Original Article

Mini-implant supported canine retraction with micro-osteoperforation: *A split-mouth randomized clinical trial*

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ABSTRACT

Objectives: To investigate, using a split-mouth randomized clinical design, the effect of micro-osteoperforation (MOP) on mini-implant supported canine retraction using fixed appliances.

Materials and Methods: Thirty subjects (seven males and 23 females) with a mean age of 22.2 (3.72) years were randomized into three canine retraction groups: Group 1 (MOP 4-weekly maxilla/8-weekly mandible; n = 10); Group 2 (MOP 8-weekly maxilla/12-weekly mandible; n = 10) and Group 3 (MOP 12-weekly maxilla/4-weekly mandible; n = 10) measured at 4-week intervals over 16 weeks. Subjects also completed pain (5-point Likert scale) and pain impact (Visual Analogue Scale) questionnaires. The primary outcome was the amount of canine retraction over 16 weeks at MOP (experimental) and non-MOP (control) sites.

Results: Mean overall canine retraction was 4.16 (1.62) mm with MOP and 3.06 (1.64) mm without. After adjusting for differences between jaws, all MOP groups exhibited significantly higher canine distalization than the control group: 0.89 mm more (95% confidence interval [CI] = 0.19 to 1.59 mm; $P = .01$) in the MOP-4 group, 1.08 mm more (95% CI = 0.49 to 1.68 mm; $P = .001$) in the MOP-8 group and 1.33 mm more (95% CI = 0.55 to 2.10 mm; $P = .002$) in the MOP-12 group. All subjects reported pain associated with MOP with 60% classifying it as moderate and 15% severe. The main impact of this reported pain was related to chewing and speech.

Conclusions: MOP can increase overall mini-implant supported canine retraction over a 16-week period of observation but this difference is unlikely to be clinically significant. (*Angle Orthod.* 2019;89:183–189.)

KEY WORDS: Accelerated tooth movement; Micro-osteoperforation

INTRODUCTION

A number of innovations have been described over recent years that aim to reduce orthodontic treatment time with fixed appliances.[1] Among these, surgical disruption of alveolar bone continuity has been suggested to facilitate the acceleration of orthodontic tooth movement.[2] Although the biological and clinical effects of surgical procedures on the alveolus during orthodontic treatment are poorly understood, surgery can induce a localized inflammatory response, which encourages local recruitment and stimulation of osteoclasts and increased remodeling. However, the evidence base relating to the efficiency of surgical-assisted orthodontics is currently small and associated with potential bias in many of the studies that have been performed, with more clinical trials needed.[3]

Micro-osteoperforation (MOP) is one of the least invasive surgical techniques described for use in conjunction with orthodontic treatment. It involves the

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production of multiple transmucosal perforations within alveolar bone, sited in close proximity to the region of desired tooth movement and in specific configurations, depending on the tooth movement required.[4] To date, the evidence base for MOP is small and contradictory, with some early data derived from animal models[5] and a single clinical trial in humans[6] that demonstrated significant increases in rates of orthodontic tooth movement in conjunction with this technique. However, more recent evidence was less encouraging, suggesting that rates of tooth movement were not altered in the presence of MOP.[7] Additionally, there is currently no evidence regarding the efficiency of this technique over the whole period of orthodontic treatment.

A better understanding of the clinical effectiveness of MOP is therefore desirable in orthodontics. The current study investigated MOP using mini-implant supported canine retraction with fixed appliances. This split-mouth randomized trial focused on canine retraction within the maxilla and mandible following the extraction of first premolar teeth, and the effects of multiple MOP carried out at specific time points during a 16-week period of observation. In addition, feedback was also collected from participants relating to their experience of MOP during treatment.

MATERIALS AND METHODS

Trial Design

This was a single-center split-mouth randomized clinical trial registered at ClinicalTrials.gov (DF CD1412/0089P). Ethical approval was obtained from the Medical Ethics Committee, University of Malaya (Malaysia) (DF CD1301/0009).

