crowding.

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L'ORTHODONTIE OSTEOGENIQUE ACCÉLÉREÉ VS L'ORTHODONTIE CONVENTIONNELLE BASÉE SUR L'EXTRACTION DENTAIRE EN CAS DE CHEVAUCHEMENT DENTAIRE : UN ESSAI CONTROLÉ RANDOMISÉ

Résumé

Les objectifs de cette étude contrôlée randomisée étude étaient: 1) d'évaluer l'efficacité de l'orthodontie accélérée par stimulation ostéogénique du parodonte (OASOP) lors du traitement des chevauchements dentaires sévères chez des patients ayant une malocclusion de classe I; 2) de comparer la durée du traitement et les changements dans l'inclinaison des incisives supérieures et inférieures en appliquant les deux approches (la technique d'OASOP modifiée sans extraction et l'approche traditionnelle d'extraction orthodontique); 3) d'étudier la stabilité à court terme des résultats obtenus en appliquant la technique OASOP.

Trente patients (13 hommes et 17 femmes) d' un âge moyen de 20,43 années ont participé à l'étude. 15 patients ont été choisis au hasard pour subir un traitement OASOP sans extraction dentaire. Les 15 autres patients ont reçu un traitement conventionnel avec extraction des premières prémolaires supérieures et inférieures.

Le traitement orthodontique dans le groupe OASOP était plus rapide que celui du groupe d'extraction tout au long de l'expérience ($p<0,001$). À la fin du traitement, il n'y avait pas de différences statistiquement significatives dans la largeur de l'espace Inter-canines; cependant, la largeur de l'espace inter-2èmes prémolaires était statistiquement plus élevée dans le groupe OASOP que dans le groupe d'extraction.

Par rapport à un traitement orthodontique traditionnel, la procédure d'OASOP présente un choix thérapeutique sûr pour les patients atteints de chevauchements dentaires modérés à graves et qui désirent bénéficier d'un traitement orthodontique dans une durée relativement courte.

Mots-clés: mouvement dentaire accéléré - orthodontie accélérée par stimulation ostéogénique du parodonte - chevauchement dentaire – corticotomie alvéolaire.

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Introduction

Dental crowding is one of the most common forms of malocclusion. Two conventional methods to resolve dental arch crowding through orthodontics are extraction and non-extraction [1]. Extraction is usually reserved for moderate to severe conditions. Non-extraction therapy is usually used to resolve mild to moderate crowding and usually results in proclination of the incisors [1].

An increasing number of adult patients are seeking orthodontic treatment and a short treatment time has become a recurring request. Unfortunately, many potential orthodontic patients jeopardize their dental health and decline treatment, due to the long treatment duration [2]. To meet their expectations, a number of surgical techniques have been developed to accelerate orthodontic tooth movement [3]. Rapid tooth movement following surgery as a consequence of changes in the physiology and/or composition of alveolar bone has been described [4].

In 2001, Wilcko et al. [5] introduced a technique combining alveolar corticotomy and bone grafting to prevent the risk of dehiscence and fenestration while increasing the scope of orthodontic corrections. The inclusion of a grafting procedure makes possible the simultaneous augmentation and reshaping of the supporting alveolar bone [5]. The combination of corticotomy-facilitated orthodontic treatment and periodontal alveolar augmentation has been named the "Accelerated Osteogenic Orthodontics (AOO)" procedure which was modified to "Periodontally Accelerated Osteogenic Orthodontics" (PAOO) by Wilcko et al. [6].

In an attempt to gain a better understanding of the modality of tooth movement following corticotomy, pre- and post-treatment radiographic analyses were made in a series of case reports [6 -9]; the authors mentioned that rapid orthodontics with corticotomies can accelerate tooth movement by increasing the bone turnover, decreasing the bone density [7, 8] and decreasing the hyalinization of the periodontal ligament [9]. This has been explained by the so-called the regional acceleratory phenomenon (RAP); i.e. osteoclasts and osteoblasts increase by local multicellular mediator mechanisms containing precursors, supporting cells, blood capillaries, and lymph [10]. The new interpretation of the rapid movement as "bone matrix transportation" allows conventional orthodontic tooth movement 300% to 400% faster, and according to Wilcko et al. [11], this technique provides an alternative to bicuspid extraction by increasing the envelope of movement 2 to 3 folds and by augmenting the alveolar volume.

Nowzari et al. [12] stated in their case report, using a modified surgical approach and limiting the corticotomy to the buccal and labial aspects, that the PAOO was an effective treatment approach in adults in decreasing treatment duration and in reducing the risk of root resorption. Final lateral cephalometric analysis showed proclination of the upper and the lower anterior teeth [12].

Aljhani and Zawawi [13] applied the combined non-extraction orthodontic treatment with the corticotomy technique in an adult patient, 25 years old, with severely crowded dental arches to accelerate tooth movement and shorten the treatment time. Buccal and lingual corticotomies with alveolar augmentation procedure in the maxilla and the mandible were performed. The total treatment time was 8 months with no adverse effects observed at the end of active treatment. The addition of the decortication procedure to the conventional orthodontic therapy decreased the duration of treatment significantly. Final lateral cephalometric analysis showed minimal proclination of the upper and lower anterior teeth with mild upper and lower lip protrusion [13].

