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Evaluation of the Effect of Micro-osteoperforations versus Piezopuncture on the Rate of Orthodontic Tooth Movement Associated with Canine Retraction

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Abstract

AIM: The aim of the study was to investigate the effectiveness of using micro-osteoperforations (MOPs) or piezocision in accelerating tooth movement, during canine retraction, compared to standard canine retraction.

PATIENTS AND METHODS: A split-mouth study design was carried out with two Groups A and B. Each group contained 10 patients; in each patient, one side was used as a control side and the contralateral side received either MOPs (Group A) or piezocision (Group B). The assessment data were collected by direct intraoral measurements, every 2 weeks, over a 3 months retraction period.

RESULTS: Independent t-test, paired t-test, and ANOVA were used to analyze the results. In Group A, there was a statistically significant difference between the study and control sides ($p < 0.001$) with a total of 4.2 ± 0.5 mm canine retraction in the MOPs assisted canine retraction side versus a 2.8 ± 0.2 mm total canine retraction in the control side. For Group B, there was a statistically significant difference between the study and control sides ($p < 0.001$) with a total of 3.6 ± 0.4 mm canine retraction in the piezocision-assisted canine retraction side versus a 2.8 ± 0.2 mm total canine retraction in the control.

CONCLUSION: MOPs and piezocision techniques accelerated the rate of canine retraction during orthodontic treatment, with the MOPs being slightly more effective.

Introduction

The average orthodontic treatment usually necessitates an extended duration of about 20–30 months [1]. The longer the treatment duration, the higher the risk of external root resorption [2], caries, white lesions [3], as well as decreased patient satisfaction and compliance [4]. The effectiveness of non-conventional methods for accelerating orthodontic tooth movement and shortening the duration of orthodontic treatment had become the key question for many researchers [5]. A variety of methods based on the biology of tooth movement was suggested such as pharmacological methods using Vitamin D [6], prostaglandin [7], interleukins [8], leukotrienes [9], or platelet-rich plasma [10]. Physical methods were also employed (low-level laser therapy [11], electric current [12], electromagnetic field [13], and low-intensity pulsed ultrasound [14]) and surgical methods such as corticotomy [15], [16], micro-osteoperforations (MOPs) [17], [18], and piezocision [19], [20]. Surgical corticotomy is one popular and commonly used method to accelerate orthodontic tooth movement, control anchorage, and enhance molar intrusion and distalization [21]. It enhanced the regional acceleratory phenomenon (RAP) which has the main effect in accelerating OTM [22], [23]. Different surgical corticotomy methods were investigated by many researchers [24], [25], the main drawback was that it is an invasive technique which may cause undesirable side effects such as pain, swelling, and post-operative bleeding, and may negatively affect patients' quality of life [26]. For that reason, other less invasive surgical techniques were introduced to minimize these side effects such as MOPs and piezoelectric surgery (piezocision). MOPs are a procedure in which small pinhole perforations are created in the bone around the teeth to accelerate the rate of tooth movement during orthodontic treatment [27]. This procedure activates the release of cytokines that, in turn, recruit osteoclasts to the area to increase the rate of bone resorption, and does not require a prolonged execution time or any advanced training. On the other hand, piezocision [28] is a technique used for corticotomy [29] carried out by modulated ultrasonic frequency that permits highly precise and safe cutting of hard tissues.

Accordingly, the aim of our study was to investigate the effectiveness of using MOPs or piezocision in accelerating tooth movement, during canine retraction, compared to standard canine retraction.

Patients and Methods

Twenty female and male patients with an age range from 15 to 25 years were enrolled in this study. They were recruited from the Outpatient Clinic at the Department of Orthodontics, Faculty of Dentistry, Minia University. The inclusion criteria were healthy general medical condition, healthy periodontal condition, full unit Class II canine relation, severe crowding, and/or protrusion that required extraction of the maxillary first premolars followed by canine retraction, normal shape and structure of maxillary canines, no history of fillings or root canal treatment, and normal shape and structure of maxillary first molars. The study aim and detailed procedure were explained to the patients and/or guardians along with the potential side effects and informed consents were signed. All safety precautions were followed during perforations and piezocision.

Pre-orthodontic records were taken for all the patients and analyzed (study casts, digital extraoral and intraoral photographs, and panoramic and lateral cephalometric radiographs). The sample was randomly divided into two groups, each contained 10 patients. A split-mouth study design was employed for each patient; in which one side served as control while the contralateral side was the study side. Assignment of patients and the choice of the side of intervention were done through a computer-generated randomization technique (www.random.org). In Group A: MOPs assessment was performed on the study side. In Group B: Piezocision assessment was performed on the study side.

