Review Article

MICRO PERFORATIONS IN ORTHODONTICS: AN ANSWER TO PROLONGED DURATION OF ORTHODONTIC TREATMENT-A REVIEW

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ABSTRACT

One of the major problems with orthodontic therapy is its prolonged duration, which forces patients to select alternate therapy modalities with subpar outcomes and negative side effects. Additionally, it may worsen any unfavorable effects brought on by orthodontic treatment. MOP, i.e., micro osteotomic perforations, have been utilized to activate the bone's inherent mechanisms, which quicken tooth movement. Orthodontic forces cause the periodontal ligament (PDL) to be under more strain, which causes the intended resorption and deposition of the tooth's surrounding bone. This results in orthodontic tooth movement. To increase the activity of osteoblasts and their bone resorption, the PDL stress triggers the release of inflammatory cytokines and other inflammatory mediators. This review's objective is to evaluate the most recent research on micro-osteoperforations and determine whether they can speed up orthodontic tooth movement in a clinical environment. Studies on MOPs have shown both conclusive and inconclusive results. This review provides a succinct summary of the change observed with MOPs and indicates if they were clinically relevant. Several studies have supported the idea that MOPs can double the rate of orthodontic tooth movement.

External root resorption occurs more frequently and for longer periods when teeth are moving through atrophic ridges. However, there was no appreciable increase in bone volume. Therefore, since more adult patients choose orthodontic treatment, extensive research is needed to understand how MOPs affect tooth movement across atrophic ridges. The approaches taken to apply MOP across studies differ significantly. To draw an objective conclusion, it is important to distinguish between tipping and the bodily movement of the teeth. In order to make a wise choice, it is necessary to thoroughly assess anchorage loss following MOPS during en-masse retraction of teeth. To ascertain long-term stability, it is necessary to monitor the effects of MOPs and maintain these findings after therapy.

Key words: Micro osteotomic peforations, Orthodontics, Tooth movement, Orthodontic forces

Introduction

One of the major problems with orthodontic therapy is its prolonged duration, which forces patients to select alternate therapy modalities with subpar outcomes and negative side effects. Additionally, it may worsen any unfavorable effects brought on by orthodontic treatment. The frequency of white spot plaques and caries, periodontal issues, soft tissue trauma, and orthodontically driven root resorption are all closely correlated with the length of the therapy. Since the invention of fixed orthodontics, researchers and practitioners have attempted to shorten the length of treatment using various techniques and appliances with varying degrees of success [1, 2]. Self-ligating braces, wires and brackets manufactured to demand, medicines, cell mediator injections, low-level laser and phototherapy are examples of nonsurgical therapies to reduce orthodontic treatment time. Additionally, surgical procedures have been performed to shorten the length of the treatment after speeding up tooth movement. Less invasive surgical procedures include piezocisions, piezopunctures, and micro-osteoperforations, as well as osteotomies and corticotomies surgical procedures with or without bone grafts [3, 4].

MOP, i.e., micro osteotomic perforations, have been utilized to activate the bone's inherent mechanisms, which quicken tooth movement. Orthodontic forces cause the periodontal ligament (PDL) to be under more strain, which causes the intended resorption and deposition of the tooth's surrounding bone. This results in orthodontic tooth movement. To increase the activity of osteoblasts as well as osteoclasts for bone resorption, the PDL stress triggers the release of inflammatory cytokines and other inflammatory mediators [5, 6].

Inflammatory mediators can be elevated by a surgically induced traumatic event, which momentarily increases bone metabolic activity and resorption. This phenomenon of micro orthodontic perforation can be described as the localized acceleratory process, and it may have an impact on how quickly teeth move. Following surgical procedures like corticotomy, MOP, & corticision, the number of degenerative bone biomarkers such as TNF- and TRAP+ osteoclasts are noticeably increased and is consistent across various interventions [7, 8]. The pace of tooth movement in orthodontic tooth movement has been most significantly and consistently impacted by surgical techniques like

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corticotomies involving mucoperiosteal flaps and osteotomy surgical techniques. However, because these procedures are intrusive, unpleasant, and expensive, doctors do not frequently use these traditional surgical techniques. Moreover, an additional specialist doctor will be required to carry out these procedures [9, 10].

