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Effects of Micro-osteoperforations on Maxillary Molar Distalization Using Miniscrew Anchored Pendulum Appliance: A Split-mouth Randomized Controlled Trial

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Abstract

Purpose: This split-mouth trial was designed to assess how Micro-OsteoPerforation (MOP) affected maxillary molar distalization. **Material and methods:** This study included 16 patients with bilateral Class II molar relationship requiring nonextraction treatment with bilateral maxillary molar distalization. In the study, a split-mouth design was adopted. A bone anchored pendulum appliance (BAPA) was used for distalization. MOP (the experimental group) was assigned randomly to one side of the maxillary arch, though the other side acted as a control. 3 MOPs were carried out distal to the upper first and second molars just prior to starting distalization using Propel at 3, 6, and 9 mm from the alveolar bone crest and all were 5 mm in depth crossing through the cortex and entering the spongious bone. Data were collected from pre and postdistalization cone-beam computed tomography (CBCT) and digital models. **Results:** Comparing the MOP sides to the control sides, the overall distalization duration was noticeably shorter on the MOP sides ($P = 0.042$). On the contrary, the total distance moved by the maxillary first molar showed no significant difference between the two sides. All CBCT variables showed that neither side was significantly different from the other except the U1-PTV which showed more palatal movement of the upper incisors in the MOP sides than the control sides ($P = 0.006$). **Conclusions:** MOP can be an effective method for accelerating molar distalization as it shortens the total duration of distalization.

Keywords: Accelerated orthodontic treatment, CBCT, Micro-osteoperforation, Molar distalization, Tooth movement

1. Introduction

Treatment time is a significant concern among orthodontic patients. In general, the average length of duration needed for fixed appliance therapy is 24 months [1]. Thus, orthodontists desire to accelerate tooth movement because prolonged treatment increase the likelihood of adverse outcomes like gingival inflammation, tooth decay, and in particular external root resorption [2]. Also, shortening the treatment time helps to meet the demands of patients while minimizing long term consequences [3].

Clinicians are continually working on techniques to hasten the rate of tooth movement. Recently, Many strategies including surgical and nonsurgical procedures have been proposed for this purpose, thus patients can receive faster and more efficient treatment alternatives [4]. Low-level laser therapy, resonance vibration, and the systemic or local administration of drugs or hormones had been used as non-surgical methods [4,5].

Many surgical procedures have been attempted to hasten the process of tooth movement [3]. Because of the invasive nature of these procedures, their association with postsurgical pain, swelling, and interdental bone loss, they may not be acceptable to most patients [6]. These reasons arises a need for minimally invasive treatment options [7].

Micro-osteoperforation (MOP) is a safe, minimally invasive procedure involves making small holes in the bone in a controlled way [8]. This micro trauma to the bone increases the expression of cytokines and chemokines that are normally released due to

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orthodontic forces. This causes a greater influx of osteoclasts to the area. As a result, bone density decreases and bone resorption increase making tooth movement easier and faster. Also, this process of faster bone remodeling extends beyond the affected area to the surrounding tissues. Thus, the MOP may not essentially placed in close proximity to the tooth to be moved [9].

The Consortium for Translational Orthodontic Research (CTOR) pioneered the concept of MOP. MOP has been investigated in many trials for its potential to hasten the progression of orthodontic tooth movement. Following several successful clinical studies, CTOR patented the technique. In 2010, Propel Orthodontics (Ossining, NY, USA) was granted the permission to market the device. Since then, the Propel device has gained popularity and is being marketed globally [10]. The MOP procedure is performed using local anesthetic infiltration, hence no additional pain or discomfort experienced by the patients compared with usual orthodontic treatment. Although this procedure reduces bone density, it does not result in external apical root resorption. Thus, it is easy, efficient and safe [11].

Distalization of the maxillary molars is a treatment modality that is typically essential for Class II patients requiring nonextraction treatment. Patients with minor skeletal discrepancies may benefit from distalizing maxillary molars to resolve class II molar relationships [12]. However, distalization of upper molar is challenging and rarely considered, because of the difficulty encountered to do so as the upper second and third molars have been erupted. Moreover, it may necessitate a lengthy treatment duration, which is distributed between the molar distalization phase followed by complete bonding of fixed appliance [13]. Increased treatment time amongst patients receiving maxillary molar distalization with fixed orthodontic therapy will raise the possibility of treatment-related complications.

Canine retraction has been the focus of most research investigating MOP [14–16]. Hence, more research is warranted to explore the effect of this method on other types of tooth movements, as molar distalization. Therefore, this split-mouth trial was designed to assess how MOP affected the maxillary molar distalization.