Although effective, corticotomy techniques described above present significant postoperative discomfort [3, 14]. Their aggressive nature is related to the use of a bone bur that could potentially damage the roots of neighboring teeth in case of severe crowding in the anterior mandible [15].

Sebaoun et al. [3] described in a case report the use of Piezocision in conjunction with bone grafting; this minimally invasive approach was much less traumatic for the patient and allowed the correction of severe crowding without extraction in a shorter time. The authors found that the majority of even severe malocclusions can be resolved within 5 to 9 months and postoperative pain was usually minimal and well tolerated by patients.

Experimental studies evaluating the PAOO are scarce in the literature, and till now no study has demonstrated its efficacy by piezosurgical intervention. Also, there are no published clinical trials comparing the traditional extraction-based treatment outcomes versus the PAOO-based non-extraction treatment outcomes in the correction of severe crowding of Class I malocclusion patients. Therefore, the aims of the current study were three fold:

1) Evaluate the efficacy of orthodontic treatment depending on PAOO;

2) Compare the upper and lower incisors inclination as well as the treatment duration between the PAOO-based non-extraction orthodontic treatment and the conventional extraction-based orthodontics.

3) Evaluate the short-term stability of the results achieved by the PAOO technique.

Materials and methods

Study design

A prospective randomized controlled trial was conducted on 30 patients (13 males and 17 females) with a mean age of 20.43 ± 2.67 years who had severe dental crowding (5-7 mm according to Carey's arch length analysis [16]). The research project was conducted at the Orthodontic Department of Dental Faculty at Al-Baath University, Hamah, Syria.

The patients were allocated to one of the two groups:

Group 1: the correction of dental crowding was performed by accelerated decrowding without extraction combining alveolar corticotomy and bone augmentation (PAOO).

Group 2: the correction of dental crowding was performed by conventional decrowding after extraction of the four first premolars without any surgical intervention.

Patients' recruitment and assignment

An evaluation of patients referred to the Orthodontic Department for treatment was performed and those who were planned for first premolars extraction were included according to the following inclusion criteria: 1) An indication for first premolars extraction for decrowding (Class I with severe crowding in the anterior region); 2) permanent dentition with an age range between 16 and 24 years; 3) good general health with no diseases that would contraindicate local anesthesia; 4) absence of craniofacial syndromes, cleft lip / palatal division or previous dento-facial traumas; 5) absence of systematic diseases and no concurrent medication; 6) good oral hygiene with no periodontal disease in the upper jaw; 7) no previous orthodontic treatment; 8) absence of restorative or endodontic treatment; 9) absence of structural or morphological teeth abnormalities; and 10) no signs of bimaxillary protrusion.

The research project was explained to 51 candidates and information sheets about the proposed trial were given. Upon acceptance to participate, the patients' informed consent was obtained. Forty-two patients met these criteria.