In order to address these issues, less invasive surgical techniques such as micro-osteoperforation, piezopuncture and piezocision have been designed. In piezocision, the corticotomies are made through the gingiva, but in corticision, the corticotomies are made through the cortex bone without using mucoperiosteal flaps. Additionally, the micro-osteoperforation technique uses mini-screws or the Propel device to start the bone injury, while piezopuncture uses piezoelectrical equipment with a sharp point to induce some breaches in the cortex [11, 12]. The MOP fixes most issues brought on by conventional surgical procedures. However, unlike other less extensive surgical procedures, it can be carried out by an orthodontist using widely accessible orthodontic tools to quicken tooth movement. It makes difficult orthodontic movements simpler and aids in anchoring adjustment. Although MOP is still a recent technique, there are contradictory findings regarding its positive and negative consequences. This study attempted to integrate these findings and assess how MOP affected the speed of tooth movement. Additionally, it evaluated any negative impacts the intervention might have on the patients receiving it [13, 14].

Basics of MOP

By triggering the production of cytokines that attract osteoclasts to the site of injury and accelerate bone resorption, MOPs cause a decrease in bone density. MOPs are minimally invasive because flap elevation is not needed during the surgery. Micro-osteoperforations (MOPs) are most basically defined as localized trauma to the alveolar bone. Micro-osteoperforations are an ancillary method for speeding the rate of OTM by producing transmucosal osteoperforations in the cortical bone, around the teeth that require movement, according to a group of orthodontists who first presented the technique [15, 16]. They noted more osteoclastic and bone remodeling activity at the perforation sites, and increased tooth mobility in their initial animal investigation of MOPs on rats. Encouraged by these findings, they performed clinical studies on 20 elderly patients having class II division I malocclusion. They saw a rise in the levels of chemokines and cytokines, which are chemical mediators that stimulate osteoclastic activity. They observed that the pace of canine retraction surged 2.3 times following the 28-day testing period, which encouraged them to believe that using MOPs could speed up the entire orthodontic treatment process [17, 18].

How does MOP work

By triggering Frost's (1983) "Regional Acceleratory Phenomenon" (RAP), which describes the amplification of the alveolar bone's regenerative process in response to unpleasant stimuli, MOPs increase the rate of bone resorption. The localized trauma caused by MOPs leads to transient osteopenia. As a result, tooth movement is expedited through the perforated alveolus since it has less bone resistance [19, 20]. The rise in local pro-inflammatory chemical mediators, such as chemokines and cytokines, is the cause of the temporary osteopenia seen after the activation of RAP. Increased bone turnover and decreased resistance to tooth movement arise from these chemical mediators penetrating the alveolus around the MOPs and activating osteoclastic activity. Using the prostaglandin E2 or the RANK/RANKL pathway, chemokines recruit osteoclast precursor cells and cytokines and trigger the differentiation of adult osteoclasts from the precursor cells [21-25].

Higher osteoclast activity, a higher rate of resorption, and a resulting decrease in bone density are brought on by the increased release of these substances. MOP can be employed in clinical situations where dense cortical bone restrains the orthodontic results since the activated osteoclasts temporarily reduce bone density. According to a study, MOPs cause the periodontal ligament cells to undergo apoptosis and activate the pathways that cause cell proliferation. In response to orthodontic stresses, the aforementioned physiologic processes quicken tooth movement [26-29].

Any orthodontic appliance not limited to fixed appliances, removable appliances, transparent aligners, etc., can be complemented by MOP. The osteoclasts are activated by chemical mediators such as CCL 3, CCL 5, and IL 8 released in response to tooth movement. Proteins specifically from the cytokine family are also secreted in addition to chemokines. Macrophages and cells generate these pro-inflammatory cytokines in the periodontium, including fibroblasts, endothelial cells, and osteoblasts [19, 30, 31]. They amplify or maintain the inflammatory response while triggering bone resorption. Chemokines from the surrounding blood arteries invade the alveolus during orthodontic tooth movement and develop into macrophages or osteoclasts. One chemokine is Monocyte Chemoattractant Proteins (MCP-1), also known as Chemokine Ligand (CCl-2). In a split-mouth investigation studies evaluated the bone structures at the sites after performing surgical insults on the bone surrounding the maxillary second premolars [32-34]. They concluded that more surgical insults result in a lesser maturity of the bone surrounding the teeth being moved, less bone quantity, poorer bone density, increased osteoclastic activity, and faster orthodontic tooth movement. Applying orthodontic forces during tooth movement triggers an array of chemical reactions linked to aseptic inflammation. According to the events' sequelae, orthodontic tooth movement is a "periodontal phenomenon" accompanied by a considerable rise in leucocyte concentration in the alveolar bone [35-38].