Participants, Setting, and Eligibility Criteria

Participants were recruited from subjects attending the Department of Orthodontics at the University of Malaya. Eligibility criteria included: (1) aged 18 years and above at the start of treatment; (2) molar relationship either class I, $<$ unit class II or class III; (3) extraction of all four first premolar teeth as part of the orthodontic treatment; (4) maximum anchorage required using a mini-implant; (5) no systemic disease; (6) good oral hygiene; and (7) no periodontal disease. Participants were excluded if they had significant vertical skeletal discrepancies, systemic diseases requiring long-term antibiotic use, phenytoin, cyclosporin, anti-inflammatory drugs, bisphosphonates, systemic corticosteroids or calcium channel blockers, poor oral hygiene for more than two visits, or active periodontal disease.

Interventions

Participants were fitted with a pre-adjusted edgewise fixed appliance (3M Unitek, Monrovia, Calif) MBT prescription and 0.022 $\times$ 0.028-inch slot. A standardized six-weekly archwire sequence of 0.014-inch, 0.018-inch, 0.017 $\times$ 0.025-inch nickel titanium (NiTi) (3M Nitinol SuperElastic) was used for alignment, followed by a working archwire of 0.018 $\times$ 0.025-inch stainless steel (S/S) (GAC PAK Stainless Steel ACCUFORM). This working wire was used to minimize binding and friction during canine retraction.[7] Orlus (Ortholution.com) 1.6-mm diameter mini-implants were placed under local anesthesia in a buccal position between the first permanent molar and second premolar and ligated directly to the first molar for anchorage. Canine retraction was carried out on the working archwire using 3M Unitek AlastiK elastomeric chain, force 140–200 g (measured directly using a Correx Force Tension gauge, Haag-Streit Diagnostics, Koeniz, Switzerland). The chain was placed directly to the mini-implant posteriorly (as a fixed point of anchorage) and the canine bracket anteriorly. Canine retraction was initiated one visit following placement of the working archwire. At the randomized experimental sites, three separate MOPs were made directly through the buccal mucosa adjacent to the extraction site in a vertical direction 2 mm apart and 3 mm in depth (measured using a rubber stopper) using an Orlus screw (Ortholution.com), width 1.6 mm and length 6 mm (Figure 1A,B). After hemostasis was achieved using a cotton pellet and local pressure, paracetamol (1000 mg) was prescribed to be taken as necessary.

Postoperative pain and the impact of this pain on daily function was evaluated for each subject using a self-administered questionnaire. This questionnaire evaluated overall pain intensity based on a 5-point Likert scale throughout the study period and the impact of any pain on daily function based on a Visual Analogue Scale.[8,9]

Sample Size Calculation

Sample size calculation was based upon a previous trial investigating monthly canine retraction rate using power chain with conventional-ligated brackets over a three-month period (mean = 0.84 mm/month; SD = 0.21 mm/month). Assuming the smallest difference requiring detection in canine retraction velocity to be 0.25 mm/month (30% increase) using a paired *t* test, alpha level of 0.05 and power of 80% with an intracluster correlation coefficient of 0.5,[8] 10 mouth sides would be needed per trial arm, giving a total of 30 mouth sides (15 patients) overall. Another 15 patients were added to account for possible dropouts and enable statistical analysis of confounders.