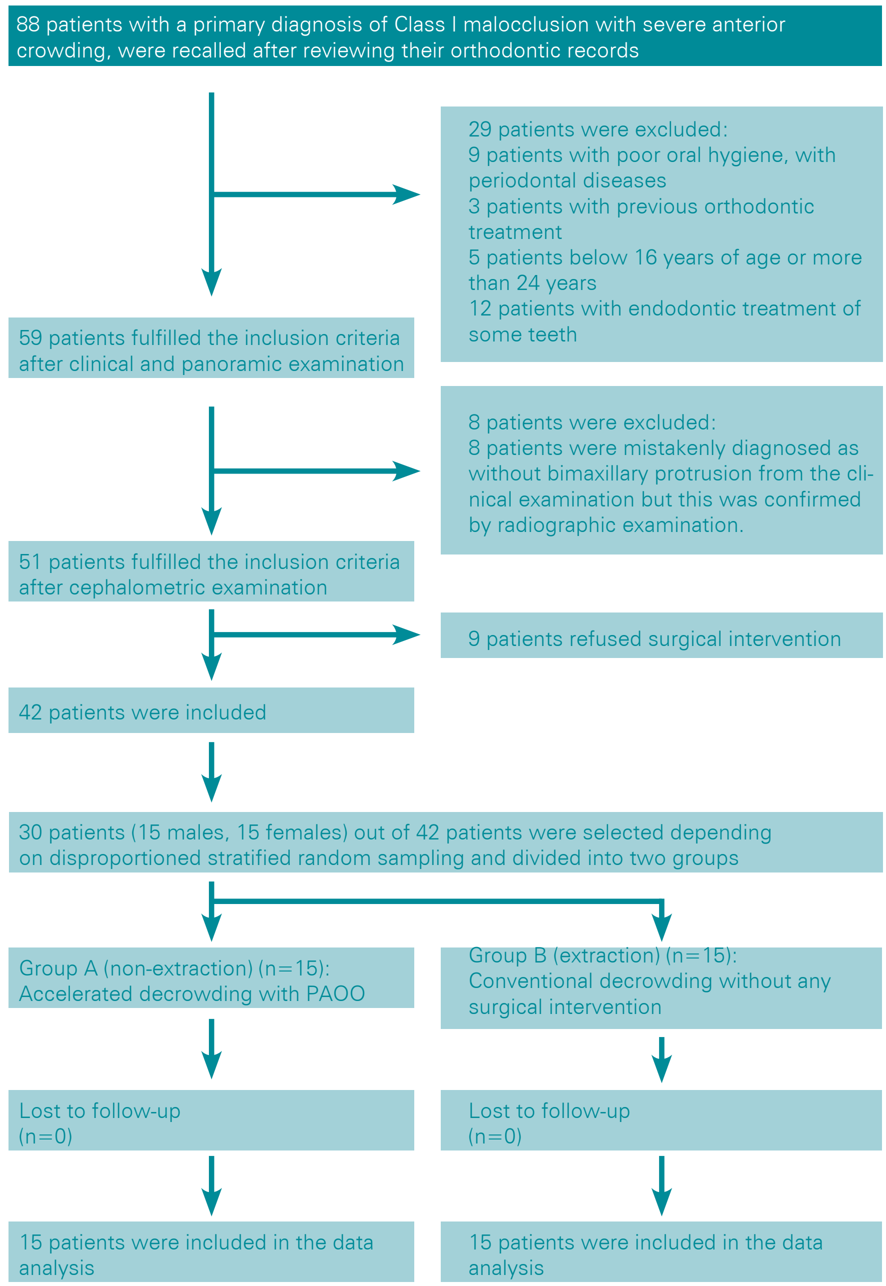

Fig. 1: Participant flow diagram.

The sample size was calculated using Minitab® Version 15 (Minitab Inc., State College, Pennsylvania, USA). Two primary outcomes were measured: the relapse of maxillary and mandibular incisor irregularity according to Little's index 1975 [17]. The variance of these two measurements was obtained from a previous paper [18] and a sample size of 4 patients for each group was required in relation to the maxillary incisor irregularity and 14 patients for each group in relation to the mandibular incisor irregularity. The larger number was taken as target size. Using the paired-samples t-test with an alpha level of 0.05 and a power of 90%, assuming that the smallest difference in the mandibular incisor irregularity was 1.5 mm between the two related groups, a sample of 29 subjects was required. Therefore, 30 patients were randomly selected using a sequence of 30 numbers generated by Minitab® 16 (Minitab Inc, State College, Pa). A flow diagram of patients' recruitment, allocation and follow-up is given in figure 1.

Randomization of the patients

Each patient was asked to pick an opaque sealed envelope from a container to allocate the treatment approach. The containers included 15

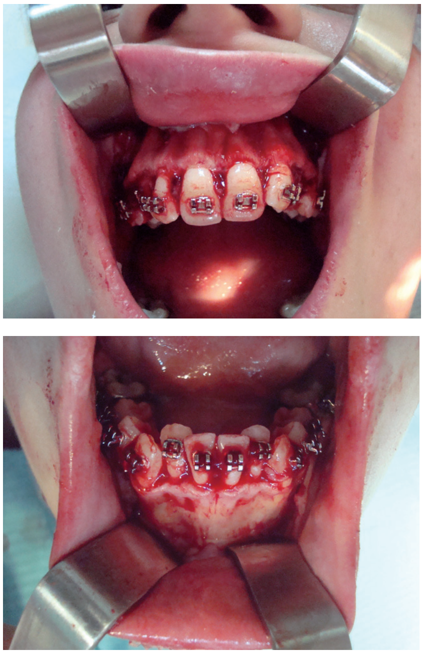

Fig. 2: Maxillary and mandibular labial flaps reflected.

Fig. 3: Corticotomy cuts and perforations.

Fig. 4: Bone graft in place.

envelopes with the word 'non-extraction' indicating the PAOO group and 15 envelopes with the word 'extraction', indicating the conventional orthodontic treatment. All patients were treated with pre-adjusted fixed appliances, with "0.022 X 0.028" slot brackets (Roth prescription, American Orthodontics®, Sheboygan, WI, USA). The orthodontic treatment and the surgical intervention were performed by the same principal researcher who was an orthodontist and a PhD student; he had previously undergone training in oral and maxillofacial surgery.

PAOO group

Both maxillary and mandibular arches were banded and bonded during the first week preceding the PAOO surgery. This was followed by the placement of the first arch wires (0.012 Copper-Nitinol, American Orthodontics®, Sheboygan, WI, USA) so fully engaged from second molar to second molar.

Under local anesthesia, full-thickness envelope flaps were reflected using sulcular incisions on the buccal sides of maxillary and mandibular incisors and premolars regions only by a 12B Bard-Parker blade (BD, Franklin Lakes, NJ, USA). No vertical releasing incisions were made. No flap elevation or corticotomy was performed on the palatal or lingual side. The flaps were reflected beyond the apices of the teeth to avoid damaging the neurovascular complexes exiting the alveolus, the neurovascular bundles, the bone and the genioglossus attachment and to allow adequate decortication around the apices (Fig. 2).