How the procedure of MOP carried out clinically

The treatment is most typically performed on the buccal cortex. Radiographs can be used to assess the quality of the bone, the position of nearby important structures, the width of the interradicular bone, and other factors. Before beginning MOP, informed consent should be acquired. To rule out the possibility of postoperative adverse effects, the practitioner should thoroughly review the patient's medical and dental histories. The site should be as close to the target teeth as possible, away from the anchor teeth, in the associated gingiva, and up to 1mm superior to the mucogingival junction to maximize the effects of MOP. Planning extractions closure to MOP procedures may have an additional impact on the action of MOPs because tooth extraction also activates RAP [39-41]. MOP should be positioned more apically and, if possible, oriented apically for root position modifications like incursion and/or torque correction so that it may be applied through the associated gingiva. The doctor can still access the apical tissues.

Which instruments are used in carrying out MOP

The MOP tool introduced by Propel INC, is a portable disposable used to administer tiny osteoperforations. The device has a 1.5mm width and a depth that can be adjusted between 3,5 and 7mm. Even if the Propel device was created specifically for MOPs, it is not yet a part of clinical practice. Nevertheless, an increasing number of researchers are experimenting with mini-implants for the same reason. Propel INC has been used in investigations by several other researchers [18, 42].

Mini-implants have recently been used in scientific experiments, and comparable outcomes have been noted. MOPs have been successfully implanted using self-drilling mini-implants with a thickness range of 1.2 mm to 1.8 mm. Any armamentarium that causes the desired thickness and depth is favored since biochemical and molecular events are thought to occur consistently regardless of the instrument utilized as long as the depth and design are followed [24, 43].

What care should be taken post-operatively after MOP

A recent mouse study found a vitamin E-enriched diet to have a favorable impact on the rate of OTM. Therefore, additional research may determine whether vitamin E supplementation could be utilized in conjunction with MOPs for greater success. To preserve periodontal health, patients should be instructed to gargle with 0.2 percent Chlorhexidine (CHX) mouthwash twice daily for five days. Regular mouthwashes and saltwater rinses can be used in place of chlorhexidine mouthwash if patients have satisfactory periodontal health. Following the first day of the procedure, it was reported that there was little to no pain or discomfort, for which analgesics are unnecessary [44, 45]. But because every person experiences pain differently, acetaminophen is the go-to analgesic. Because they are known to slow the pace of OTM, analgesics such Non-Steroidal Anti-Inflammatory Drugs (NSAIDs) were contraindicated.

How many times should the MOP be carried out to achieve the desired results

According to clinical studies conducted on animals, the rise in pro-inflammatory chemical markers lasts only 14 to 28 days. It was seen that the levels of pro-inflammatory chemical markers decreased to the baseline after this time. Researchers recommended that MOPs be repeated every 28 days until the intended outcome was attained as a result of this. It is more cost-effective because a doctor does not need a larger inventory. After all, the process can be done with microscrews [46-49].

Alikhani and colleagues compared the effects of one, three, and four micro osteoperforations on the acceleration of OTM. They concluded that while a single MOP was ineffective in producing the desired results, three to four MOPs produced the best results [10]. Feizbakhsh and colleagues discovered that even 2 MOPs were sufficient to produce the desired effects. Consequently, there were typically 2-4 perforations per site, spaced 2 mm apart in the vertical direction [20, 50-53].

What should be the depth up to which penetration should be carried out

Feizbakhsh and associates found that even two MOPs were enough to achieve the required results. As a result, each site usually had 2-4 perforations that were 2 mm apart in the vertical direction [20].