First, the subjects were referred to an oral surgeon to extract the first premolars without squeezing of the socket. A healing interval of about 6 weeks was taken before the start of orthodontic treatment. Regular orthodontic treatment was initiated by bonding both arches with a fixed orthodontic appliance to achieve initial leveling and alignment stage (OrthoPro MBT, 0.022’slot, Orthoprodent, USA). After the full completion of leveling and alignment; determined when an arch wire sized 0.017 × 0.025 inch St. St. could be inserted passively in the bracket slot, canine retraction was carried out in the control side directly on a mini-screw using closed coil spring (Figure 1). The retraction force was 150 g as measured using a force gauge (Coprex, Swiss made).

In Group A, 12 MOPs were made to a depth of 6 mm; distributed as follows: Three buccally between the canine and lateral incisor roots and three between the canine root and the socket of the extracted premolar

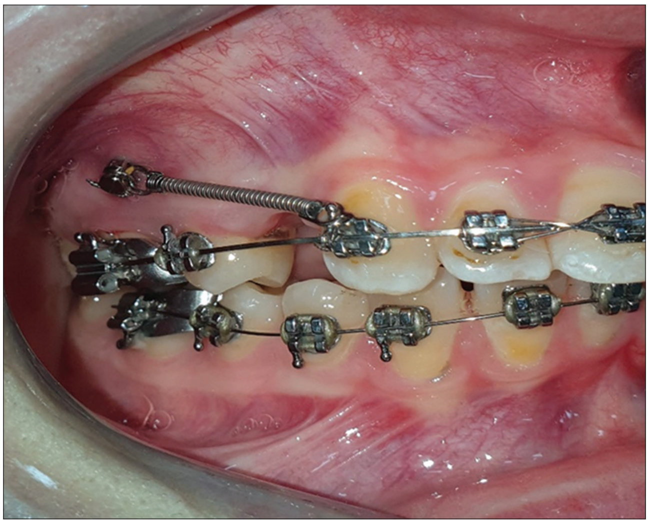

Figure 1: Retraction on the control side

(Figure 2). Further, three MOPs were made on the palatal side between the canine and lateral incisor roots and three between the canine root and the socket of the extracted premolar. This procedure was repeated every 2 weeks, such that MOPs were made 6 times over the 3 months study period. The mini-screws used to provide a perforation depth of 6 mm were 1.6 mm in diameter and 8 mm in length as the average gingival thickness is 2 mm.

