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Review Article

The Biomechanical and Cellular Response to Micro-Perforations in Orthodontic Therapy

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ABSTRACT

The long duration of orthodontic treatment is one of the main issues that forces patients to choose other therapeutic modalities with poor outcomes and unfavorable negative effects. It can also exacerbate any adverse effects caused by orthodontic therapy. Micro-osteotomy perforations (MOPs) have been used to trigger the bone's natural processes that accelerate tooth movement. The periodontal ligament (PDL) is put under increased strain by orthodontic pressures, which leads to the desired resorption and deposition of the bone around the tooth. Orthodontic tooth movement is the outcome of this. Inflammatory cytokines and other inflammatory mediators are released in response to PDL stress, which increases osteoblast activity and bone resorption. The objectives of the present study were to evaluate the most current studies on micro-osteo perforations and determine whether they help accelerate orthodontic tooth movement in a clinical setting. The results from studies on MOPs have been both conclusive and inconclusive. This evaluation determines whether the changes observed with MOPs were clinically meaningful and gives a brief explanation of those changes. According to multiple studies, MOPs can double the pace of orthodontic tooth movement, according to several studies. When teeth pass through atrophic ridges, more external root resorption occurs over longer periods. However, the amount of bone did not significantly increase. Therefore, additional study is required to comprehend how MOPs affect tooth movement over atrophic ridges, as more adult patients choose orthodontic treatment. The methods used in different studies to apply MOP vary greatly. It is important to distinguish between tipping and the teeth's natural movement to get an impartial judgment. Assessing anchoring loss after MOPS at the time of en-masse retraction of teeth is essential to making an informed decision. Monitoring the effect of MOPs and maintaining these results after treatment is essential to determining long-term stability.

Keywords: Micro-osteo perforations, Orthodontics, Tooth movement, Orthodontic forces

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Introduction

The length of orthodontic treatment is among its main issues, forcing patients to choose other forms of therapy with unfavorable negative consequences and poor results. It could also make any negative outcomes from the orthodontic procedure severe. There is a high correlation between the length of treatment and the occurrence of soft tissue wounds, white spot plaques and cavities, periodontal problems, and orthodontically induced root resorption. Utilizing a variety of methods and resources, scientists and clinicians have tried, with different levels of accomplishment, to abbreviate the length of medicine since the development of permanent orthodontics [1, 2]. Nonsurgical treatments to shorten orthodontic treatment times include medication, cell mediator injections, self-ligating braces, wires and brackets made to order, low-level lasers, and phototherapy. Moreover, following accelerating tooth movement, surgical operations have been carried out to reduce the duration of the therapy. Both osteotomies and corticotomies, with or without bone grafts, are less invasive surgical techniques, as are piezocisions, piezo punctures, and micro-osteoperforations [3, 4].

MOP, or micro-osteotomic perforations, was used to speed up tooth movement by triggering the bone's natural processes. The periodontal ligament (PDL) is put under increased strain by orthodontic pressures, which results in the desired resorption and deposition of the bone around the tooth. Orthodontic tooth movement is the outcome of this. Inflammatory cytokines and other inflammatory mediators are released in response to PDL stress, which increases osteoblast and osteoclast activity for bone resorption [5, 6].

A traumatic experience that is medically generated can raise inflammatory mediators, which temporarily increases bone resorption and metabolic activity. Micro-orthodontic perforation is a condition that may affect the speed at which teeth move and is referred to as the localized acceleratory process. The frequency of degenerative bone biomarkers, such as TNF- and TRAP+ osteoclasts, is conspicuously elevated and constant across different treatments after surgical operations such as corticotomy, MOP, and corticision [7, 8]. In orthodontics, surgical procedures like as osteotomy and corticotomies using mucoperiosteal flaps have had the most substantial and persistent effects on the rate of tooth movement. However, surgeons do not often employ these old surgical techniques since they are costly, uncomfortable, and intrusive. Furthermore, these treatments will need to be performed by a different expert physician [9, 10].

Low-invasive surgical processes such as micro-osteo perforation, piezopuncture, and piezocision were improved to solve these problems. While corticotomies are done via the gingiva in piezocision, they are produced through the cortex bone in corticision, which does not need mucoperiosteal flaps. Furthermore, the micro-osteoperforation approach initiates bone damage using mini-screws or the Propel device, whilst piezopuncture induces certain breaches in the cortex using piezoelectrical equipment with a sharp tip [11, 12]. The MOP resolves the majority of problems caused by traditional surgical techniques. It can, however, be done by an orthodontist utilizing commonly available orthodontic instruments to accelerate tooth movement, in contrast to other less involved surgical treatments. It facilitates anchoring adjustment and simplifies challenging orthodontic motions. Despite being a relatively new approach, MOP has been shown to have both beneficial and negative effects. This study made an effort to reconcile these outcomes and assess the impact of MOP on tooth movement speed. It also evaluated any adverse impact the intervention could have on the people who received it [13, 14].

Results and Discussion

Basics of MOP

MOPs reduce bone density by inducing the synthesis of cytokines that draw osteoclasts to the site of damage and speed bone resorption. Since flap assessment is not required at the time of the procedure, MOPs are considered minimally invasive procedures. The most basic definition of micro-osteoperforations (MOPs) is localized damage to the alveolar bone. Following a group of orthodontists who initially introduced the procedure, micro-osteoperforations are an accessory approach for accelerating the pace of OTM by creating transmucosal osteo perforations in the cortical bone, surrounding the teeth that need to shift [15, 16]. In their first animal study using MOPs on rats, they observed enhanced tooth mobility and increased osteoclastic and bone remodeling activity at the perforative sites. Inspired by these results, they conducted clinical research on 20 senior citizens with class II division I malocclusion. Chemokines and cytokines, which are chemical mediators that promote osteoclastic activity, were found to be more prevalent. They believed that employing MOPs might expedite the complete orthodontic treatment procedure after seeing that the velocity of canine retraction increased by 2.3 times during the 28-day trial period [17, 18].