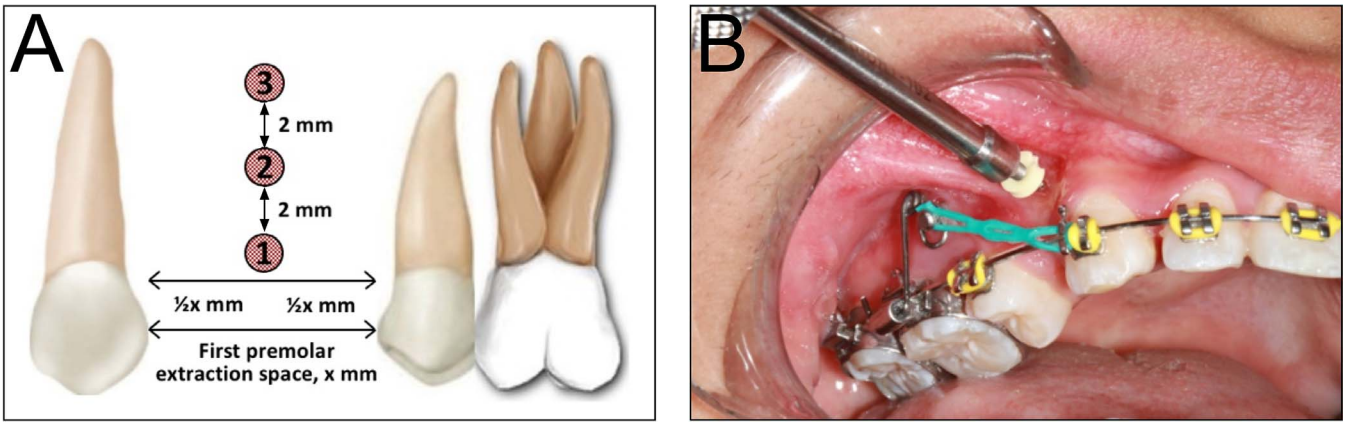

Figure 1. MOP placement (A) Site and (B) Clinical application with the mini-implant.

Randomization

Randomized block sampling was carried out using RANDOM.ORG online software to allocate participants into three intervention groups on a 1:1:1 basis. The three intervention groups consisted of different timed intervals of MOP during mini-implant facilitated canine retraction over the 16-week period of observation: Group 1 (4-weekly in the maxilla, MF-MOP-4; 8-weekly in the mandible, MF-MOP-8); Group 2 (8-weekly in the maxilla, MF-MOP-8; 12-weekly in the mandible, MF-MOP-12) and Group 3 (12-weekly in the maxilla, MF-MOP-12; 4-weekly in the mandible, MF-MOP-4). A simple randomization method drawing lots was employed to assign the side of the maxilla and mandible to MOP intervention, while the opposing side served as the split-mouth control.

Data Collection

Data collection took place over a period of 16 weeks following the start of mini-implant facilitated canine retraction. At each 4-weekly review, the power chain was replaced and the distance from the central point of the canine bracket to the superior margin of the mini-implant (maxilla) and the inferior margin of the mini-implant (mandible) and the distance from the canine cusp tip to the mesiobuccal groove of the first molar was clinically measured using electric digital calipers (accurate to 0.01 mm). MOP was carried out at the experimental sites according to the randomized intervention group. A self-administered questionnaire was obtained from each subject at 16 weeks.

Error of the Method

Intra-observer and inter-observer calibration was conducted for canine retraction measurements[10] with a random error of 0.049 mm for inter-observer evaluation and 0.020 mm for intra-observer; while systematic error was 0.045 mm for the inter-observer evaluation and 0.020 mm for the intra-observer. Both errors were small and not significant ($P < 0.001$).

Blinding

It was not possible to blind clinicians and subjects to the allocated intervention site. However, all data were coded before processing and analysis, ensuring blinding at this stage of the study. The outcome measurements was also blinded.

Statistical Analysis

Descriptive statistics were calculated including means and standard deviation (SD) after checking the distribution of the trial outcome. Crude differences among experimental and control groups were calculated by one-way analysis of variance. Additionally, linear regression was used with robust standard errors taking into account clustering of canines within each patient. Initially, the administered intervention and possible confounders (age, sex, and jaw) were used in univariable models with canine distalization as the dependent variable. Afterward, all variables with $P \leq .20$ were added in a multivariable model with the administered intervention to calculate adjusted estimates and their 95% confidence intervals (CI). ANOVA testing was also employed to test association of pain intensity for the three intervals of MF-MOP. Pairwise multiple comparison was performed with Bonferroni adjustment to detect the mean pain differences between different intervals. Chi-square test was employed to test associations with the impact of pain on daily functions for the three intervals of MF-MOP. Analyses were run in Stata 14.2 (StataCorp, College Station, Texas) and SPSS 23.0 (SPSS Inc., Chicago, Ill) with a two-sided $P \leq .05$ considered significant in all cases.

