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APPRAISAL OF ANCHORAGE LOSS DURING MAXILLARY MOLAR DISTALIZATION ASSISTED WITH TWO APPROACHES OF MICRO-OSTEOPERFORATIONS: A PROSPECTIVE CLINICAL INVESTIGATION

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Abstract

Objectives: This study aimed to assess anchorage loss in central incisors and premolars after maxillary molar distalization with MOPs to accelerate tooth movement.

Methods: Thirty class II patients indicated for maxillary molars distalization received mini-implant-supported distal jet appliance and were randomized to receive micro-osteoperforations on the buccal side, buccal and palatal side or no application. Micro-osteoperforations were applied in a repeated manner with each activation of the device. Study casts obtained before and after treatment were laser scanned to obtain 3D digital models. The pre and post-digital models were superimposed according to the same reference points to allow measurement of anchorage loss of central incisors and premolars. Data were analyzed using the one-way ANOVA test for intergroup comparison and the paired t-test for intragroup comparison.

Results: No significant differences were found at T4 among the three groups. However, there was statistically considerable anchorage loss in central incisors and 1st premolars (on both sides combined and separate) after maxillary molar distalization in all groups compared to baseline.

Conclusion: The application of MOPs on buccal or buccal and palatal sides did not cause considerable anchorage loss compared to no application after maxillary molar distalization. However, the anchorage loss was considerable after treatment.

Keywords: Micro-osteoperforation, Maxillary Molar Distalization, Distal Jet, Anchorage Loss

Introduction

Distalization is a standard treatment for correcting Class II malocclusion in the maxillary arch. This treatment aims to achieve a Class I molar and canine relationship, which can be accomplished through extraoral or intraoral methods [1,2]. However, orthodontic treatments may sometimes cause unintended tooth movements, such as tipping molars or moving incisors forward. To avoid these unwanted effects, temporary skeletal anchorage devices can support intraoral distalization appliances, which can help maintain proper tooth alignment [2–4]. Shortening the duration of orthodontic treatment is a significant research area in modern orthodontics. Patients often expect a shorter treatment period than the traditional 20 months or longer that fixed orthodontic treatment can take, especially adult patients who may avoid treatment due to the lengthy duration [5]. Various surgical and nonsurgical techniques have been developed to speed up tooth movement. While surgical techniques like corticectomies have shown promising results, they are invasive and may not be practical for routine use alongside orthodontic treatment [6,7].

Micro-osteoperforation is a minimally invasive technique that involves creating small perforations in the alveolar bone using mini-screws or specialized instruments without raising a flap [8]. MOPs stimulate cell biodiversity and can lead to Regional Acceleratory Phenomenon (RAP), as described by Frost [9]. This is a phenomenon where a repairing tissue, when subjected to a regional stimulant intervention such as minor osteo-corticoperforations, recovers at a faster rate than the normal repair process. The biological response to orthodontic force is crucial in accelerating tooth movement and is closely linked to bone resorption and osteoclastic activity [10]. A recent systematic review has highlighted the effectiveness of MOPs in accelerating tooth movement. The review found that MOPs significantly increased the rate of tooth movement after one month of application compared to no application. However, it's worth noting that the studies pooled in the review only used MOPs in canine retraction. There were concerns about the risk of bias as the pooled studies showed significant heterogeneity. Nevertheless, a sensitivity analysis, which included only low-risk-of-bias studies, did not yield significant results [11]. The previous systematic review concluded that MOPs did not cause considerable anchorage loss in canine retraction studies compared to the control group [11].

A recent scoping review has analyzed all the available evidence and concluded that the effectiveness of MOPs in speeding up orthodontic treatment is not definitive for several reasons that include, studies of short duration, great diversity of available evidence, small sample size and combining patients with dissimilar characteristics as a wide age range, gender and variety of maloclusions. Additionally, research on MOPs primarily focuses on canine movements, while other teeth are less considered [8]. A single study has investigated the use of MOPs in the distalization of maxillary molars with the distal jet appliance [12]. The study found that the rate of tooth movement was lower than anticipated, but it did not evaluate the amount of anchorage loss resulting from the distalization of maxillary molars. This study aims to assess anchorage loss in central incisors and premolars after maxillary molar distalization with MOPs to accelerate tooth movement.