Conditions where MOP can be applied

MOPs are recommended for accelerating tooth movement, facilitating root movement, the dental expansion that is symmetrical and asymmetrical, translating teeth into spaces lacking in structure, like old extraction spaces, and reducing root resorption brought on by orthodontic movements. According to previous research on orthodontic patients, age has an impact on bone quality, density, and metabolism. Therefore, to reduce confounding factors, most studies have concentrated on the 18–45 age group. When using MOPs for canine retraction, most studies have had beneficial results [52, 53].

In cases of open bite, it has been proved that the use of MOPs for molar intrusion without needing auxiliaries. The author showed that three-dimensional molar control prevented clockwise mandibular rotation in the repair of hyper-divergent patients with clear aligner therapy by combining clear aligners with selected micro osteoperforations in lateral and posterior locations [54-57].

Conditions where MOP should be avoided

Patients with widespread periodontitis with gingival and bone involvement should not undergo this surgery. Cardiovascular issues like angina pectoris, myocardial infarction, etc., pulmonary issues like chronic obstructive pulmonary disease, severe asthma, etc., renal issues like dialysis and transplant, hepatic issues resulting in impaired liver function, endocrine issues like diabetes mellitus,

adrenal insufficiency, hyperthyroidism, etc., and hematological issues are just a few of the conditions that put a patient at high risk. Without previous medical approval, this treatment should not be performed on patients with systemic diseases who are high-risk candidates for infection and septicaemia [58-62].

Patient compliance regarding MOPs

Although MOPs are considered invasive operations, the absence of bone augmentation, corticotomy incisions, or flap elevation makes them more patient-friendly. According to documented patient instances, the patient did not experience pain or discomfort beyond the first 24 hours, which increased patient acceptance of the surgery and their willingness to have it repeated more than once. After the damage brought on by osteoperforations, it has been. discovered that MOPs had a stronger impact on oral health-related quality of life (OHRQoL) [20, 63-66]. It was reported that MOPs mostly affected psychological discomfort and that these effects persisted for up to 3 days post-procedure. MOPs have also been the subject of several systematic reviews. The research does not appear to corroborate the assertions of statistically significant acceleration of tooth movement, according to studies by Fu *et al*., and Sivaranjan *et al.* [28, 29].

Canine retraction acceleration of 0.45mm/month was statistically significant but not clinically relevant, according to Shahabee *et al*.'s systematic review [24]. Given that the average premolar extraction space is 7.1mm, an acceleration of 0.45mm might reduce the length of the entire treatment by about 2 months. Furthermore, the rate of acceleration during en-masse retraction can be decreased, which raises the question of whether the repeated damage to the alveolar bone and its adverse effects are justified [11-12, 67-69].

Table 1. Details of systematic reviews on MOPs

Authors' details and year of publication	Objectives of systematic review	Outcomes
Shahabee *et al*., 2020 [24]	Evaluate the effects of MOPs on the rate of tooth movement and assess the adverse effects on patients	Conducted meta-analysis and systematic review. The difference observed in retraction of canine- 0.45 mm per month is statistically significant but clinically not very substantial. No significant change in pain levels at the site of MOP. Adverse effects- higher root resorption among MOPs patients(single study)
Santos *et al*., 2020 [43]	Evaluate the effects of MOPs on the rate of tooth movement using the Propel system and possible side effects	No advantage of MOP on OTM. There are no adverse effects on root resorption, anchorage, periodontal health, or pain. Mops impacts quality of life for 3 days post-procedure.
Fu *et al*., 2019 [28]	Evaluate effectiveness and safety of minimally invasive surgery on accelerating OTM	Evidence does not support the effectiveness of single MOPs. Evidence suggesting an acceleration of tooth movement was low. No increase in pain, periodontal deterioration or root resorption following MOPs. The reliability of data supporting the acceleration of OTM deemed low due to the heterogeneity of data
Sivaranjan *et al*., 2020 [29]	Evaluate the effects of MOPs on the rate of tooth movement, treatment duration, and adverse effects of MOPs	Evidence for the positive effect of MOPs on OTM was low due to the short study duration and single number of MOP. Evidence suggesting no detrimental effect on anchorage loss while using tads was of low quality. Evidence suggesting lack of Negative effect on pain, gingival recession and root resorption was high quality

Impact of MOPs on the Orthodontic tooth movement

Surgical guides are necessary to help the doctor prevent mistakes because the procedure's success depends on the accuracy of the perforation and location. There has not been much research done in this area recently. In a study using cadaver mandibles, it was found that using surgical guides that were 3D printed avoided root penetration on either side of the hole, thus lowering the possibility of adverse effects [70-73]. In their work, Alkasaby *et al*. successfully used a 3D-printed MOP surgical guide [13].