Selective partial decortication (bone activation) was performed on the labial aspect of the maxillary and mandibular anterior teeth and premolars. These teeth underwent major movement; the molars served mostly as anchorage units. The limited labial decortication was accomplished with circumscribing corticotomy cuts outlining the roots of the teeth. Small round corticotomy perforations were done where possible. The corticotomies and decortications were performed using the OT7 and OT8 ultrasonic microsaws (Piezosurgery, Mectron Medical Technology) between roots from the distal of the second right premolar to the distal of the opposing second premolar on both arches. The vertical corticotomy cuts stopped about 2 mm short of the alveolar crests. Both corticotomy cuts and perforations were extended through the entire thickness of the cortical plate, just barely into the cancellous bone (Fig. 3). Additional corticotomy perforations were made where it was possible to attain supplementary bleeding points. The design of the corticotomy cuts and perforations was irrelevant. No bony luxation was performed following the partial decortication. A resorbable bovine bone (Bio-Oss® 0.25 to 1.0 mm, Osteohealth Co., Shirley, NY, USA) was soaked into a clindamycin phosphate/sterile water solution (approximately 10mg/mL) just prior to placement. The graft was then spread over the partially decorticated bone (Fig. 4).

The mucoperiosteal flaps were coronally advanced to cover the grafting materials and sutured into place with interrupted loop 4/0 non-resorbable Gore-Tex® sutures. Sutures were left in place for a minimum of two weeks.

The participants were given amoxicillin, 500 mg, 3 times / day for 7 days and chlorhexidine mouthrinse 0.12% for 2 weeks.

Non-steroid anti-inflammatory drugs were contraindicated following surgery. This precaution was undertaken to avoid their possible interferences with the RAP. However, pain killers were allowed only when the pain was unbearable.

Unlike conventional orthodontics, the orthodontic appliance was activated every two weeks until the end of treatment after PAOO. The first orthodontic adjustment was performed approximately 2 weeks following surgery. Thereafter, the orthodontic adjustments were made at about 2-weeks intervals until the treatment was completed. Copper-nitinol and stainless steel wires were placed in sequence (0.012 Niti, 0.14 Niti, 0.016 Niti, 0.016X0.022 Niti, 0.019X0.025 Niti, 0.019X0.025 SS) to level and align the arches. Finishing of the occlusion was completed (class I for molars and canines, normal overjet, normal overbite, upper and lower midlines were coincident to one another and to the facial midline) then upper and lower teeth were ligated with ligature wire for 3 months. The braces were removed subsequently.

Extraction group (Conventional treatment)

Both maxillary and mandibular dental arches were banded and bonded a week following the extraction of the first premolars. Then, the first arch wires (0.012 Copper Nitinol) were placed so fully engaged from second molar to the opposite second molar. Thereafter, the orthodontic adjustments were made at about 3 weeks intervals until the treatment was completed.

Copper nitinol and stainless steel wires were placed in the same sequence then that for the PAOO group to level and align the arches, to close the spaces resulting from extraction, to achieve a normal overjet and overbite. At the end of the treatment, upper and lower midlines were coincident to one another and to the facial midline, class I molars and canines relationships were achieved; the fixed appliances were debonded and maxillary and mandibular clear overlay retainers were constructed and placed immediately following the removal of the orthodontic appliances.

Outcome measures

The measured outcomes for both groups included duration of the orthodontic treatment, inter-canines width, inter-2nd premolars-width, incisors axial inclination, labial spatial positioning in relation to the esthetic line of Ricketts [19], SNA and SNB angles, maxillary and mandibular arch length analysis, maxillary and mandibular incisors irregularity using Little Index [17].

Statistical analysis

In PAOO group, means and standard deviations were calculated at T1 (at the beginning of the treatment), T2 (at the end of the treatment and debonding), and T3 (after 1 year of debonding); also the differences between T1 and T2 and T2 and T3 were measured. The changes during the treatment and the 1 year post-treatment periods were analyzed separately.

In the extraction group, means and standard deviations were calculated for T1 and T2 measurements as well as for the differences between the T1 and T2 measurements.

Statistical analysis was conducted using Minitab® 15. In each treatment group, paired-sample t-test or Wilcoxon matched-pairs signed-rank test was employed to evaluate intragroup differences (with α set at 0.05). Two-samples t-test or Mann-Whitney U test was applied to evaluate intergroup differences (with α set at 0.05).

Measurements on dental casts

Maxillary and mandibular dental casts were measured with a digital caliper by the same investigator at T1 and T2 in the extraction group, and at T1, T2 and T3 in the PAOO group to the nearest 0.01 mm. All measurements were linear. The following variables were assessed for each set of casts.