2. Material and methods

2.1. Trial design

Randomized, controlled, split-mouth study design was applied for this trial to reduce the intra-individual variation. This clinical trial was approved by the Research Ethics Committee at Tanta University, Faculty of Dentistry by the ethical code (#R-ORTH-11-22-4). Informed consent form was signed by each patient after explaining the study's objectives.

Sample size calculated to be 16 patients based on the result of previous study which employed a comparable split-mouth study design [17]. Patients with the following criteria were included: (1) Ages between 16 and 22 years old, (2) Malocclusion requiring nonextraction treatment plan with bilateral maxillary molar distalization, (3) Class II molar relationships exist bilaterally on either Class I or mild Class II skeletal discrepancy, with an acceptable soft tissue facial profile, (4) No prior orthodontic treatment, (5) Maxillary first and second molars are fully erupted, (6) Good periodontal health and oral hygiene. The following groups of patients were excluded: (1) Patients with systemic disease, (2) Chronic intake of non-steroidal anti-inflammatory drugs (NSAIDs) or any medication that interfere with tooth movement, (3) Severe Class II skeletal relationship, (4) Class II subdivision molar relationship, (5) Poor oral hygiene and periodontal disease, (6) Previous orthodontic treatment.

2.2. Randomization

MOPs were administered randomly to either the left or right side of the patients (experimental group) and the contralateral sides received no MOPs and acted as control group. The subject numbers 1–16 were written on papers enclosed in opaque, sealed envelopes, and stored in box. The 16 envelopes included: 8 allocation papers for the right MOPs, and 8 for the left MOPs. At the beginning of the intervention, the patient pick one of the envelopes to find his or her number and, therefore, the experimental side to which MOP would be assigned.

2.3. Study setting

Routine orthodontic records were taken for each patient before start of orthodontic treatment were including orthodontic study model, digital panoramic radiograph, lateral cephalometric radiograph and extraoral and intraoral photographs.

2.4. Distalization appliance (Fig. 1)

Bone Anchored Pendulum Appliances (BAPA) were applied to all subjects. The BAPA consisted of: classic pendulum appliance [18]. excluding the auxiliary wires that extend to the bands of the first

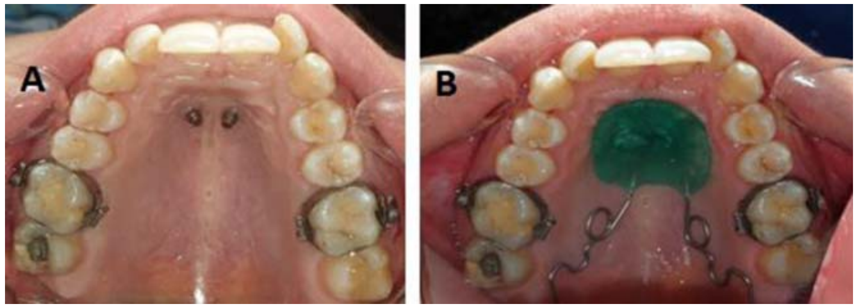

Fig. 1. Bone anchored pendulum appliances (BAPA) used for distalization; A: miniscews after insertion in the anterior para median area of the mid-palatal suture, B: BAPA cemented over the miniscrews and pendulum springs activated.

premolars and two 8 × 1.8 mm titanium miniscrews (3 S miniscrew, World Bio Tech Co., LTD, Korea) as rigid bone anchors. The miniscrew was inserted with the patient under local anesthesia (2% Mepivacaine, Alex for chemical industries and drugs, Alexandria, Egypt) in the anterior para median region of the mid-palatal suture.

Following soft tissue healing, alginate impressions were taken with the mini-implants and upper molar bands in place, then stone models were poured. The pendulum springs were constructed using 0.032″ TMA wires. The springs were performed to include a closed helix loop that had two arms; one was short which represented the retentive arm and the other was long which represented the active or distalizing arm. The two pendulum springs for the right and left sides were positioned in the palate close to the median raphe as possible to allow a wide range of action giving flexibility to the spring for easy insertion into the lingual sheath.

Nance acrylic button was fabricated on the stone model. The mini-implant's head was connected to the acrylic plate, using chemically curing composite resin. Before inserting the appliance in the mouth, the pendulum springs were activated extra orally on the model. The activation of the appliance was done by bending the springs a 90° angle resulting in 300 gm of distalizing force. Reactivation and follow-up were performed every 3 weeks. Once the first molar reached super Class I on one side, the spring terminal end was deactivated on the same side.