Table 2. Details of research conducted in animals on MOPs

Authors details with year of publication	Design of research	Research duration	Details about MOPs carried out	The instrument used for MOPs	Outcomes
Cramer et at., 2019 [74]	7 mature male beagle dogs (avg age 24 mos)	7 weeks	8 MOPs; 2 in the area surrounding the bifurcation of upper second premolar, six perforations distal to upper 2nd molar at 7 mm depth	Propel device	Teeth on the experimental side moved 0.05-0.27mm more than on the control side Not statistically significant

Cheung *et al*., 2016 [75]	6 male Sprague-Dawley rats; split-mouth study	21 days	Perforations were performed on palatal bone mesial to left maxillary molar. Five perforations were performed 1mm deep at a width of 1.2mm, 1 to 3mm apart	Automated driver for Mini-implant	Control side tooth movement=0.29±0.15mm; MOP site tooth movement=0.54±0.13mm
Ji-Won Lee., 2018 [76]	8 beagle dogs	10 weeks	Nine MOPs on the buccal side with a pilot drill of a diameter of 1.2 mm Three perforations to the cortical bone surrounding root of 2nd Premolar, three perforations in the vicinity of the root of 4th premolar, and three centered in the edentulous ridge and 3mm depth	Pilot drill	MOP group showed higher OTM. After the observation period, the mean distance of the 2nd premolar in the MOP group was 1.86 times The distance of the fourth premolar in the MOP group was 1.74 times more
Kim *et al*.,2019 [77]	24 female rabbits	4 weeks	Location- mesial to mandibular first molar; 2 MOPS were performed vertically 2mm apart at a depth of 3mm using microscrew of 1.4mm diameter	Microscrews	Tooth movement higher on MOP site by 32%
Teixeira *et al*., 2010 [55]	48 adult male Sprague-Dawley rats; split-mouth study	28 days	3 shallow perforations mesial to the first maxillary on experimental side molar	Handpiece with a round bur	Control site average tooth movement=0.29mm average tooth movement on MOPs site=0.62mm
Sugimori *et al*., 2018 [65]	50 male wistar rats	14 days	Three perforations on the buccal cortical bone mesial to left maxillary first molar; diameter and depth- 0.25±0.005	Handpiece with a round bur	On days 4-14- OTM is higher on the MOPs site. Decrease in bone volume and density

Studies on MOPs have shown both conclusive and inconclusive results. **Tables 1 and 2** provide a succinct summary of the change observed with MOPs and indicate if they were clinically relevant. Several studies have supported the idea that MOPs can double the rate of orthodontic tooth movement. Adult patients have a higher incidence of the atrophic ridge. External root resorption occurs more frequently and for longer periods when teeth are moving through atrophic ridges. A study detected a 1.8 times increase in OTM across the atrophic ridge with osteoperforations in a study that looked at the impact of osteoperforations on the atrophic ridge of beagle dogs. However, there was no appreciable increase in bone volume. Therefore, since more adult patients choose orthodontic treatment, extensive research is needed to understand how MOPs affect tooth movement across atrophic ridges [10, 78-81].

Long-term stability has not been the focus of much research. According to Reitan, remodeling of gingival fibers has taken 232 days and is supported by animal experiments on dogs. Due to insufficient time for gingival fiber remodeling, the acceleration of OTM may jeopardize the durability and retention of the results. Post retention follow-up is required to evaluate the long-term retention of the effects of rapid orthodontics. Bacteremia is a serious concern in any process when an instrument comes into contact with blood. This has been declared as fact for various surgical operations like the implantation and removal of molar bands, piezocision, etc. [15, 74, 82-84].

