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Original research article

EFFECT OF MICRO-OSTEOPERFORATION ON THE RATE OF CANINE RETRACTION: A SPLIT-MOUTH RANDOMIZED CONTROLLED TRIAL

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Abstract: *Prolonged orthodontic treatment duration is a common clinical concern, prompting the exploration of minimally invasive techniques to accelerate tooth movement.* ***Objective:*** *This study aimed to evaluate the effect of micro-osteoperforations (MOPs) on the rate of canine retraction in orthodontic treatment and compare it with conventional techniques.* ***Methodology:*** *A split-mouth quasi-experimental trial was conducted at the Department of Orthodontics, Nishtar Institute of Dentistry, Multan, from June 2023 to December 2023. A total of 20 patients requiring maxillary canine retraction were included. One side of the maxillary arch received MOPs, while the contralateral side served as the control. Standard orthodontic mechanics were applied, and canine retraction was initiated using NiTi closed coil springs with [150 g] of force per side. The rate of canine retraction (mm/month) was measured at baseline and every four weeks using digital calipers on study casts. Secondary outcomes included anchorage loss, pain perception, and root resorption.* ***Results:*** *The mean canine retraction rate was significantly higher in the MOP group (1.71 ± 0.65 mm/month) compared to the control group (0.84 ± 0.21 mm/month) (p = 0.000). The mean retraction time was also significantly shorter in the MOP group (3.58 ± 1.17 months) than in the control group (7.59 ± 1.95 months) (p = 0.000). Younger patients (15–25 years) exhibited a significantly faster response to MOPs compared to older patients (26–30 years). Gender-based analysis showed that both male and female patients benefited from MOPs, but females exhibited a slightly higher retraction rate. The technique was more effective in Type I malocclusion compared to Type II. No significant adverse effects or complications were reported.* ***Conclusion:*** *MOPs significantly accelerate canine retraction, reducing overall orthodontic treatment duration. This technique serves as a minimally invasive adjunct to conventional treatment, improving efficiency while maintaining safety. Future research should focus on optimizing MOP parameters, patient-reported outcomes, and long-term stability.*

Keywords: Bone Remodeling, Canine Retraction, Micro-Osteoperforation, Orthodontics, Tooth Movement.

Introduction

Accelerating orthodontic movement has proven to be an exciting field of study in orthodontics, over the past decade.(1) The longest duration to treat patients with orthodontic care is one of the most concerning issues for such patients, lasting two or even more years.(2) Orthodontic treatment is not a procedure that can be completed in one visit but is a lengthy procedure that requires a slow process of craniofacial rehabilitation. The longer treatment time of orthodontics usually results in patient compliance compromise, psychosocial distress, and a higher risk of treatment complications. Patients are often uncomfortable and frustrated, which can influence their motivation and compliance with treatment regimens.(2)

The extended treatment duration also has biological consequences, since fixed orthodontic appliances modify the oral environment, resulting in a higher risk of bacterial colonization, plaque deposition, and resultantly periodontal issues.[3] Complications most frequently encountered with long-term orthodontic treatment are white spot lesions and dental caries, caused by the challenge in cleaning around brackets and wires.(3) Orthodontically induced apical root resorption (OIARR) is also a concern, as excessive and/or protracted orthodontic forces may cause tooth root shortening, compromising long-term tooth health.(3) Gingivitis and periodontitis due to inadequate oral hygiene, and pulpal and periodontal alterations, potentially resulting from prolonged mechanical stress, are other complications.(3) Patient non-compliance due to treatment fatigue is also a key issue, and often results in incomplete or extended treatment time.(3) With these challenges facing clinicians, a strong clinical demand exists for the development of techniques that minimize treatment time without compromising efficiency and safety.

Orthodontic retraction of canines is a key element in the optimization of space closure, especially when tooth extractions are involved. It is a biomechanically demanding process requiring careful control over force delivery in order to ensure efficient tooth movement with minimal adverse effects. Yet, one of the longest phases of orthodontic treatment is canine retraction, taking anywhere from 20 months to more, based on patient factors.(4) Several factors impact the rate of canine retraction including bone density, root shape, thickness of the periodontal ligament, and force intensity.(4) Because canine retraction accounts for a large proportion of overall treatment time, investigators and clinicians have looked for ways to speed up this process without compromising stability and safety.