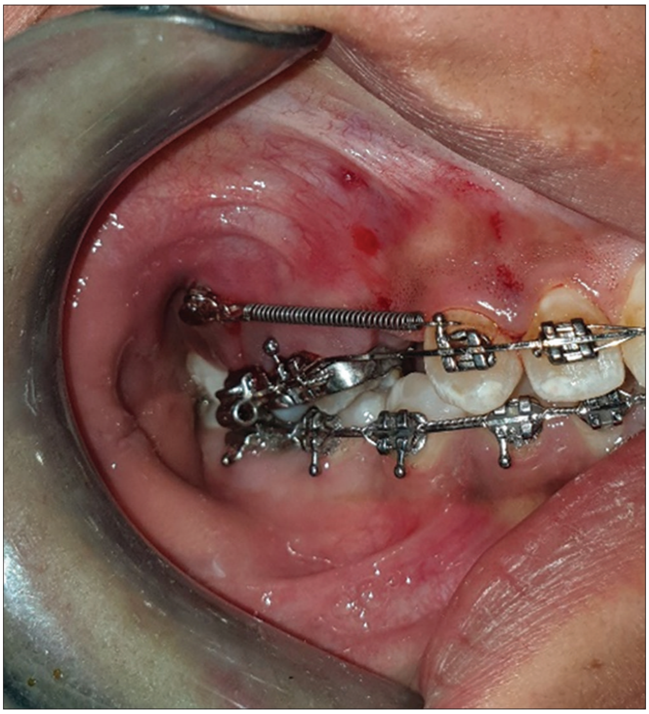

Figure 2: Micro-osteoperforations on the buccal side

In Group B using Piezotome and piezo surgical knife – BS 1insert and BP blade 15, two vertical interproximal piezocision cuts were placed (not including the free gingiva) on the mesio- and disto-buccal sides of the maxillary canines, piezocision cuts were performed 5 mm apical to the mesial and distal interdental papilla of the maxillary canines (Figure 3). Incision lengths were approximately 10 mm apically and the grooves in between the roots of the neighboring teeth were used as a guide for the cut lines. The incisions were made to a depth of 3 mm and a width of 3 mm. The cuts were placed only on the buccal side under copious saline irrigation (sodium chloride 0.9% w/v), then the area was sutured with an interrupted loop, non-resorbable Vicryl 4-0 black silk suture material. The sutures were left in place for 1 week and the patients were clinically checked every 2 weeks with a total of 5 times over 3 months. Data for the evaluation of each intervention were collected by direct intraoral measurements. The measurements were taken from the canine cusp tip to the mesiobuccal cusp tip of the maxillary 1st molar using digital intraoral caliper (IOS, China). Measurements were taken immediately before the beginning of canine retraction and every 2 weeks along the following 3 months.

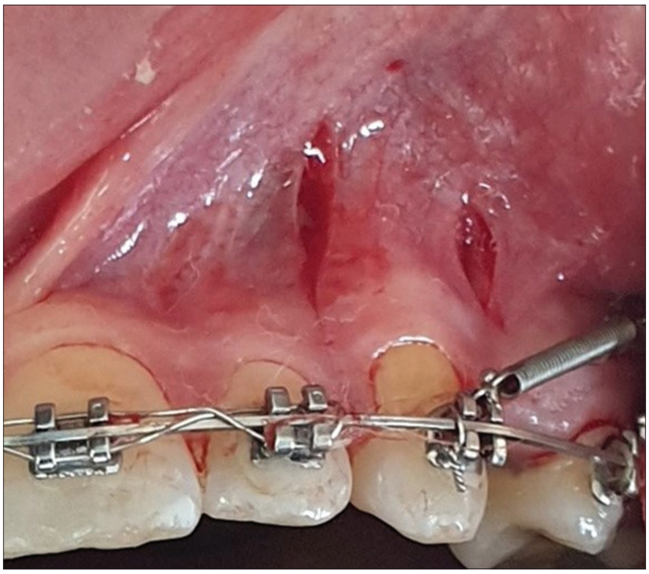

Figure 3: Piezocision cuts

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov–Smirnov and Shapiro–Wilk tests and showed parametric (normal) distribution (split-mouth technique). Repeated measure ANOVA test was used to compare between more than 2 groups in related samples. Paired sample t-test was used to compare between two groups in related samples. Independent sample t-test was used to compare between two groups in non-related samples. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Distance between canine tip and MB tip of first molar

A. Relation between piezocision and control

The means and standard deviations for the piezocision group are shown in Table 1 and Figure 4.

Table 1: The mean and SD values of distance between canine tip and MB tip of first molar for the piezocision group (paired sample t-test)

Variables (weeks)	Distance between canine tip and MB tip of first molar				
	Piezocision		Control		p-value
	Mean	SD	Mean	SD	
0	20.52	1.00	20.52	1.00	1ns
2	19.44	1.04	19.88	1.02	<0.001*
4	18.66	1.04	19.32	1.01	<0.001*
6	18.05	1.09	18.84	1.07	<0.001*
8	17.67	1.06	18.60	1.05	<0.001*
10	17.26	1.09	18.14	1.06	<0.001*
12	16.93	1.09	17.76	1.02	<0.001*

*Significant (p<0.05) ns: Non-significant (p>0.05). SD: Standard deviation.

a. 0 week:
There was no statistically significant difference between piezocision and control groups where $p = 1$.

b. 2 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

c. 4 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

d. 6 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

e. 8 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

f. 10 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

g. 12 weeks:
There was a statistically significant difference between piezocision and control groups where $p < 0.001$.

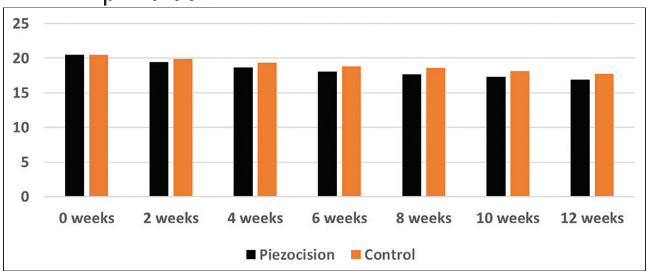

Figure 4: The mean distances between the canine tip and MB tip of the first molar in the piezocision group

B. Relation between MOPs and control

The means and standard deviations for the MOPs group are shown in Table 2 and Figure 5.

a. 0 week:
There was no statistically significant difference between MOPs and control groups where $p = 1$.