Despite being flapless, the MOP method still entails piercing the gingiva and making alveolar holes, which increases the risk of temporary bacteremia. Azeem *et al*., however, observed a low rate of these side effects (3.3 percent). Since there has not been much information reported on bacteremia linked to MOPs, doctors should use caution when applying the same. It is challenging to objectively assess the mean orthodontic tooth movement due to the lack of standardization of the device or wire used for retraction [18]. Alikhani *et al*. retracted the teeth more by tipping them than by moving the body, using a 0.16x0.022-inch wire in a 0.022-inch slot [14]. This could result in a false-positive test that shows faster tooth movement [15, 75-77, 81].

Studies with 0.019x0.025 inch SS wires reduced tooth tilting and provided a more accurate assessment of tooth movement. Alkebsi *et al*. found that anchorage loss was lower at MOP sites (0.39mm) than at control sites (0.36mm) but that the difference was statistically insignificant, making it impossible to accurately assess anchorage loss in the current literature because canine retraction places less stress on anchor units than end mass retraction [13]. According to the results of another investigation, anchoring loss is not statistically significantly impacted by MOPs [85].

Root resorption in MOP patients has to be studied more in-depth. In a study by Chan *et al*., greater root resorption of the maxillary first premolar at the location of MOPs was seen after applying a buccal tipping force of 150g for 28 days. According to the authors, when the bone turnover rate

increases due to the perforation injuries to the alveolus, the worsening of root resorption near MOPs may subsequently impact the increase in osteoclastic activity [19]. However, according to other studies, MOPs did not raise the prevalence of root resorption. Significant root resorption was seen, and it was more pronounced on the control site than on the MOP side, according to Alkebsi *et al.* [13].

This is consistent with the results of Tsai *et al*., who found that the control group experienced statistically significantly more root resorption than the MOP group [30]. According to Alkasaby *et al*., MOP increased OIIRR for the mesiobuccal roots that were farther away from the MOP site and decreased orthodontically induced inflammatory root resorption (OIIRR) for the neighboring distobuccal roots through a decrease in the density of the surrounding alveolus [31]. Animal studies have also demonstrated full healing with minor root surface damage caused by mini-implants, resulting in normal periodontal structure. Continuous cementum repair occurs on the root surface at the injury site when mini-implants are placed and withdrawn immediately [86].

Therefore, it is wise to evaluate both the MOPs' action and the supporting periodontium's response before starting the process. Even in cases with an enhanced bone density that offers more resistance to orthodontic tooth movement, a decrease in the pace of tooth movement enables the clinician to minimize the overall treatment period for patients. According to studies, several therapeutic techniques, such as fixed mechanotherapy, detachable appliance therapy, molar distalization, and clear aligner therapy, can be complemented by MOP [87].

The tendency for a collection of teeth connected by a wire to distribute stresses equally is a significant problem in split-mouth investigations. Therefore, it is impossible to avoid force dispersal to adequately assess how the dental unit will respond to force applied, even if RAP remains confined to the point of application. For prolonged RAP benefits, it is necessary to repeat the MOP procedure until the desired results are obtained, according to previous clinical trials on animals that have shown that the concentration of chemical mediators or pro-inflammatory markers persist for 2-4 weeks, after which there is a gradual return to baseline levels. Further research is required to determine patient acceptance of MOP repetition until space closure is achieved.

Table 3. Details of studies carried out in humans concerned with MOPs

Authors details with the year of publication	Design of research	Research duration	Details about MOPs carried out	The instrument used for MOPs	Outcomes
Sivaranjan *et al*., 2019 [12]	30 patients; RCT; split-mouth study	canine retraction on 0.018x0.025 in SS wire in 0.022x0.028 in MBT slot	16 weeks	3 MOPs were placed distal to the canine surface. They were placed 5mm and 8mm gingival to the alveolar crest. Each perforation was 3mm deep and performed by a min-implant with a 1.6mm diameter	mini-implant	average orthodontic tooth movement in non MOPs site was 0.76mm and on the MOPs site was 1.04mm; results were not considered statistically significant