1. Incisor irregularity: the sum, in millimeters, of the 5 distances between the anatomic contacts from the mesial aspect of the left canine through the mesial aspect of the right canine in both arches according to the method described by Little 1975 [17].
2. Canine-canine width: distance between crown tips of the right and left canines, measured in both arches.
3. inter-2nd premolars width: distance between the central fossae of the second contralateral premolars, measured in both arches.

Measurements of lateral cephalometric radiographs

Lateral cephalometric radiographs were made and cephalograms were traced; measurements were made by the same investigator at T1 and T2 in the extraction group, and at T1, T2 and T3 in the non-extraction group. The cephalometric landmarks were located, angular and millimetric variables were measured.

The cephalometric landmarks were: sella, nasion, A-point, maxillary incisor tip point, mandibular incisor tip point, mandibular incisor apex point, B-point, pogonion, menton, gonion. Cephalometric planes were drawn and the following measurements were made:

1. ls -E Line (mm): line formed perpendicular to the E Line at ls-point.
2. li -E Line (mm): line formed perpendicular to the E Line at li-point.
3. Maxillary central incisor to SN angle (U1-SN).
4. Incisor-mandibular plane angle (L1- MnP).
5. SNA angle.
6. SNB angle.

Error of measurement

Twenty randomly selected orthodontic models were re-measured one month later to estimate the error of measurement. The paired t-test for differences between the replications showed no statistically significant dif-

Groups Phase	PAOO group	Extraction group	p-value
Alignment and leveling duration	5. 73 ± 1.35	10.48 ± 2.23	<0.001*
Finishing duration	1,38 ± 0.39	10.28 ± 2.3	<0.001*
Total duration	7,19 ± 1.54	20.76 ± 1.25	<0.001*

* Mann-Whitney U test used instead of two-sample t-test.
Table 1: Comparison of treatment duration (mean and standard deviation) between PAOO and non-extraction groups.

ferences. These results indicated the reliability of the measurements.

To determine the error of tracing and measuring, 20 cephalograms were randomly selected, retraced, and variables were re-measured by the same examiner one month after the initial procedure. The paired t-test for differences between the replications showed no statistically significant differences and indicated the reliability of the measurements. No systematic error was detected when paired t-test was applied. Intra-class correlation coefficient (ICC) confirmed the high reliability of the measuring procedure (r=0.992).

Results

The orthodontic treatment in the PAOO group was faster than that in the extraction group throughout the experiment (Table 1). There was a significant difference (p< 0.001) between the extraction and the non-extraction groups at all intervals. The alignment and leveling stages took 5.73 months in the PAOO group while they took 10.48 months in the extraction group. The mean of total treatment duration for PAOO group was 7.19 months versus 20.76 months for the extraction group.

Dental cast data during treatment

In table 2, the differences in variables between the extraction and the non-extraction groups before treatment (at T1) are presented. These variables were not statistically significant different at T1. In the extraction group, Carey's arch length analysis was 5.84 mm for maxillary teeth and 6.03 mm for mandibular teeth; this reflects a very severe crowding according to Carey. In the PAOO group, Carey's arch length analysis was 6.08 mm for the maxillary teeth and 6.28 mm for the mandibular teeth; this also refers to a very severe crowding.

The irregularity index was 10.39 mm for maxillary teeth and 10.72 mm for mandibular teeth in the extraction group; this corresponds to a very severe irregularity according to Little [17]. In the non-extraction group, the irregularity index was 10.24 mm for the maxillary teeth and 11.15 mm for the mandibular teeth; this also corresponds to a very severe irregularity.

At T2, inter-2nd premolars width and inter-canines width increased significantly in the PAOO group in both jaws (Table 3). However, in the extraction group, maxillary and mandibular inter-canines width increased insignificantly; maxillary inter-2nd premolars width increased slightly and insignificantly. Mandibular inter-2nd premolars width showed a slight and insignificant decrease (Table 4).

In table 5, a comparison of dental changes at the end of treatment (T2) between extraction and PAOO groups is presented.

Cephalometric data during treatment

The differences between the 2 groups weren't significant for all cephalometric measurements at T1 (Table 2). During T2, a statistically insignificant decrease (-1.87 degrees; p=0.160) occurred in U1-SN in the extraction group (Table 4). During the same period, this angle increased significantly (6.36 degrees; p=0.001) in the non-extraction group (Table 3).

Incisor-mandibular plane angle (L1-MnP) measurements decreased (1.37 degrees) in the extraction group insignificantly (p=0.304) and increased significantly (6.93 degrees) (p<0.001) in the non-extraction group.

SNA and SNB angles increased in the non-extraction group at T2 for 0.93 degrees and 1.5 degrees, respectively (Table 3) and decreased in the PAOO group for 1.13 degrees and 0.07 degrees, respectively (Table 4). These changes were statistically significant for SNB in the non-extraction group and for SNA in the PAOO group (p=0.025).

In the extraction group, there was a significant increase in ls-E line and li-E line values (2.12 mm and 2.88 mm, respectively; p<0.001) (Table 4). However, in PAOO group, there was a decrease in ls-E line and li-E line values (0.18 mm and 1.05 mm, respectively). This decrease was significant for li-E line (p<0.001) and insignificant for ls-E line (p=0.084) (Table 3).