Materials and methods

Trial design

The current study was a single-center, multi-arm randomized clinical trial with an equal allocation ratio and superiority trial framework.

Participants

The participants for this study were young adults (male/female) in the age range of 14 to 17 years who had bilateral class II molar relationship, skeletal class I or mild class II, average or decreased vertical height, good oral hygiene, and fully erupted first and second molars. Those with congenital dental-skeletal disorders or required surgical correction, posterior crowding or spacing, periodontally compromised teeth, and bad oral hygiene were excluded from the study. Patients who experienced repeated appliance breakage and missed multiple appointments were also discontinued from the trial.

Randomly selected participants from the outpatient clinic of the Orthodontic Department at the Faculty of Dental Medicine, Al-Azhar University (Boys), Cairo, Egypt, were enrolled in this study after the study procedures were explained to them and informed consent was obtained. The patients were then randomized to receive repeated applications of MOPs on the buccal side only, buccal and palatal sides, or none (control group). The study was approved by the Ethics Committee at the Faculty of Dental Medicine (Boys), Al-Azhar University, Cairo, Egypt (Approval code 651/2053) and registered on ClinicalTrials.gov (ID: NCT05171738).

Sample size calculation

The sample size was determined using G*power software [13] by considering the findings of previous studies [12,14]. The following parameters were used: 80% power, an independent t-test for comparing two means, and a two-sided significance level of 5%. It was estimated that a minimum of 25 participants would be required to detect a clinical difference with adequate power. The total sample size was increased to 30 patients to account for possible dropouts.

Randomization

Allocation sequence generation was done by computer-generated simple randomization using online software [15]. After enrolling eligible participants, they were randomly assigned to three groups of ten each. Allocation sequence concealment was done via telephone, as the random number list was kept secure with the supervisor, who was not involved in the procedures or the outcome assessment. As the nature of the intervention made it impossible to blind the operators and the patients, only the statistician was blinded to the data analysis, using codes assigned to different groups.

Interventions

Before starting orthodontic treatment, each patient underwent standardized extraoral and intraoral photography, orthodontic study model creation, and panoramic and lateral cephalometric radiography. Maxillary molar distalization was performed on all participants using a distal jet appliance (American Orthodontics, Washington, Sheboygan, USA). The separation and banding of maxillary first molars and premolars were performed before taking impressions and fabricating the appliance. The distal jet (American Orthodontics) appliance was manufactured as a single unit with four solder joints at the first premolar and first molar bands. The mini-implant insertion slots were positioned 1 mm distal to the third rugae area, 3 mm lateral to the mid-palatal raphe, and 3mm away from the palatal mucosa. After appliance insertion and cementation of the bands, patients were advised to follow oral hygiene measures for two weeks before mini-implant placement. This was done as a prophylaxis. After administering local anesthesia and disinfecting the site, two mini-implants (OAS-T1511, Biomaterials Korea Inc. Company) were installed into the (2mm diameter) insertion slot. They were positioned perpendicular to the palate and directed away from the roots of the adjacent teeth (Figure 1) [16].

Fig. (1): showing the distal jet appliance with the mini-implants inserted in their slots.

Before the MOPs application, patients were instructed to rinse their mouths with a 0.2% chlorhexidine mouthwash. During the study's observation period, the subjects in the MOPs groups received repeated MOPs with each activation [17,18]. During the procedure, under local anesthesia, two MOPs were applied between the second premolars and first molars, first molars and second molars, and distal to the second molars (Figure 2) using orthodontic mini-screws that were 1.4 mm wide (manufactured by Hubit, Korea). The MOPs were performed at a depth of 5 to 6 mm, and the drill was inserted until it entered the spongy bone by crossing through the cortical plate [12]. Participants in the MOP groups received six MOP applications on only the buccal or buccal and palatal sides. After the first activation, subjects were seen after four weeks for subsequent activation. After each MOP application, participants were instructed to use chlorhexidine mouthwash three times daily for three days and avoid non-steroidal anti-inflammatory drugs since they could hinder tooth movement [19].