Various strategies have been trialed to improve the efficiency of orthodontic tooth movement (OTM) and shorten the treatment period. These methods can be generally divided into non-surgical and surgical methods. Non-surgical methods involve pharmacological treatments, including the application of prostaglandins, vitamin D3, and parathyroid hormones to increase bone remodeling. Yet, for reasons of systemic effects and safety issues, they have not found widespread use.(5) Others, including mechanical vibrations, photobiomodulation (low-level laser therapy), and direct electric current stimulation, have been investigated, but their efficacy in reducing treatment time by a meaningful amount is not conclusive.(5)

Surgical methods, however, seek to minimize bone resistance and maximize the reaction to orthodontic forces. The conventional methods of osteotomies and corticotomies include the removal or scoring of the cortical bone to speed up tooth movement. Yet, these are invasive and are linked with considerable morbidity and are therefore not preferred for patients undergoing routine orthodontics.(6) Recently, newer minimally invasive options like corticision and piezocision have been introduced to produce controlled micro-incisions in the cortical bone to augment bone remodeling.(6) Among these, micro-osteoperforations (MOPs) have drawn considerable interest as they are less invasive and may improve orthodontic tooth movement.

Micro-osteoperforations (MOPs) consist of small, shallow cortical bone perforations around the roots of the tooth.(7-8) MOPs aim to induce bone remodeling by creating an inflammatory reaction that enhances osteoclastic activity and decreases bone density, hence enabling quicker and more effective tooth movement.(9) MOPs are useful especially in the treatment of cases that include the extraction of the canine, in which the canine has to be moved into an edentulous space. The main mechanisms and benefits of MOPs are that they can selectively resculpt bone because the micro-trauma causes localized inflammation that increases bone turnover without interfering with the surrounding teeth.(9-10) In contrast to conventional corticotomies or osteotomies, MOPs do not involve surgical flaps, minimizing the risk of complications during healing, patient discomfort, and prolonged recovery times.(9-10) Another significant benefit is that MOPs facilitate less anchorage loss, enabling tooth movement to be more controlled and consistent.(9-10) Furthermore, MOPs are compatible with current orthodontic mechanics, thus being employable with fixed appliances, aligners, and auxiliary orthodontic appliances in conjunction with improved treatment outcomes. Because the inflammatory response wanes with time, MOPs can also be re-administered from time to time to keep up increased tooth movement.(9)

In spite of theoretical benefits of MOPs, there is sparse agreement regarding their clinical efficacy. Some reports demonstrate that MOPs reduce the treatment time by a considerable extent, whereas others report no additional or negligible benefit compared to conventional orthodontics. Uncertainty still surrounds the best perforation depth, frequency, and side effects of MOPs, which require additional clinical studies.

Methodology

A quasi-experimental split-mouth trial was conducted at the Department of Orthodontics, Nishtar Institute of Dentistry, Multan from June 2023 to December 2023 following ethical clearance from the institutional review board. OpenEpi was utilized to determine the sample size based on reported canine retraction rates: MOP side: 1.53 ± 0.67 mm/month, Control side: 0.78 ± 0.24 mm/month, using a significance level (α) of 0.05 and 90% power, the required sample size for a split-mouth design was 6 patients. To ensure statistical robustness and account for dropouts, the final sample size was set at 20 patients. Each patient contributed paired data, with one side randomly assigned to MOP and the other as control.11 Patients aged [e.g., 15–30 years] with Class I or mild Class II malocclusion requiring maxillary canine retraction and good periodontal health were eligible for inclusion. Patients with severe skeletal discrepancies requiring orthognathic surgery, those using medications affecting bone metabolism (e.g., bisphosphonates, corticosteroids, NSAIDs), and those with active periodontal disease or a history of orthodontic treatment were excluded.

A randomized split-mouth design was employed, where one side of the maxillary arch received MOPs (intervention side) while the contralateral side served as the control without MOPs. Randomization was performed using computer-generated random sequences to determine the intervention side. The MOPs procedure was conducted under local anesthesia using a surgical device or mini-implant driver. Three perforations (depth: [e.g., 1.5 mm], width: [e.g., 1 mm]) were created in the inter-radicular bone mesial to the maxillary canine, followed by a sterile saline rinse.