Table 5 illustrates a comparison of cephalometric changes at the end of treatment (T2) between extraction and PAOO groups. No statistically significant differences in SNA and SNB angles were detected, but there were statistically more changes in PAOO group than in the extraction group in the following variables: the distance between ls-point to the E line, the distance between li-point to the E line, the maxillary central incisor to SN angle (U1-SN) and the incisor-mandibular plane angle (L1- MnP).

Groups Variables	Extraction	PAOO	p-value
Maxillary arch length analysis (mm)	5.839 ± 0.738	6.076 ± 0.757	0.392
Mandibular arch length analysis (mm)	6.034 ± 0.787	6.278 ± 0.684	0.450
Maxillary incisor irregularity	10.39 ± 3.35	10.24 ± 2.08	0.885
Mandibular incisor irregularity	10.72 ± 3.44	11.15 ± 1.91	0.678
Maxillary inter-canines width	33.40 ± 3.33	32.10 ± 3.61	0.535
Mandibular inter-canines width	25.34 ± 2.50	24.11 ± 1.76	0.381
Maxillary inter-2nd premolars width	37.39 ± 3.44	39.40 ± 3.37	0.313
Mandibular inter-2nd premolars width	32.08 ± 2.75	32.90 ± 3.85	0.661
U1-SN	103.3 ± 6.66	104.3 ± 9.81	0.747
L1-MnP	91.3 ± 8.42	92.8 ± 12.16	0,698
SNA angle	82.4 ± 3.58	83.3 ± 3.85	0.513
SNB angle	79.4 ± 4.37	80.1 ± 3.16	0.653
Is -E Line	3.13 ± 2.42	3.29 ± 2.80	0.865
Ii -E Line	-0.01± 3.03	0.45 ± 2.56	0.656

Table 2: Comparison of dental and cephalometric variables (mean and standard deviation) before treatment (at T1) between extraction and non-extraction groups.

Time Variable	T1	T2	T2-T1	
	Mean ± SD	Mean ± SD	Diff	p-value
Maxillary inter-canines width	3.33±33. 40	35.29 ± 0.94	1.89	0.214
Mandibular inter-canines width	25.34 ± 2.50	26.88 ± 0.76	1.54	0.165
Maxillary inter-2nd premolars width	37.39 ± 3.44	38.17 ± 1.47	0.78	0.503
Mandibular inter-2nd premolars width	32.08 ± 2.75	32.07 ± 1.49	-0.01	0.997
U1-SN	103.3 ± 6.66	101.43 ± 3.28	-1.87	0.160
L1-MnP	91.3 ± 8.42	89.93 ± 4.38	-1.37	0.304
SNA	82.40 ± 3.58	81.27 ± 3.93	-1.13	0.025
SNB	79.43 ± 4.37	79.37 ± 4.26	-0.067	0.823
Is -E Line	3.13 ± 2.42	5.25 ± 2.85	2.12	<0.001
Ii -E Line	-0.01 ± 3.03	2.87 ± 2.93	2.88	<0.001

Table 3: Means and standard deviations of dental and cephalometric variables of PAAO group at T1, T2, and T3, and differences in measurements from T1 to T2 and T2 to T3.

	PAAO group						
Time Variable	**T1**	**T2**	**T3**	**T2-T1**		**T3-T2**	
	Mean ± SD	Mean ± SD	Mean ± SD	Diff	p-value	Diff	p-value
Cast analysis							
Maxillary arch length analysis (mm)	6.08 ± 0.76	0.23 ± 0.09	0.31 ± 0.16	-5.85	<0.001	0.07	0.066
Mandibular arch length analysis (mm)	6.28 ± 0.68	0.24 ± 0.08	0.36 ± 0.28	-6.04	<0.001	0.12	0.095
Maxillary incisor irregularity	10.24 ± 2.08	0.00 ± 0.001	0.44 ± 0.45	10.55	0.001	0.12	0.001*
Mandibular incisor irregularity	11.15 ± 1.91	0.00 ± 0.001	0.831 ±0.62	10.67	0.001	0.51	0.001*
Maxillary inter-canines width	32.10 ± 3.61	33.72 ± 3.29	33.69 ± 3.26	1.62	0.006	-0.03	0.241
Mandibualr inter-canines width	24.11 ± 1.76	26.37 ± 1.20	26.30 ±1.22	2.26	0.001	-0.07	0.008
Maxillary inter-2nd premolars width	39.40 ± 3.37	41.48 ± 1.90	41.44 ± 1.92	2.08	0.033	-0.04	0.05
Mandibular inter-2nd premolars width	32.90 ± 3.85	34.94 ± 2.26	34.88 ± 2.23	2.04	0.049	-0.06	0.190
Lateral cephalometric analysis							
U1-SN	104.30 ± 9.81	110.93± 9.05	110.47 ± 9.31	6.63	0.001	-0.46	0.277
L1-MnP	92.80 ± 12.16	99.73 ± 12.73	99.07 ± 12.60	6.93	<0.001	-0.67	0.060
SNA angle	83.30 ± 3.85	84.23 ± 4.23	84.13 ± 4.34	0.93	0.085	-0.1	0.082
SNB angle	80.10 ± 3.16	81.3 ± 3.29	81.23 ± 3.31	1.5	0.025	0.00E	0.529
Is -E Line	3.29 ± 2.8	3.11 ± 2.62	3.27 ± 2.70	-0.18	0.084	0.16	0.041
Ii -E Line	0.45 ± 2.56	-0.60 ± 2.64	-0.54 ± 2.65	-1.05	<0.001	0.06	0.258