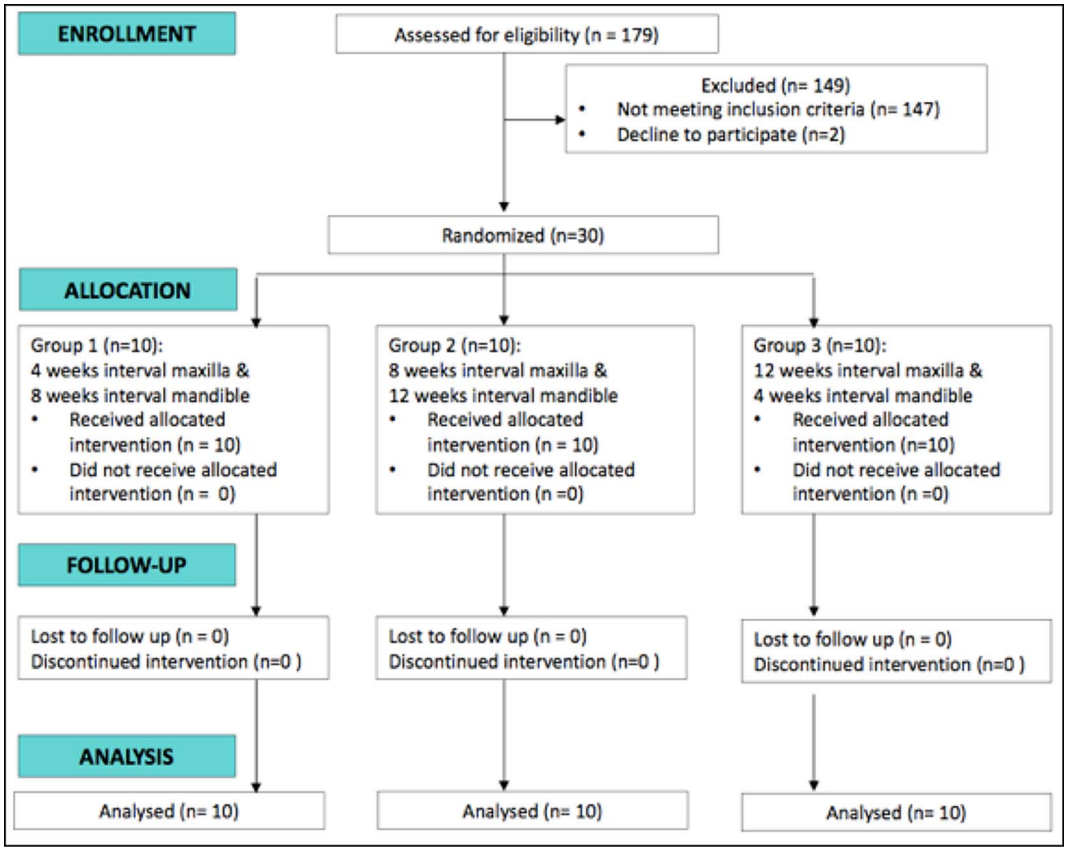

Figure 2. CONSORT diagram showing the flow of subjects through the trial.

RESULTS

A CONSORT diagram showing subject flow through the trial is shown in Figure 2. Thirty subjects were enrolled into the study between September 2014 and March 2016 with data collection complete by March 2017 and no dropouts. A total of 10 subjects were allocated to each Group (Groups 1–3. The total randomized sample consisted of seven males and 23 females with a mean age of 22.2 years (SD: 4.00).