Table 2: The mean and SD values of distance between canine tip and MB tip of first molar for micro-osteoperforations group (paired sample t-test)

Variables (weeks)	Distance between canine tip and MB tip of first molar				
	Micro-osteoperforations		Control		p-value
	Mean	SD	Mean	SD	
0	20.47	1.04	20.47	1.04	1ns
2	19.17	1.05	19.85	1.07	<0.001*
4	18.35	1.02	19.16	1.12	<0.001*
6	17.62	1.04	18.70	1.09	<0.001*
8	17.17	1.00	18.52	1.13	<0.001*
10	16.73	1.05	17.96	1.15	<0.001*
12	16.30	1.08	17.64	1.08	<0.001*

*Significant (p<0.05) ns: Non-significant (p>0.05). SD: Standard deviation.

b. 2 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

c. 4 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

d. 6 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

e. 8 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

f. 10 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

g. 12 weeks:
There was a statistically significant difference between MOPs and control groups where $p < 0.001$.

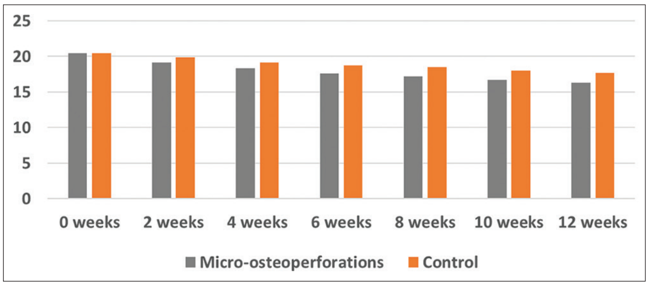

Figure 5: The mean distances between the canine tip and MB tip of the first molar in the micro-osteoperforations group

C. Relation between piezocision and MOPs

The means and standard deviations for the piezocision and MOPs group are shown in Table 3 and Figure 6.

a. 0 week:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.919$.

Table 3: The mean and SD values of distance between canine tip and MB tip of first molar (independent sample t-test) (repeated measure ANOVA)

Variables (weeks)	Distance between canine tip and MB tip of first molar				
	Piezocision		Micro-osteoperforations		p-value
	Mean	SD	Mean	SD	
0	20.52	1.00	20.47	1.04	0.919 ns
2	19.44	1.04	19.17	1.05	0.578 ns
4	18.66	1.04	18.35	1.02	0.518 ns
6	18.05	1.09	17.62	1.04	0.386 ns
8	17.67	1.06	17.17	1.00	0.298 ns
10	17.26	1.09	16.73	1.05	0.287 ns
12	16.93	1.09	16.30	1.08	0.212 ns
p-value	<0.001*		<0.001*		

*Significant (p<0.05) ns: Non-significant (p>0.05). SD: Standard deviation.

b. 2 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.578$.

c. 4 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.518$.

d. 6 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.386$.

e. 8 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.298$.

f. 10 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.287$.

g. 12 weeks:
There was no statistically significant difference between piezocision and MOPs groups where $p = 0.212$.

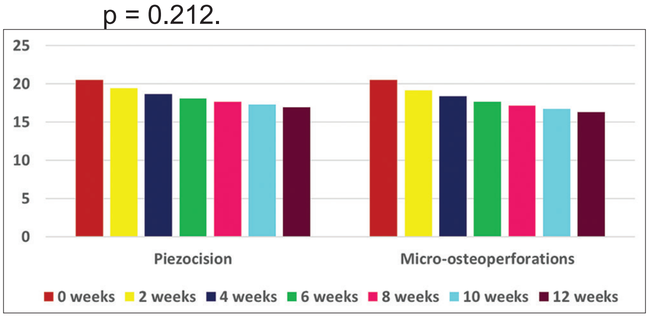

Figure 6: The mean distances between the canine tip and MB tip of the first molar both groups

D. Relation between time periods

a. Piezocision
There was a statistically significant difference between 0 week, 2 weeks, 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference between 0 weeks and each of 2 weeks, 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

Furthermore, a statistically significant difference was found between 2 weeks and each of 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 4 weeks and each of 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

Furthermore, a statistically significant difference was found between 6 weeks and each of 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 8 weeks and each of 10 weeks and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 10 weeks and 12 weeks groups where $p < 0.001$.

b. MOPs

There was a statistically significant difference between 0 week, 2 weeks, 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference between 0 week and each of 2 weeks, 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

Furthermore, a statistically significant difference was found between 2 weeks and each of 4 weeks, 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 4 weeks and each of 6 weeks, 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

Furthermore, a statistically significant difference was found between 6 weeks and each of 8 weeks, 10 weeks, and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 8 weeks and each of 10 weeks and 12 weeks groups where $p < 0.001$.