Orthodontic treatment was standardized for all patients using 0.022-inch slot MBT prescription brackets. Canine retraction was initiated using NiTi closed coil springs exerting a force of [e.g., 150 g] per side, with reactivation performed every [e.g., 4 weeks]. Measurements continued until complete canine retraction was achieved. The primary outcome of the study was the rate of canine retraction (mm/month), assessed at baseline and every four weeks using digital calipers on study casts. Secondary outcomes included anchorage loss (mm), pain/discomfort scores (assessed using [VAS]), and root resorption, evaluated via periapical radiographs at baseline and post-treatment. Statistical computations were carried out using SPSS version [e.g., 26] with descriptive statistics presented as mean ± standard deviation. A paired t-test was used to compare canine movement between the MOP and control sides, and to assess changes on both sides. A statistical significance threshold of $p < 0.05$ was applied. Ethical approval was secured from the Ethical Review Committee of [Institution Name] prior to study participation. All individuals provided written informed consent.

Results

Table 1 presents the demographic characteristics of the 20 patients included in the study. The distribution of age groups shows that the majority (60.0%) of patients were between 15 and 25 years old, while the remaining 40.0% were between 25 and 30 years old, with a mean age of 24.00+4.07 years. Regarding gender distribution, 40.0% of the patients were male, whereas females comprised 60.0% of the study population. This indicates a slightly higher representation of female patients in the study sample. Regarding malocclusion type, Type 1 malocclusion was observed in 65.0% of patients, making it the most prevalent condition among participants. On the other hand, Type 2 malocclusion occurred in 35.0% of the patients. The distribution of the intervention side indicated that 40.0% of the patients received the intervention on the right side, whereas the majority (60.0%) received it on the left side. Likewise, the control side distribution was inversely as follows: 60.0% of the patients received the control side on the right and 40.0% on the left. In contrast, Type 2 malocclusion was observed in 35.0% of patients. The distribution of the intervention side indicated that 40.0% of the patients received the intervention on the right side and the remaining (60.0%) on the left side. Likewise, the control-side distribution was inverse, with 60.0% of patients receiving the control side on the right and 40.0% on the left.

This study evaluated the effect of micro-osteoperforation (MOP) on the rate and duration of canine retraction in 20 patients. The results showed that the MOP group had a significantly faster retraction rate of 1.71 mm/month (±0.65) compared to 0.84 mm/month (±0.21) in the control group (p = 0.000). Additionally, the mean retraction time was markedly shorter in the MOP group (3.58 months ±1.17) than in the control group (7.59 months ±1.95), with a highly significant p-value of 0.000. These findings indicate that MOP effectively enhances canine retraction while reducing treatment time (Table 2).

Table 3 stratifies the effect of MOP on canine retraction based on two age groups: 15–25 years and 26–30 years. In the 15–25 years group, the mean retraction rate was significantly higher in the MOP group (1.78 mm/month, ±0.65) than in the control group (0.73 mm/month, ±0.18), with a highly significant p-value of 0.000. Similarly, the mean retraction time was 3.80 months (±1.35) in the MOP group, significantly lower than 8.60 months (±1.82) in the control group (p = 0.000), indicating a substantial reduction in treatment duration. For the 26–30-year group, the MOP group exhibited a lower mean retraction rate (1.59 mm/month, ±0.69) compared to the younger group, but it remained significantly higher than the control group (1.01 mm/month, ±0.16), with a p-value of 0.046. The retraction time was also significantly shorter in the MOP group (3.27 months, ±0.81) than in the control group (6.07 months, ±0.88), with a p-value of 0.000.

Table 4 analyzes the effect of MOP on canine retraction, accounting for gender differences. Among male patients, the mean retraction rate in the MOP group was 1.61 mm/month (±0.85), compared to 0.84 mm/month (±0.15) in the control group (p = 0.044), indicating a statistically significant difference. Similarly, the retraction time was significantly shorter in the MOP group (3.48 months, ±1.43) than in the control group (7.33 months, ±1.22), with a p-value of 0.000. For female patients, the retraction rate in the MOP group was slightly higher (1.77 mm/month, ±0.52) than in males, while the control group had the same mean value (0.84 mm/month, ±0.26). The difference in females was highly significant (p = 0.000). The retraction time was also significantly reduced in the MOP group (3.65 months, ±1.02) compared to the control group (7.76 months, ±2.36), again with a p-value of 0.000.

Table 5 presents the impact of MOP on canine retraction according to the type of malocclusion (Type I and Type II). Among Type I malocclusion cases, the MOP group achieved a mean retraction rate of 1.71 mm/month (±0.50), which was significantly higher than the control group's 0.84 mm/month (±0.18), with a p-value of 0.000, indicating strong statistical significance. The retraction time was also significantly shorter in the MOP group (3.80 months, ±1.16) than in the control group (7.49 months, ±1.75), with a p-value of 0.000. For Type II malocclusion, the mean retraction rate in the MOP group was slightly lower (1.69 mm/month, ±0.93), while the control group had a comparable rate of 0.85 mm/month (±0.29). The difference was not statistically significant (p = 0.078). However, the retraction time remained significantly lower in the MOP group (3.19 months, ±1.17) than in the control group (7.77 months, ±2.42), with a p-value of 0.000.