2.5. Micro-osteoperforations (MOPs)

Three MOPs were carried out under local anesthesia distal to the upper first and second molars just prior to appliance insertion using Propel (Propel Orthodontics, Ossining, NY) at 3, 6, and 9 mm from the alveolar bone crest and all were 5 mm in depth crossing through the cortex and entering the spongious bone. BAPA were activated on the first day of MOPs. Patients were instructed to use chlorhexidine mouthwash 3 times/day for 3 days after MOPs, and to strictly avoid NSAIDs, and analgesics were restricted to paracetamol (Fig. 2).

2.6. Outcomes

The total duration (by months) of distalization was the primary outcome measure and was calculated for both sides. Alginate impressions were obtained for the upper arches before distalization (T0) and after completion of distalization in both sides (T1). The dental models were scanned (Smartoptics scanner for lab work, Germany) with a 1 : 1 proportion. The constructed two-dimensional cast image was then imported to Facad Orthodontic Tracing Software, version 3.10 (www.facad.com) for measuring the antero-posterior crown tip movement of the first molars and canines [19] (Fig. 3).

Cone-beam computed tomography (CBCT) image was taken for the maxillary arch before distalization (T0), and after completion of distalization (T1). The Digital Imaging and Communications in Medicine (DICOM) files obtained from the radiology center were opened using Mimics Medical software (Materialise Mimics Innovation Suite version 21.0)

Fig. 2. The Propel device used for micro-osteoperforations (MOPs).

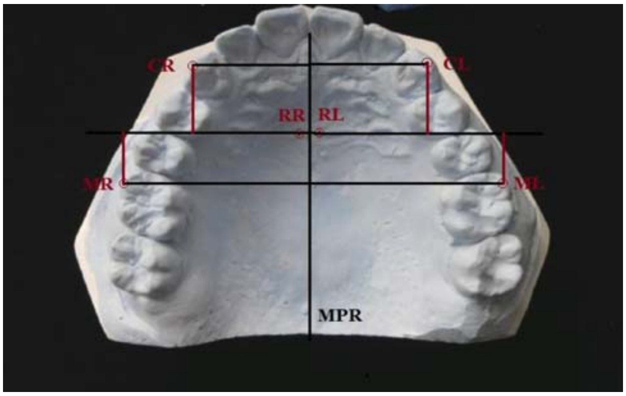

Fig. 3. Lines created on the scanned model to measure the antero-posterior movement of the maxillary first molars and maxillary canines.

upon which the landmarks were identified, and measurements were done as special analysis to be used to all CBCT images of all patients.

CBCT image was used to measure the horizontal and vertical positional changes, and the angular tipping of the following group of teeth: maxillary first and second molars, premolars, and central incisors. The pterygoid vertical plane (PTV), which is regarded as a stable plane of reference in the sagittal direction utilized to measure the horizontal linear displacement [20]. The vertical linear measurements were based on the Frankfort Horizontal (FHP) which is considered as reliable as the true horizontal plane [21]. The following landmarks were used for all linear measurements: mesio-buccal cusp tips of the second and first molars, cusps tips of the second and first premolars, and incisal edges of the upper central incisors. Angular measurements obtained by measuring the angle created between the tooth long axis and Frankfort Horizontal (FHP) from sagittal view (Fig. 4 and 5).

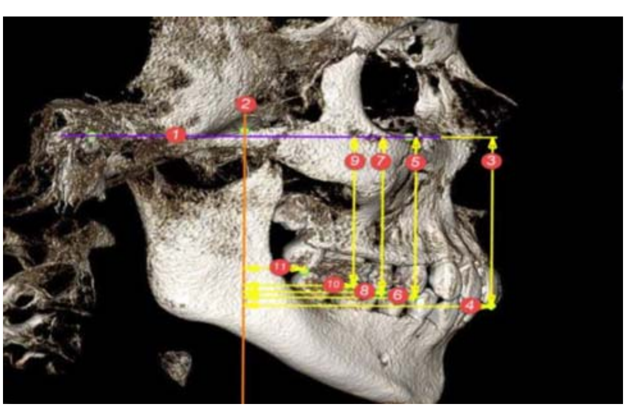

Fig. 4. Landmarks and linear measurements identified on the CBCT image (sagittal view).1: Frankfort Horizontal Plane (FHP), 2: pterygoid vertical (PTV) plane, 3: U1-FHP mm, 4: U1-PTV mm, 5: U4-FHP mm, 6: U4-PTV mm, 7: U5-FHP mm, 8: U5-PTV mm, 9: U6-FHP mm, 10: U6-PTV mm, 11: U7- PTV mm.