Over the 16-week observation period, the mean overall canine retraction was 3.06 mm (SD = 1.64 mm) in the untreated control group and 4.16 mm (SD = 1.62 mm) in the MOP groups. Specifically, the mean canine retraction was 3.96 mm (SD = 1.71 mm) in the MOP-4 group, 4.15 mm (SD = 1.40 mm) in the MOP-8 group, and 4.39 mm (SD = 1.78) in the MOP-12 group, with significant differences among groups (Table 1). Initial regression analysis indicated that, apart from the experimental group, jaw (maxilla vs mandible) significantly affected canine retraction (Table 2). After taking this confounder into consideration, all MOP groups exhibited significantly higher canine distalization than the control group: 0.89 mm more (95% CI = 0.19–1.59 mm; $P = .01$) in the MOP-4 group, 1.08 mm more (95% CI = 0.49–1.68 mm; $P = .001$) in the MOP-8 group, and 1.33 mm more (95% CI = 0.55–2.10 mm; $P = .002$) in the MOP-12 group. Finally, upper canines were distalized 0.94 mm more (95% CI = 0.26–1.62 mm; $P = .008$) during the 16-week observation period than lower canines (Figure 3).

All subjects returned completed pain intensity questionnaires and all of the subjects reported pain associated with MOP. In those receiving MF-MOP-4, 60% reported moderate (score 2/5) and 15% reported severe (score 3/5) pain in both the maxilla and mandible. In contrast, the majority reported only mild (score 1/5) pain for MF-MOP-8 and MF-MOP-12 sites (70% and 75%, respectively). MF-MOP-4 sites demonstrated the highest mean pain score of 1.75 (0.72) followed by a similar mean pain score for MF-MOP-8 and MF-MOP-12 of 1.35 (0.59) and 1.30 (0.57),

Table 1. Descriptive Statistics of the Trial's Outcome, Canine Retraction (mm)[a]

Group	N	Mean (SD)	*P*
Control	60	3.06 (1.64)	.004
MOP-4	20	3.96 (1.71)	
MOP-8	20	4.15 (1.40)	
MOP-12	20	4.39 (1.78)	

[a] MOP indicates micro-osteoperforation; SD, standard deviation.

Table 2. Regression Analysis With Amount of Canine Distalization as Dependent Variable[a]

		Univariable		Multivariable*	
Factor	Group	b (95% CI)	*P*	b (95% CI)	*P*
Age	Per year	−0.02 (-0.14–0.09)	.66	NT	
Sex	Female	*Referent*		NT	
	Male	0.21 (-0.56–0.97)	.58	NT	
Jaw	Mandible	*Referent*		*Referent*	
	Maxilla	0.94 (0.27–1.61)	.007	0.94 (0.26–1.62)	.008
Group	Control	*Referent*			
	MOP-4	0.89 (0.20–1.59)	.01	0.89 (0.19–1.59)	.01
	MOP-8	1.08 (0.49–1.67)	.001	1.08 (0.49–1.68)	.001
	MOP-12	1.33 (0.56–2.10)	.001	1.33 (0.55–2.10)	.002x

[a] CI indicates confidence interval; MOP, micro-osteoperforation; NT, not tested.
* An interaction term of experimental group with jaw ($P = .46$) was tested and ultimately dropped.

respectively. Meanwhile, at the control side, no pain was reported. The main reported impact of pain following MOP was related to chewing and speech. However, the impact on general activities, including mood and social interaction were not statistically significant ($P > .05$). Overall, pain associated with MOP, regardless of the interval, produced some effect on participants daily activities with the exception of sleep.

DISCUSSION

Main Findings in the Context of Existing Evidence

This trial demonstrated that MOP was able to significantly increase overall mini-implant supported canine retraction in the maxilla and mandible over a 16-week period of time in combination with elastomeric power chain and fixed appliances. This was in agreement with a previous split-mouth prospective