Table 4: Mean and standard deviation of dental and cephalometric variables in the extraction group at T1 and T2, and differences in measurements from T1 to T2.

Study of relapse in PAOO group

Table 3 presents the average changes in variables from T2 to T3 in the PAOO group. At T3, maxillary Carey's arch length analysis was 0.31 mm and the mandibular Carey's arch length analysis was 0.36 mm. The increase from T2 to T3 was 0.07 mm in the upper jaw and 0.12 mm in the lower jaw; these differences between T2 and T3 were not statistically significant in both jaws (p=0.066 and p=0.095, respectively).

PAOO treatment produced a statistically significant decrease (p=0.001) in maxillary and mandibular incisors irregularity. The mean of maxillary and mandibular incisors irregularity increased insignificantly 0.44 mm and 0.83 mm, respectively, during the first year post-treatment period. This was considered an insignificant relapse by Little.

Mandibular inter-canines width decreased significantly during the first year post-treatment period but this slight decrease was not clinically significant (0.07mm). For maxillary inter-canines width, there was a decrease of 0.03mm (p=0.241). So no significant relapse occurred in maxillary and mandibular inter-canines width in

Groups Variable	PAOO group	Extraction group	Difference	p-value
Maxillary inter-canines width	33.72 ± 3.29	35.29 (0.94)	1.57	0.270
Mandibular inter-canines width	26.37 ± 1.20	26.88 (0.76)	0.51	0.385
Maxillary inter-2nd premolars width	41.48 ± 1.90	38.17 (1.47)	3.31	0.005
Mandibular inter-2nd premolars width	34.94 ± 2.26	32.07 (1.49)	2.87	0.021
U1-SN	110.96 ± 9.06	101.43 3.28	9.53	0.001
L1-MnP	99.70 ± 12.70	89.93 4.38	9.78	0.012
SNA	84.23 ± 4.23	81.27 3.93	2.97	0.057
SNB	81.30 ± 3.29	79.37-80 4.26	1	0.494*
Is -E Line	3.11 ± 2.62	5.25 2.85	2.14	0.042
Ii -E Line	-0.60 ± 2.64	2.87 2.93	3.47	0.002

Table 5: Comparison of changes at the end of treatment (T2) between extraction and non-extraction groups.

the PAOO group. Maxillary and mandibular inter-2nd premolars width decreased significantly in the PAOO group during the first year post-treatment period (T3). This increase wasn't clinically significant (0.04, 0.06 mm, respectively).

The mandibular and maxillary incisors axial inclination in the PAOO group retroclined to a lesser degree from T2 to T3. The changes were statistically insignificant at T3. The mandibular and maxillary incisors axial inclination was stable during the first year following debonding. Also SNA and SNB angles, upper and lower lips position were stable at T3 although there was a statistically significant change (p=0.041) in ls-E line but this change was not clinically significant (0.16 mm).

Discussion

This randomized controlled trial was undertaken to primarily investigate the influence of PAOO technique on decrowding in comparison with the standard orthodontic technique (with extraction) and secondarily to study the stability of the results after PAOO treatment.

The current findings showed that the PAOO technique accelerated the treatment significantly. The rate of treatment duration in the PAOO group was about 3 times less than that of the standard treatment group.

The current findings corroborate the clinical observations of Wilcko et al. [5, 6] and Hajji [20] who reported similar significant reductions in treatment times and found that the accelerated osteogenic orthodontics technique provides efficient and stable orthodontic tooth movement [21].

In the case study of Nowzari et al. [12], ideal esthetic and functional results were achieved in 8 months (one-third the average treatment time) [12]. Wilcko et al. [3] reported an average of 6.1 months of treatment duration for the PAOO procedure. Our study result agreed with these observations.

According to Aljhani and Zawawi [13], the comprehensive orthodontic treatment of adult patient who presented with severe lower crowding was completed in 8 months; the treatment duration was significantly less than that of a conventional orthodontic treatment.

The addition of the corticotomy procedure has been reported to shorten the conventional orthodontic treatment time. It was claimed that teeth can be moved 2 to 3 times further in 25 to 30% less time required for traditional orthodontic treatment [6, 11, 22-26]. The current study confirms the previously published findings and supports their results concerning the duration of treatment.