A statistically significant difference was found between 10 weeks and 12 weeks groups where $p < 0.001$.

Discussion

In an era of speed and high competition, decreasing the duration of orthodontic treatment is turning to be a must. MOPs and piezoelectric surgery (piezocision) are new emerging methods for accelerating orthodontic tooth movement yet under investigation by many researchers [30], [31]. Many approaches were presented for canine retraction into the extraction space; discussing anchorage preparation and the magnitude of the used retraction force (magnitude, direction, and force decay) [32], [33]. [34]. Aboul-Ela *et al*. [24] stated that titanium mini-screws provided an easy and effective skeletal anchorage for canine retraction. In the current study, direct anchorage using mini-screws between the 2nd premolars and 1st permanent molars, during canine retraction on a closed coil spring, was selected. This set up eliminates any anchorage loss from the molars which may result in confusing false results during measurements. The chosen force magnitude was 150 g adopted from Barlow and Kula [35] who concluded, in their systematic review, that there was no added advantage in the 200 g force over the 150 g force magnitude concerning the rate of canine retraction. The statistical analysis of the direct intraoral measurements for Group A (MOPs group) showed a significantly higher rate of canine retraction in the study side. This was in agreement with the trial carried out by Alikhani *et al*. [36] who found a 2–3-fold rise in the rate of orthodontic tooth movement with MOPs. When this method was experimented on rats, it was observed to be effective in enhancing the rate of tooth movement [37]. Further, investigations on rats by Tsai *et al*. revealed similar results [38]. In this study, the rate of canine retraction in the MOPs side was higher by nearly 1.5-fold compared to canine retraction in the control side over the 3 months period. The highest rate was observed during the first 4 weeks, measuring nearly 0.9 mm every 2 weeks, that was in agreement with other clinical trials and is explained by the accelerator effect that accompanies the MOPs procedure which is at its maximum in the 1st month [22], [26]. Wilcko *et al*. [16] theorized that the rapid orthodontic canine retraction and minimal apical root resorption that accompanied periodontal accelerated osteogenic orthodontics were attributable to increased regional bone turn over (the RAP) and the associated osteopenia, that is, calcium depletion and diminished bone density, precipitated by selective decortication. They further explained that the dynamics of the physiologic tooth movement in these patients might be more appropriately described as bone matrix transportation. In addition, the rate of tooth movement is controlled by osteoclast recruitment and activation [21]. Therefore, regardless of the shape or the extent of the cut; bone resorption will not occur unless osteoclasts are activated. This means that similar to MOPs, the effectiveness of corticotomy [25] or piezocision [39] can be related to the activation of cytokines that are released in response to the trauma induced during the cuts [40].

Similarly, Group B showed a significantly higher rate of canine retraction in the study side that was in agreement with other studies [19], [28]. The rate of canine retraction in the piezocision side was higher by nearly 1.3-fold compared to standard canine retraction over the 3 months period. The ability of piezocision to accelerate canine retraction can be also explained by the RAP as with the MOPs. On reviewing the literature, piezocision cuts were placed vertically close to the canine to be retracted and as far as possible from the anchor teeth [41] such that the longer and the deeper the incision, the more the effect of the RAP [20].

On the other hand, there was no statistically significant difference between piezocision and MOPs groups. Nevertheless, the MOPs group was 0.2-fold faster than the piezocision group.

Within the limitations of this study, it can be deducted that the adjunctive use of either MOPs or piezocision with orthodontic treatment could be clinically worthwhile; with MOPs being slightly more effective over piezocision.

Conclusion

- MOPs and piezocision techniques accelerated the rate of canine retraction during orthodontic treatment
- MOPs technique provided a slightly greater acceleration than piezocision.

Research ethical approval

This study was made with the approval of the Ethical Committee of the Faculty of Dentistry, Minia University.

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