Raghav *et al.*, 2021 [25]	Fattori *et al.*, 2020 [80]	Alqadasi *et al.*, 2021 [81]	Aboalnaga *et al.*, 2019 [15]
60 subjects; single center parallel arm; randomized controlled trial	24 patients; RCT; split-mouth study	8 subjects; 3D randomized clinical trial; split-mouth study	18 patients; split mouth; randomized controlled trial
en masse retraction on o.016x0.022in SS wire in 0.018 MBT slot	en masse retraction on 0.019x0.025 in SS wire in 0.022x0.028	canine retraction on 0.018x0.025 in SS wire in 0.022x0.028 in MBT slot	canine retraction on 0.017x0.025 in SS wire in 0.022 in Roth slot
4 mos	until space closure was achieved	3 mos	4 mos
Two perforations were made mesial to the canine and three perforations distal to the canine. The perforations were 5mm deep and made with a lance pilot drill with a diameter of 2mm	Three perforations were made in the vertical plane in the extraction space and repeated until space closure. Each perforation was 6mm deep.	3 MOPs distal to maxillary canine; 1.5-2mm width and 5-7mm depth	three MOPs vertically placed midway in the center of the extraction space
Lance Pilot Drill	Excellerator RT (Propel)	mini-implant	TAD (1.8 × 8 mm)
The statistically significant en-masse retraction was observed only in the first month. After the first month, no significant difference in retraction was observed No significant anchorage loss was observed.	After completion of space, a closure difference was observed between the control and experimental group. The control group RTM/month was 0.614mm/mo. The experimental group RTM was 0.672mm/mo No statistically significant difference in pain experienced by the patient The experimental group had a higher impact on quality of life	The difference in canine retraction between the MOP site and control site was −0.32 ± 1.14 mm. Not statistically significant. Root resorption was seen with MOPs −0.04 ± 0.04 mm	The amount of Canine retraction was higher on the MOPs side. The canine cusp tip moved 0.6±0.7mm farther on the MOP side than the control. The canine center and apex also moved farther on MOPs side by 0.37±0.63mm and 0.47±0.56mm, respectively Anchorage loss and root resorption values were insignificant. The pain was mild to moderate and experienced only up to a week post MOPs.

Alikhani *et al.*, 2013 [14]	Ozkan *et al.*, 2021 [27]	Jaiswal *et al.*, 2021 [26]
20 subjects; Randomized single-blinded experimental study	24 patients; RCT; split-mouth study	16 patients; split mouth; randomized control trial
canine retraction on 0.016x0.022 in SS wire in 0.022x0.028 in MBT slot	canine retraction on 0.019x0.025 in SS wire in 0.022x0.028 in MBT slot	canine retraction on 0.019x0.025 SS wire in 0.022x0.028 in Roth slot
28 days	28 days	six months or until complete canine retraction, whichever was earlier
3 MOPs distal to canines either on the left or right side at a depth of 2-3mm and 1.5mm wide	3 MOPs distal to canine 3mm apart at a depth of 4mm and 7 mm based o site allocation.	Three perforations were performed in the center of the extraction space. Each perforation was 3mm apart from the other. The perforations were 7mm deep and made using Propel of 1.5mm diameter
Propel	miniscrew of 1.6mm width	Excellerator RT (Propel)
tooth movement was increased 2.3 times on the experimental site; findings were statistically significant	The canine retraction was highest in MOPs of 7mm depth, followed by MOPs at 4mm depth and the control group. Molar medicalization was highest in the MOP-7 group, followed by the control group and then the MOP-4 group.	A significant increase in RTM was observed in the 2nd, third and fourth months. Canine tipping was greater in the two-time MOP group. Anchorage loss was higher in the single-time MOP group. A significant increase in IL-2 was observed in the two-time MOP group.