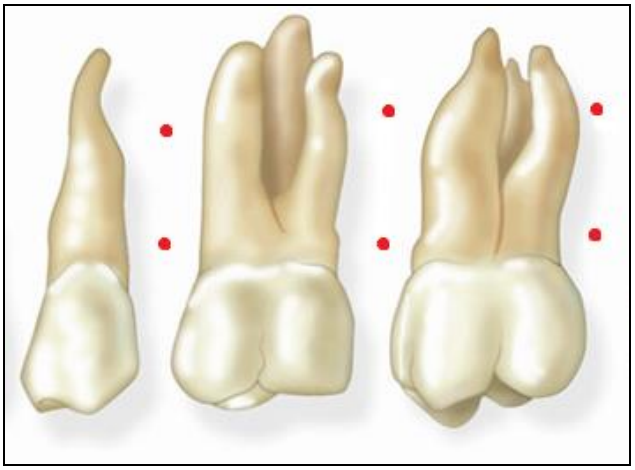

Fig. (2): Diagram showing the target sites for MOPs.

Outcomes

Anchorage loss was assessed by superimposition and comparison of the pre-and post-distalization digital study models to determine the mean distance of central incisors, 1st and 2nd premolars in reference to the rague plane on the left and right sides.

For each patient, upper impressions were taken just before molar distalization (T0) and after the end of the last activation (T4). The impressions were poured with dental stone immediately after each visit and marked with the patient identification data (Name, number, and date). Each stone model was then scanned using a 3Shape E4 scanner to obtain the STL format of the digital model. Using the attached 3Shape computer software, the sequential digital models of each patient were superimposed. Using 5-point superimposition, model (T4) was superimposed on model (T0), where point localization was done on the two models in parallel. The points were selected on the most anterior, prominent, and posterior points of the incisive papilla and the medial 2/3rd of the right and left third rugae areas. Color-coded superimposition was used to verify the accuracy of the superimposition [20]. The reference planes were reconstructed as follows: The mid-sagittal plane was placed, and the rugae plane was constructed perpendicular to the mid-sagittal plane at the medial 2/3rd level of the right-third rugae. Reference points were marked on the central incisors and premolars, and linear measurements were taken in reference to the rugae plane (Figure: 3).

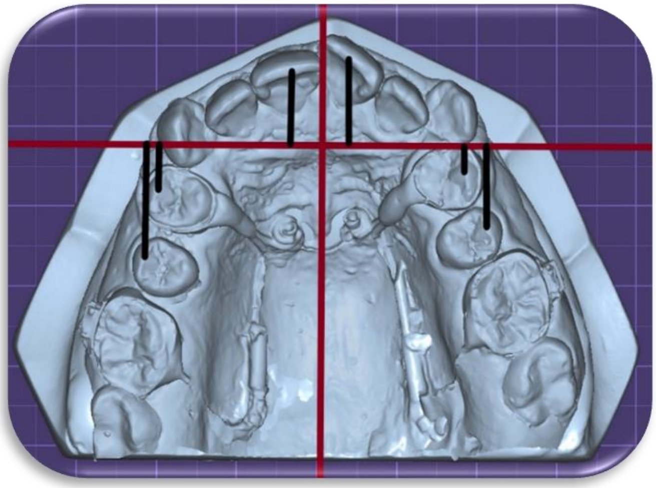

Fig. (3) Showing: Linear measurements in relation to the reference plane.