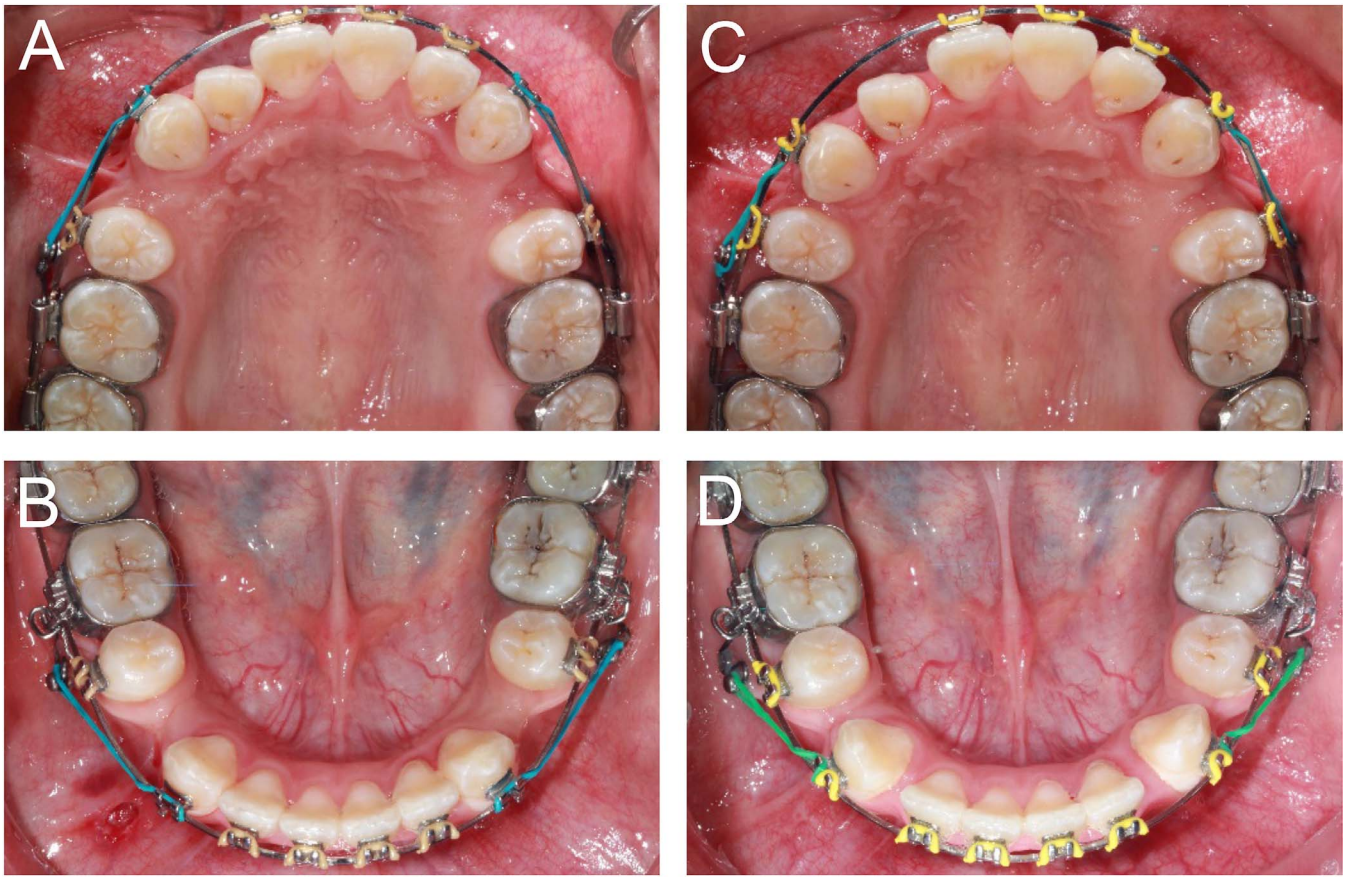

Figure 3. Maxillary and mandibular dental arches from a representative subject within the trial (A, B) Start of canine retraction; (C, D) At 16 weeks of canine retraction. MOP was randomized to the upper right and lower left quadrants in this subject.

investigation, although that study only reported on maxillary canine retraction and demonstrated a higher mean difference of 0.63 mm retraction per month in the presence of MOP compared to the 0.28 mm per month (average of the three MOP groups from Table 2 and adjusted per 4 weeks) found in the present study.[6] More recently, another study found no evidence that MOP increased rates of canine retraction.[7] In the current study, the canine retraction achieved over the 16-week period of observation was also below that found using other forms of more invasive surgical interventions.[3,11] Overall, the increased retraction achieved using MOP was probably not clinically significant and therefore it is difficult to justify the increased patient burden associated with this intervention as a means of reducing orthodontic treatment time.