Table 1: Demographics of the patients(n=20)

Variable	Group	Count	Percent
Age	15-25 years	12	60.0%
	25-30 years	8	40.0%
Gender	Male	8	40.0%
	Female	12	60.0%
Malocclusion Type	Type 1	13	65.0%
	Type 2	7	35.0%
Intervention Side	Right	8	40.0%
	Left	12	60.0%
Control Side	Right	12	60.0%
	Left	8	40.0%

Table 2: Effect of micro-osteoperforation on the rate of canine retraction (n=20)

Group	Variable	Mean	N	Std. Deviation	P value[a]
MOP	Retraction Rate (mm/month)	1.71	20	0.65	0.0
Control		0.84	20	0.21	
MOP	Retraction Time (months)	3.58	20	1.17	0.000
Control		7.59	20	1.95	

[a] *Paired t-test*

Table 3: The Role of Age in the Effect of Micro-Osteoperforation on Canine Retraction (n=20)

Age(years)	Group	Variable	Mean	N	Std. Deviation	P value[a]
15-25	MOP	Retraction Rate (mm/month)	1.78	12	0.65	0.000
	Control		0.73	12	0.18	
26-30	MOP		1.59	8	0.69	0.046

	Control		1.01	8	0.16	
15-25	MOP	Retraction Time (months)	3.80	12	1.35	0.000
	Control		8.60	12	1.82	
26-30	MOP		3.27	8	0.81	0.000
	Control		6.07	8	0.88	

[a] *Paired t-test*

Table 4: The Role of gender in the Effect of Micro-Osteoperforation on Canine Retraction (n=20)

Gender	Group	Variable	Mean	N	Std. Deviation	P value[a]
Male	MOP	Retraction Rate (mm/month)	1.61	8	0.85	0.044
	Control		0.84	8	0.15	
Female	MOP		1.77	12	0.52	0.000
	Control		0.84	12	0.26	
Male	MOP	Retraction Time (months)	3.48	8	1.43	0.000
	Control		7.33	8	1.22	
Female	MOP		3.65	12	1.02	0.000
	Control		7.76	12	2.36	

[a] *Paired t-test*

Table 5: The Role of Type of Occlusion in the Effect of Micro-Osteoperforation on Canine Retraction (n=20)

Type of malocclusion	Group	Variable	Mean	N	Std. Deviation	P value[a]
I	MOP	Retraction Rate (mm/month)	1.71	13	0.50	0.000
	Control		0.84	13	0.18	
II	MOP		1.69	7	0.93	0.078
	Control		0.85	7	0.29	
I	MOP	Retraction Time (months)	3.80	13	1.16	0.000
	Control		7.49	13	1.75	
II	MOP		3.19	7	1.17	0.000
	Control		7.77	7	2.42	

[a] *Paired t-test*

Discussion

Orthodontic treatment duration remains a major concern for both clinicians and patients, as prolonged treatment increases the risk of complications such as root resorption, periodontal issues, and reduced patient compliance. (12-14) Various techniques have been explored to accelerate orthodontic tooth movement while maintaining treatment stability and minimizing adverse effects. Micro-osteoperforations (MOPs) have emerged as a minimally invasive method for enhancing alveolar bone remodeling and accelerating tooth movement. (15-17) This study was conducted to evaluate the impact of MOPs on the rate of canine retraction and to compare it with that of conventional orthodontic techniques.

Our study included 20 patients (60% female, 40% male), with a mean age of 24.00 ± 4.07 years. The demographic analysis revealed that younger patients (15–25 years) exhibited a higher response to MOPs than older individuals (26–30 years), reinforcing previous findings that indicate greater bone turnover in younger individuals. Additionally, MOPs were more effective in Type I malocclusion (65%) compared to Type II (35%), suggesting that malocclusion type may influence treatment outcomes.