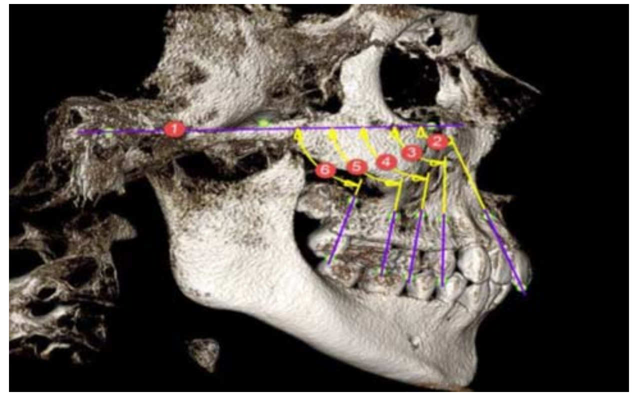

Fig. 5. Angular CBCT measurements (sagittal view) with Frankfort Horizontal Plane (FHP) (1), 2: U1-FHP, 3: U4-FHP, 4: U5-FHP, 5: U6-FHP, 6: U7− FHP.

2.7. Statistical analysis

SPSS software, version 21.0 was employed to statistically analyze the data gathered for the study. For all tests, the cutoff point for significant differences was set at P less than or equal to 0.05. The mean differences between the experimental and control groups were compared by using independent sample t-test.

2.8. Reliability of measurements

Randomly chosen CBCTs and models were measured two times within 2 weeks interval, and then data were evaluated using Cronbach alpha to test the intraexaminer reliability. Cronbach alpha (The reliability coefficient) was 0.89, 0.95 for model and CBCT measurements, respectively, which meant excellent agreement of the measurements.

3. Results

Study sample comprised of 16 patients (10 females; and 6 males) with 17.5 (±0.9) years old. The study's duration was successfully completed by all patients.

MOP side showed a significant difference compared with control side regarding the total duration of distalization (6.67 ± 0.43 vs. 7.0 ± 0.45 months respectively; $P = 0.042$). Conversely, the overall distance moved by the maxillary first molar showed nonsignificant difference between both sides on both models and CBCT. All CBCT variables showed nonsignificant difference between both sides except U1-PTV which showed more palatal

Table 1. Independent samples t-test comparing the full duration of distalization (months), the mean distance travelled by maxillary first molars, and maxillary canines (mm) on the dental model.

Variable	Side	Mean (T1-T0)	S. D	Mean diff	St. Error diff	C I 95% LL	C I 95% UL	t	*P*-value
Duration (months)	**MOP**	6.67	0.43	−0.331	0.156	−0.650	−0.012	2.121	0.042*
	Control	7.00	0.45						
Total distance travelled by maxillary first molars (mm)	**MOP**	7.22	0.21	−0.089	0.068	−0.229	−0.051	1.296	0.205
	Control	7.31	0.18						
Total distance travelled by maxillary canines (mm)	**MOP**	0.42	0.52	−0.125	0.175	−0.483	0.233	0.714	0.481
	Control	0.54	0.47						

Significance at *P* less than or equal to 0.05.

movement of the upper incisors in the MOP sides in comparison to the control sides (−0.25 ± 1.57 vs. 1.50 ± 1.75 mm, respectively; *P* = 0.006) which means less anchorage loss in the MOP sides. The movement of the maxillary canines measured on the dental models showed nonsignificant difference between both sides. Both sides exhibited mesial tipping, with no significant differences between them (Tables 1 and 2).

4. Discussion

One of the key struggles in orthodontics is the extended treatment time. Longer treatment durations can be incredibly demotivating for our patients, especially those in the older ages and are frequently linked to other detrimental effects like an elevated risk of root resorption and dental caries [2]. Accordingly, this study was designed to assess how

Table 2. Independent samples t-test of pre and postevaluation CBCT variables (T1-T0) measured on the experimental (MOP) and control sides.