Statistical methods

The level of statistical significance was set at 5%. Statistical analysis was done using R and R Studio software [21,22]. Data organization, manipulation, and summarization were done using the “tidyverse” R package [23]. Continuous data were summarized into mean and standard deviation. The normality of data distribution was explored using the Shapiro-Wilk test function from the “rstatix” R package [24]. The one-way ANOVA test was used for intergroup comparisons using the “anova_test” function from the “rstatix” R package [24]. The paired t-test was used to compare the intragroup values between T0 and T4 using the "t_test" function from the "rstatix" R package and the "paired" argument was set to “True” [24]. Effect sizes and their respective 95% confidence intervals were calculated using Cohen`s d effect size with the hedge`s bias correction for small sample sizes using the Cohen`s d effect size function from the “rstatix” R package and setting the argument “paired” into “True” [24]. Results were tabulated using the “knitr” and “kableExtra” R packages [25,26]. Interclass correlation coefficients were calculated to determine intra-observer and inter-observer agreement using the ICC function of the “psych” R package [27]. Higher values (closer to one) indicate better reliability.

Results

Thirty patients ranging from 14 to 17 years old were enrolled and randomly divided into three groups of ten each to receive MOPs after activation of the distalization appliance on only the buccal side or buccal and palatal or none. Twenty-seven patients were analyzed at the end of the study, with one patient lost to follow-up from each group (Fig. 6). Table 1 shows the baseline characteristics of the patients.

Table 1: Baseline characteristics

Variables / Groups	**Group 1**	**Group 2**	**Group 3**
Gender (M/F)	7/3	6/4	5/5
Age (mean and SD)	15.5 (2.3)	16.5 (2.4)	16 (2.5)

Group 1: MOPs on the buccal side only; Group 2: MOPs on the buccal and palatal side; Group 3: No MOPs (control); M: males; F: females; SD: standard deviation.

Good intra-rater and inter-rater agreement scores were obtained from all measurements, ranging from 0.85 to 0.91 and 0.86 to 0.93, respectively. Inter-group and intra-group comparisons are shown in Table 2 and Table 3 for both the left and right sides combined and separated, respectively. No significant differences were obtained at T4 between the three groups. However, central incisors and 1st premolars (on both sides combined and separate) showed statistically significant anchorage loss after maxillary molar distalization in all groups compared to the baseline.

Table 2 shows inter and intra-group comparisons between the two groups, including both sides.

Tooth/group	**Group 1**			**Group 2**			**Group 3**			**Intergroup comparison**
	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	P value
Central incisors	14.97 (3.12)	16.23 (3.1)	-0.81 [-1.29, -0.41]*	15.75 (3.13)	16.38 (3.02)	-0.77 [-1.37, -0.37] *	15.30 (3.11)	16.42 (3.11)	-2.1 [-3.23, -1.69] *	0.957
1st premolars	2.43 (2.6)	1.62 (2.7)	0.94 [0.43, 2.4] *	2.56 (2.72)	1.77 (2.80)	0.85 [0.54, 2.03] *	3.26 (2.07)	2.11 (2.13)	1.32 [0.84, 3.5] *	0.826
2nd premolars	9.67 (3.2)	10.45 (2.87)	-0.62 [-1.23, -0.29] *	9.58 (3.01)	10.13 (2.94)	-0.57 [-1.13, -0.16] *	9.53 (2.96)	10.28 (2.99)	-0.72 [-1.46, -0.32] *	0.083

MOPs: micro-osteoperforation group, T0: baseline, T4: after treatment, SD: standard deviation, 95% CI: 95% confidence intervals, Group 1: MOPs on the buccal side only; Group 2: MOPs on the buccal and palatal side; Group 3: No MOPs (control), *: a significant difference.

Table 3 shows inter and intra-group comparisons between the two groups for each side alone.