Some possible reasons for the differences observed in various investigations might be the different surgical techniques being used, the specific mechanics of tooth movement investigated, the method of measurement and, also, measurement reference points. Nickel-titanium coil closing springs were used in the first study, which might be expected to provide a more consistent retraction force.[6] However, elastomeric power chain is a routinely used and effective method of space closure used in many clinical situations[12] and, in this study, power chain from a specific research inventory stored under ideal and constant conditions was used. The split-mouth study design, routine replacement every 4 weeks and measurement to apply a standardized force all contributed toward minimizing variations in space closure mechanics.

Importantly, the current investigation also showed no statistically significant differences in overall canine retraction associated with the three different MOP intervals, suggesting that any regional acceleration induced by MOP had an effect that extended for at least 12 weeks. Intervals shorter than 4 weeks and longer than 12 weeks were not included because osteoclast recruitment has been found to peak at 4 weeks and gradually reduce by 12 weeks.[9] Although comparison of MOP intervals within individuals did demonstrate significantly increased tooth movement in the MF-MOP-12 group when compared to the two other intervals, further studies will be required to suggest that 12 weekly MOP is recommended to provide optimal treatment effects. Clearly, it is in the interest of the patient to keep any surgical interventions to a minimum.

Canine retraction was investigated over a 16-week period of observation, which only constituted a small portion of the overall treatment for these extraction cases. Based on the current results, it is not possible to comment on the potential effect of MOP during orthodontic alignment or other stages of treatment. If it is assumed that the biological response to different types of tooth movement is similar and that the overall response is not influenced by MOP intervals, extrapolating these findings to an average treatment duration of 18 months would suggest a possible reduction in treatment time of up to 30%. However, this is highly speculative and would need to be substantiated with more evidence from prospective studies investigating the effect of MOP over the entire period of treatment. It should be stated that the few prospective studies that have investigated the effect of specific fixed appliances or adjuncts designed to reduce treatment time have rarely found any differences over the long term.[13,14]

This investigation also found less reported pain for the MF-MOP-8 and MF-MOP-12 groups compared to the MF-MOP-4 group in relation to the overall observation period, which is supportive of keeping surgical interventions to a minimum for the benefit of the patient. However, this reported overall pain perception was subject to recall bias as the data were obtained at the end of the observation period. Indeed, a possible reason for the less painful perception with MF-MOP-8 and MF-MOP-12 intervals compared to MF-MOP-4 could be due to the phenomenon of a gradual decline in memory of pain experience after a longer duration. However, pain during fixed appliance therapy has been reported as a major reason for discontinuation of orthodontic treatment and impact on general daily activities has been shown, including eating, leisure, social life, sleep and exercise, albeit to a mild degree.[15] Interestingly, in this study, almost all daily activities except sleep were impacted following MOP, which is a further reason to keep this intervention to a minimum.

Limitations of the Study

This study had a number of limitations. Direct clinical measurement of canine retraction may have been less accurate than measurement from dental study casts or using three-dimensional superimposition. Also, the use of elastomeric chain may have resulted in less consistent space closure forces among subjects. This study only investigated canine retraction over a 16-week period of time and therefore did not represent the entirety of orthodontic treatment. Pain data were only collected at the end of the study and, as this was only a secondary outcome, the trial was likely underpowered for pain analysis. However, this randomized split-mouth investigation of MOP during canine retraction with fixed appliances added to the evidence base and should form the basis of further longer-term prospective research.

CONCLUSIONS

- MOP was associated with statistically significantly increased overall canine retraction of 1.1 mm over a 16-week period of observation.
- There were only small differences in tooth movement when intervals of 4, 8, and 12 week MOP were used.
- Moderate pain was associated with MOP at 4-week intervals while only mild pain was perceived for intervals of 8 and 12 weeks.
- The increased canine retraction achieved using MOP over a 16-week period is unlikely to be clinically significant.

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