Variable	Side	Mean (T1-T0)	S. D	Mean diff	St. Error diff	C I 95% LL	C I 95% UL	t	*P*-value
Sagittal displacement									
U7-PTV (mm)	**MOP**	−4.63	1.03	−0.375	0.441	−1.276-	0.526	0.850	0.402
	Control	−4.25	1.44						
U6-PTV (mm)	**MOP**	−7.00	3.50	0.375	1.245	−2.167-	2.917	0.301	0.765
	Control	−7.38	3.54						
U5-PTV (mm)	**MOP**	−4.13	1.50	−0.563	0.851	−2.300-	1.175	0.661	0.514
	Control	−3.56	3.05						
U4-PTV (mm)	**MOP**	−1.31	1.85	0.875	0.547	−0.243	1.993	1.599	0.120
	Control	−2.19	1.17						
U1-PTV (mm)	**MOP**	−0.25	1.57	−1.750	0.588	0.549	2.951	2.976	0.006*
	Control	1.50	1.75						
Vertical displacement									
U7-FHP (mm)	**MOP**	−2.88	0.96	−0.063	0.399	−0.877	0.752	0.157	0.877
	Control	−2.81	1.28						
U6-FHP (mm)	**MOP**	−0.13	3.12	0.063	1.122	−2.229	2.354	0.056	0.956
	Control	−0.19	3.23						
U5-FHP (mm)	**MOP**	1.50	3.41	−0.938	1.053	−3.087	1.212	0.891	0.380
	Control	2.44	2.48						
U4-FHP (mm)	**MOP**	2.19	2.90	0.063	0.984	−1.946	2.071	0.064	0.950
	Control	2.13	2.66						
U1-FHP (mm)	**MOP**	1.63	2.50	−0.250	0.773	−1.829	1.329	0.323	0.749
	Control	1.88	1.82						
Tipping									
U7-FHP angular	**MOP**	−17.25	5.34	1.313	2.607	−4.011	6.636	0.503	0.618
	Control	−18.56	8.96						
U6-FHP angular	**MOP**	−21.25	9.74	−3.813	3.357	−10.669	3.044	1.136	0.265
	Control	−17.44	9.24						
U5-FHP angular	**MOP**	−13.25	2.05	4.750	4.661	−4.770	14.270	1.019	0.316
	Control	−18.00	18.53						
U4-FHP angular	**MOP**	−6.69	5.39	0.563	1.664	−2.836	3.961	0.338	0.738
	Control	−7.25	3.91						
U1-FHP angular	**MOP**	−4.50	4.52	−1.625	1.326	−4.332	1.082	1.226	0.230
	Control	−2.88	2.78						

Significance at P less than or equal to 0.05.
(−) sign means movement in distal direction regarding PTV (−) sign means movement in occlusal direction regarding FHP, (−) sign in angular measurements means mesial tipping.

MOP affected the maxillary molar distalization using BAPA.

A split-mouth design was implemented in this study. A major advantage of this design was the exclusion of the inter-subject variability. All patients were selected with no gender bias. Researchers found that the patient's age can influence the rate of tooth movement Schubert and colleagues, Giannopoulou and colleagues [22,23]. Thus, only older patients 16–22 years old were included to avoid the potential influence of this confounding factor. BAPA was utilized for distalization in all subjects as it was found to be efficient, minimally invasive, and non-compliance intraoral molar distalizer without anchorage loss Gaballa and colleagues [24]. MOP using Propel was implemented in the current study as it is easy, efficient, minimally invasive and safe procedure Fulsundar and colleagues [11].

The whole distance travelled by the maxillary first molars, and possible canine anchorage loss were evaluated on digital models by using the medial and lateral points of the third palatal rugae as a stable and reliable reference points Lanteri and colleagues, Mote and colleagues [25,26]. The CBCT was utilized to handle the limitations of the conventional two-dimensional projections. Previous researchers concluded the superiority of CBCT images in detection of root angulation Abu-Shahab and Alassiry [27].

Regarding the current study results, MOPs showed a significant reduction in the time needed for the experimental side to move nearly the same distance of the control side as all cases were symmetrical class II, and all finished when reaching super class I molar relation. Also, the overall distance moved by the maxillary first molar showed non-significant difference between both sides on both models and CBCT. This was in agreement with some studies, Ozkan and Arici, Alkasaby and colleagues [28,29]. while other studies reported nonsignificant effect of the MOP Aboalnaga and colleagues, Alkebsi and colleagues [15,16].

Both sides exhibited mesial tipping, with no significant differences. Likewise, no significant differences were observed in molar or premolar vertical or sagittal displacement.

The amount of anchorage loss has not been yet evaluated in previous studies utilizing molar distalization with MOP. In this study, the upper incisors showed more palatal movement in the MOP sides, this palatal movement is favorable in distalization treatment as it shortens the treatment time. This was compatible with previous studies utilizing BAPA for distalization Gaballa and colleagues, Farag and colleagues [24,30].

4.1. Conclusion

MOP can be an effective method for accelerating molar distalization as it shortens the total duration of distalization.

4.2. Recommendations

(1) Further studies are recommended to assess the monthly rate of distalization with MOPs.
(2) Further studies are recommended to examine the effect of repeated MOPs on molar distalization.

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Conflicts of interest

No conflict of interest.

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