Tooth/group	Group 1			Group 2			Group 3			Intergroup comparison
	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	T0 Mean (SD)	T4 Mean (SD)	Cohen`s d [95% CI]	P value
Right central incisor	16.01 (3.1)	16.51 (2.86)	-0.45 [-1.53, 0.06]	16.11 (3.19)	16.64 (2.93)	-0.55 [-1.64, 0.02]	15.32 (3.23)	16.32 (3.28)	-1.72 [-5.15, -1.26] *	0.08
Left central incisor	15.24 (3.11)	16.2 (3.37)	-0.98 [-2.4, -0.49] *	15.39 (3.21)	16.11 (3.26)	-0.93 [-1.81, -0.59] *	15.28 (3.17)	16.52 (3.12)	-2.29 [-4.55, -1.74] *	0.541
Right 1st premolar	1.87 (2.9)	0.91 (3.2)	0.89 [0.69, 2.87] *	1.98 (3.20)	0.87 (3.38)	0.96 [0.76, 2.61] *	3.01 (2.31)	1.59 (2.56)	1.37 [1.12, 3.51] *	0.859
Left 1st premolar	3.12 (2.32)	2.58 (1.9)	0.86 [0.21, 2.48] *	3.14 (2.17)	2.67 (1.86)	0.71 [0.14, 2.37] *	3.51 (1.90)	2.62 (1.56)	1.20 [0.44, 4.66] *	0.476
Right 2nd premolar	8.76 (3.46)	9.24 (3.54)	-0.52 [-1.59, 1.1]	8.84 (3.56)	9.21 (3.45)	-0.41 [-1.47, 0.17]	8.62 (3.27)	9.27 (3.36)	-0.58 [-1.99, -0.01] *	0.09
Left 2nd premolar	10.43 (2.43)	11.24 (2.32)	-0.68 [-1.57, -0.09] *	10.32 (2.31)	11.06 (2.14)	-0.64 [-1.55, -0.05] *	10.44 (2.45)	11.29 (2.34)	-0.74 [-1.98, -0.21] *	0.176

MOPs: micro-osteoperforation group, T0: baseline, T4: after treatment, SD: standard deviation, 95% CI: 95% confidence intervals, Group 1: MOPs on the buccal side only; Group 2: MOPs on the buccal and palatal side; Group 3: No MOPs (control), *: a significant difference.

Discussion

This study aimed to evaluate the loss of anchorage in class II patients' central incisors and premolars after undergoing maxillary distalization assisted by repeated MOPs. This is the first randomized clinical trial to assess anchorage loss after maxillary molar distalization using the distal jet appliance and MOPs. Comprehensive systematic reviews have yet to report similar studies [8,11]. Thirty class II patients were randomized to receive repeated applications of MOPs on the buccal and palatal side, buccal side only, or none after the maxillary distalization using a distal jet appliance.

Anchorage loss measurements were obtained from the superimposition of 3D digital models at baseline and after treatment on prespecified stable reference structures obtained from laser scanning study models. The dental models' pre- and post-treatment scans aligned with three specific points in the incisive papilla region: the most anterior, prominent, and posterior points. This precise alignment method allows for more dependable and accurate superimposition by the software [20].

This study showed no significant difference in anchorage loss between the repeated application of MOPs on buccal or buccal and palatal sides or the control group, which agrees with a recent systematic review assessing the effect of MOPs on the rate of orthodontic tooth movement [11]. However, the previous systematic review pooled studies that used MOPs during canine retraction and measured the amount of anchorage loss in molar mesialization.

Regarding the anchorage loss on both sides in each group, central incisors and premolars showed significant anchorage loss with more labial movement of the central incisors and mesialization of the first premolars after treatment compared with the baseline. This agrees with a study by Kinzinger and colleagues that found similar anchorage loss after using mini-implants supported distal jet appliances [28]. On the other hand, the second premolars showed significant distal movement after treatment compared to baseline in each group, which could be foreseen as the bodily distal movement of the maxillary first molar and opening of the mesial space adjacent to it [28].

Considering the right or left side alone, the same results were obtained except for the right central incisor, which did not show significant anchorage loss in MOP groups before and after treatment. The right second premolar showed non-significant distal movement before and after treatment in the MOPs groups. Anchorage loss obtained in this study before and after treatment using a distal jet appliance agrees with a previous study that showed significant mesialization of first maxillary premolars and labial movement of the central incisors, which highlights the effects of using the distal jet appliance [29].

Conclusion

The application of MOPs on buccal or buccal and palatal sides did not cause considerable anchorage loss compared to no application after maxillary molar distalization using a mini-implant-supported distal jet appliance. However, anchorage loss was evident in the labial movement of central incisors and mesialization of first premolars after distalization compared to the baseline, regardless of the MOPs application.

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