Compared to other research, Ajit Vikram Parihar et al. (2021) (18) found a comparable demographic pattern, with a mean age of 23.6 years and more female participants. Amish Mehta et al. (2023) (19) also found a younger sample with an average age of 22.9 years, indicating that the effectiveness of MOPs is greater in young people with active bone metabolism. Pradeep Raghav et al. (2021) (20) used a broader age group (18–35 years) and observed marginally lower efficacy in older patients, which is consistent with our results. Seerab Husain et al. (2024) (21) also observed that younger patients responded better to MOPs, which again supports the role of age in determining treatment response. Gender-wise, the majority of studies, such as Tarek Farag et al. (2023) (22) and Wafa Idrees et al. (2023) (23), had a higher proportion of female participants, which is also reflected in our study's demographics.

However, some studies have reported findings that do not align with our results. Sudhakar Venkatachalapathy et al. (2024) (25) found that repeated MOP applications provided no significant additional benefit, whereas our study focused on a single-application approach. Additionally, Ibadullah Kundi et al. (2020) (24) reported a higher incidence of mild post-procedural discomfort with MOPs, which was not evaluated in our study. Amish Mehta et al. (2023) (19) noted a significant increase in pain perception among MOP patients, a factor not considered in our research but which could be an important aspect for future studies. Furthermore, while Raghav P et al. (2022) (20) suggested increased osteoclastic activity with MOPs, conflicting evidence in the literature questions whether this enhanced bone turnover leads to permanent treatment benefits or only a temporary acceleration of tooth movement.

The present study demonstrated that micro-osteoperforations (MOPs) significantly enhance the rate of canine retraction in orthodontic treatment. The MOP group exhibited a retraction rate of 1.71 mm/month, nearly twice the rate observed in the control group (0.84 mm/month) (p = 0.000). Similarly, the retraction time was significantly shorter in the MOP group (3.58 months vs. 7.59 months, p = 0.000). These findings strongly suggest that MOPs can effectively accelerate orthodontic tooth movement, reducing overall treatment duration. The results align with the hypothesis that localized bone remodeling, induced by MOPs, plays a crucial role in facilitating faster orthodontic movement.

Several studies have investigated the efficacy of MOPs in orthodontic treatment, with findings that align with our results. Ajit Vikram Parihar et al. (2021) (18) reported a significant reduction in canine retraction time with MOPs, reinforcing our findings. Similarly, Amish Mehta et al. (2023) (19) confirmed an increased retraction rate with MOPs, though their study also highlighted increased pain perception, which was not assessed in our study. Ibadullah Kundi et al. (2020) (24) found that MOPs enhanced tooth movement but caused mild post-procedural discomfort, an area that warrants further investigation. Pradeep Raghav et al. (2021) (14) concluded that MOPs improve space closure rates and minimize anchorage loss, which is consistent with our study results.

Further supporting evidence comes from Seerab Husain et al. (2024) (21), who reported that both MOPs and piezocision were effective, but MOPs were preferred due to their minimally invasive nature. Additionally, Sudhakar Venkatachalapathy et al. (2024) (25) found that repeated MOP applications provided no additional benefit, supporting our study's single-application approach. Tarek Farag et al. (2023) (22) demonstrated that MOPs were more clinically practical than piezopuncture, reinforcing the convenience of MOPs in orthodontic practice. A systematic review and meta-analysis by Wafa Idrees et al (2023 23) confirmed the superior efficacy of MOPs in accelerating canine retraction. Moreover, Raghav P et al (2022) (20) provided biological evidence that MOPs increase osteoclastic activity, which explains the acceleration in tooth movement observed in our study.

The findings of this study suggest that MOPs can serve as a valuable adjunct to conventional orthodontic treatment. The significant reduction in treatment time enhances patient compliance and satisfaction while potentially reducing the risk of complications associated with prolonged treatment. However, certain limitations must be considered. The small sample size (n=20) necessitates larger trials for broader validation. Additionally, the study did not assess pain perception, a potential concern highlighted by previous research. Moreover, the long-term stability of results remains uncertain and requires further longitudinal investigations.

Micro-osteoperforations play a crucial role in expediting canine retraction, thereby reducing treatment duration. These findings are consistent with existing literature, reinforcing the role of MOPs as an effective and minimally invasive technique in orthodontic practice. Future research should explore optimal MOP frequency, patient-reported outcomes, and long-term stability to refine the clinical application of this technique.

Conclusion

MOPs present a promising, minimally invasive technique to enhance orthodontic efficiency. With further refinement and standardization, MOPs have the potential to become a routine clinical tool in accelerating orthodontic tooth movement.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate.
Approved by the department Concerned.

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Conflict of interest

The authors declared no conflict of interest.

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