However, unlike the procedures described by Wilcko et al. [5], corticotomy was performed only at the buccal aspects of both the maxilla and the mandible in the present study.

This was in agreement with Germec et al. [12] and Nowzari et al. [27] who reported rapid tooth movement when corticotomy was performed at the buccal aspects of alveolar bone. The researchers noted that the suppression of palatal and lingual corticotomy reduced the length and the extent of the surgery and avoided the risk of violating vital lingual anatomy.

The concept of corticotomy as initially introduced and later adopted by several investigators relied on creating blocks of bone with the embedded teeth that can be moved rapidly with heavy forces [22-25]. On the other hand, conventional orthodontic forces were advocated by Wilcko et al. [5, 6, 11] who explained the rapid tooth movement as an illustration of regional acceleratory phenomenon; the rapid tooth movement after corticotomy-facilitated orthodontics would thus be more appropriately described as “bone matrix transportation” and not “bony block movement”, the latter hypothesis being proposed by Suya et al. [23].

The tooth movement in this treatment is merely the result of a physiologic process and not the repositioning of segments of bone [11]. Lee et al. [28] and Sebaoun et al. [29] reported systemic and histologic evidence to support the hypothesis originally proposed by Wilcko et al. that the facilitated tooth movement after corticotomy surgery is attributable to a demineralization/remineralization phenomenon rather than “bony block movement". In our study, during the surgical intervention, bone blocks surrounding the teeth were not created. Therefore, the rapid rate of tooth movement seemed to depend mostly on the RAP; i.e. the increased alveolar bone reaction rather than bony block movement. Further histological studies with longer follow-up periods are required to investigate the underlying biologic picture of the suggested mechanism.

Erdinc et al. [18] found when comparing extraction with non-extraction treatments for crowded cases that mandibular inter-canines width increased by averages of 1.13 mm in the extraction group and 0.74 mm in the non-extraction group with treatment. Maxillary inter-canines width increased by averages of 1.13 mm in the non-extraction group and 0.92 mm in the extraction group with treatment. According to Gianelly [30], this slightly larger increase in patients treated with premolar extractions might reflect lateral movement as the canines are moved distally into the premolar sites.

Our results reported an increase in mandibular inter-canines width by average of 1.54 mm in the extraction group and 2.26 mm in the non-extraction group. Maxillary inter-canines width increased by averages of 1.62 mm in the non-extraction group and 1.89 mm in the extraction group. These results were compatible with those of Erdinc et al. [18].

According to Erdinc et al. [18], the mandibular incisor axial inclination showed differences between the 2 groups. At the end of the active treatment period, the mandibular incisors were more upright in the extraction group and more proclined in the non-extraction group. In the non-extraction group, because of the proclination of the mandibular and maxillary incisors, the inter-incisal angle decreased significantly with treatment, whereas in the extraction group, the inter-incisal angle increased significantly with treatment [18]. Nowzari et al. [12] reported that maxillary incisor labial angulation was increased by 9° (from 5° to 14°) and mandibular incisors tipped labially by 4° (97° to 101°) after PAOO surgery. They indicated that most of the arch length gained occurred through expansion in the buccal segments. Since his study included only one patient, the conclusions are limited.

Aljhani et al. [13], in final lateral cephalometric analysis after PAOO treatment, showed minimal proclination of the upper and lower anterior teeth (2° and 1°, respectively) with mild upper and lower lip protrusion; the difference in E-line-upper lip and E-line-lower lip was 2 mm.

In our study, maxillary incisor labial angulation was increased by 6.63° and mandibular incisors tipped labially by 6.93°. SNA angle increased by 0.95° and SNB angle increased by 1.5°. These results disagree with those reported in Aljhani’s case report in which SNA angle was stable after treatment and SNB angle decreased by 1°.

In the study of Erdinc et al. [18], both extraction and non-extraction treatments showed exceptionally good stability. At T3, maxillary alignment was stable, but the mandibular incisors relapsed by an average of 1 mm in both groups. This was considered a minimal relapse according to Little [17]. However, the non-extraction patients started with minimal anterior irregularity, whereas the extraction patients had moderate crowding [18]. In the present study, during the first year post-treatment period, no significant relapse occurred in the PAOO group for both mandibular and maxillary arches. Same results were reported by O’Hara [32] and Ferguson et al. [33] who found that the periodontal therapy increased the alveolar volume and enhanced the stability of orthodontic clinical outcomes (less relapse).

Conclusion

Compared with traditional orthodontic treatment, the PAOO procedure that combines the advantages of corticotomy-facilitated orthodontics and periodontal alveolar augmentation offers the advantage of achieving the desired results in a significantly reduced treatment duration.

The PAOO procedure provides a safe alternative for patients with moderate to severe crowding who desire the benefits of orthodontic treatment in a relatively short period of time.

The results were stable after one year post-treatment, even though maxillary and mandibular incisors tipped labially. This indicated that most of the arch length gained occurred through expansion in the buccal segments; that’s why PAOO is contraindicated in bimaxillary protrusion cases.

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