Alkebsi *et al.*, 2018 [13]	Feizbakhsh *et al.*, 2018 [20]	Attri *et al.*, 2018 [11]
32 subjects; RCT split mouth	20 subjects; single-blinded prospective clinical trial	60 subjects; randomized controlled trial
canine retraction on 0.019x0.025 in SS wire in 0.022x0.028 in MBT slot	canine retraction on 0.019x0.025 SS wire in 0.022x0.028 in Roth slot	en masse retraction on 0.019x0.025 in SS wire in 0.022x0.028 in MBT slot
12 weeks	28 days	until space closure was achieved
Three MOPS were performed starting from 3mm from the distal surface of the canine. The perforations were 6mm above the gingival margin and 5mm apart from each other	2 MOPs distal to the canines in maxilla and mandible at a width of 1.6mm and depth of 3mm	3 MOPs 1.5mm width, 2-3mm deep, between canine and second premolar in maxilla and mandible, repeated every 28 days until space closure achieved
mini-implant	Bone screw	Propel
Average orthodontic tooth movement in non MOPs site was 1.17mm and on the MOPs site was 1.23mm; results were not considered statistically significant	mean rate of tooth movement in the experimental site was1.3mm while that on the control site was 0.64mm; results were considered statistically significant. Increase in rate of tooth movement by 2.03 times	The average rate of space closure was higher in the MOPs group. In Maxillary right experimental side OTM was 0.89(0.17) mm and control side was 0.63(0.11) mm. In the Maxillary left, the experimental side OTM was 0.88(0.21) mm, while on the control side, it was 0.53(0.19) mm. In mandibular right, experimental group OTM was 0.80(0.19) and control side was 0.53(0.19) mm. On the Mandibular left side, OTM on the MOPs side was 0.73(0.1) mm, and the control side was 0.49(0.1) mm. Statistically significant.

Methods other than MOPs for rapid tooth movement in orthodontic treatment

The acceleration of tooth movement was believed to be transient, and there was insufficient scientific information to make a well-informed choice, according to a comprehensive study that contrasted corticotomies and distractions. According to an RCT investigation, the acceleration seen with LLLT was not sustained over extended times. As researchers continue to determine the duration of laser therapy, ideal degree of energy, and frequency, other studies have shown the same results. Lasers stimulate bone regeneration, effectively demonstrated in the mid palatal

suture during RPE, making photobiomodulation or LLLT a potential approach.

Research on MOPs has numerous problems, from methodological inadequacies to unclear conclusions. These methodological restrictions must be considered while analyzing these investigations' findings. Numerous systematic evaluations examining rapid orthodontics have revealed and confirmed this considerable risk of bias **(Table 3)**. Forming concrete is challenging due to the heterogeneity of the given data. Although micro-osteoperforations may cause teeth to move more, their clinical consequences may ultimately be limited. The lack of assurance in the data necessitates cautious analysis of the findings and might prevent the technique from being used in therapeutic settings. A doctor must be aware of these details and use an evidence-based strategy. With the standardization of the many trial features, such as the wire on which retraction is conducted, future research should have objective measures to assess space closure.

Very little research has looked at patient feedback and results for the clinical MOP process. It is necessary to conduct more research on patient-experienced pain and other negative outcomes, including bacteremia and results retention. Extensive research is being done on several options for quickening orthodontic tooth movement, which would shorten the overall length of orthodontic therapy. Low-level laser therapy (LLLT), vibration therapy, piezosurgery, and corticotomies have received the majority of research attention. B oth corticotomies and MOPs use the same fundamental biological mechanism, activating the RAP to produce the desired effects. Corticotomies accelerate OTM, according to Long *et al*. comparison of corticotomy, LLLT, locally applied electrical current, pulsed electromagnetic field, and dentoalveolar/periodontal distraction. Alveolar distraction appears to be a viable option for quickening tooth movement even if LLLT and pulsed electromagnetic fields were not as effective.

Limitations of the available evidence

Only English articles were included in this review due to a language restriction. Therefore, trials published in other languages may not have been included. Only one study examined the effects of MOPs during the whole duration of space closure. In contrast, the other studies all examined the effects of MOPs for a particular model of tooth movement (canine retraction in extraction situations). Future research should examine the efficacy of MOPs during the entire treatment period, as well as for various tooth movement models, the impact of repeated MOPs, and the biological changes caused by MOPs.

Conclusion

The following inference can be made regarding the role of MOPs in speeding OTM and its related side effects based on the available data:

i) The approaches taken to apply MOP across studies differ significantly. To draw an objective conclusion, it is important to distinguish between tipping and the physical movement of the teeth.
ii) In order to make a wise choice, it is necessary to thoroughly assess anchorage loss following MOPS during en-masse retraction of teeth. To ascertain long-term stability, monitoring the effects of MOPs and maintaining these findings after therapy is necessary.

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