How does MOP work

MOPs speed up bone resorption by inducing Frost's (1983) “Regional Acceleratory Phenomenon” (RAP), which explains how unpleasant stimuli induce the alveolar bone's regenerating process to be amplified. Transient osteopenia is the result of localized trauma brought on by MOPs. This results in decreased bone resistance, which speeds up tooth movement through the perforated alveolus [19, 20]. RAP activation causes an enhancement in local pro-inflammatory chemical mediators, like chemokines and cytokines, which results in the transient osteopenia shown. These chemical mediators lead to better bone turnover and less resistance to tooth motion, which enter the alveolus around the MOPs and initiate osteoclastic activity. Chemokines employ prostaglandin E2 or the RANK/RANKL the way to draw in osteoclast precursor cells and cytokines, activating the formation of adult osteoclasts from precursor cells [21-25].

These compounds are released more often, which causes a decrease in bone density because of increased

osteoclast activity and a faster rate of resorption. MOP can be used in clinical settings when the orthodontic outcomes are limited by thick cortical bone since activated osteoclasts momentarily decrease bone density. MOPs trigger apoptosis in the periodontal ligament cells and trigger the ways that lead to cell growth, according to an investigation. The aforementioned physiological systems accelerate tooth mobility in response to orthodontic pressures [26–29].
MOP can be employed in conjunction with any orthodontic device, including those that are fixed, detachable, transparent, etc. Chemical mediators, including CCL 3, CCL 5, and IL 8, that are produced in reaction to tooth movement stimulate the osteoclasts. Apart from chemokines, other proteins belonging to the cytokine family are also released. Fibroblasts, endothelial cells, and osteoblasts are among the macrophages and cells that produce these pro-inflammatory cytokines in the periodontium [19, 30, 31]. In addition to causing bone resorption, they intensify or sustain the inflammatory reaction. When teeth shift in orthodontics, chemokines from the nearby blood vessels enter the alveolus and transform into osteoclasts or macrophages. Chemokine Ligand (CCl-2) or Monocyte Chemoattractant Proteins (MCP-1) is one chemokine. Research on split mouth examined the bone formations at the locations following surgical incisions in the bone around the maxillary second premolars [32–34]. They found that more surgical insults lead to quicker orthodontic tooth movement, less bone quantity, lower bone density, higher osteoclastic activity, and less mature bone surrounding the teeth being moved. When orthodontic pressures are used to shift teeth, varieties of chemical processes related to aseptic inflammation are triggered. Following the events, orthodontic tooth movement is described as a "periodontal phenomenon" that is accompanied by a significant increase in the concentration of leukocytes in the alveolar bone [35–38].

How the procedure of MOP carried out clinically

The buccal cortex is the most commonly treated area. Radiographs may evaluate the quality of the bone, the location of adjacent significant structures, the interradicular bone's breadth, and other aspects. It is important to obtain informed permission before starting MOP. To rule out the possibility of postoperative complications, a thorough review of the patient's medical and dental histories is required. To maximize the benefits of MOP, the location has to be as close to the aim teeth as possible, away from the anchor teeth, inside the relevant gingiva, and up to 1 mm superior to the mucogingival junction. Because tooth extraction also induces RAP, synchronizing the closure of extractions to the MOP process may have an added influence on the activity of MOPs [39–41]. To apply MOP through the related gingiva, it should be positioned more apically and, if at all feasible, directed apically for root position changes such as intrusion and/or torque correction. Still, the apical tissues are accessible to the physician.

Which instruments are used in carrying out MOP

Propel INC. invented the MOP tool, a portable disposable device for making microscopic osteo perforations. The device's width is 1.5 mm, and its depth is adjustable from 3 to 7 mm. The Propel device is not yet used in clinical practice, even though it was developed especially for MOPs. However, for the same reason, more and more researchers are experimenting with mini-implants. Several other researchers have employed Propel INC in their experiments [18, 42].
Recent scientific studies have employed mini-implants, with similar results seen. Implanting MOPs has been accomplished with success by utilizing self-drilling mini-implants that range in thickness from 1.2 mm to 1.8 mm. Any armamentarium that produces the required thickness and depth is advised since biochemical and molecular processes are believed to operate regularly irrespective of the instrument used as long as the depth and design stay intact [24, 43].

What care should be taken post-operatively after MOP

The latest investigation on animals has shown that a diet rich in vitamin E increases OTM levels. Thus, for greater effectiveness, future studies may examine if vitamin E supplements might be utilized in addition to MOPs. Patients should be instructed to gargle with mouthwash containing 0.2% chlorhexidine (CHX) twice a day for 5 days to preserve periodontal health. If patients have adequate periodontal health, they can use regular mouthwashes and saltwater rinses instead of chlorhexidine mouthwash. According to reports, there was minimal to no suffering or agony after the first day of the treatment; thus, analgesics are not required for this [44, 45]. Acetaminophen is the preferred analgesic, however, since each individual uniquely feels pain. Non-steroidal anti-inflammatory drugs (NSAIDs) and other analgesics were prohibited since they are known to impede the rate of OTM.

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

Clinical research on animals has shown that the increase in pro-inflammatory chemical markers usually lasts 14–28 days, afterwards which they return to their initial levels. As a result, researchers suggested that MOPs be performed every 28 days until the desired result was achieved. Because a doctor doesn't need a larger inventory, it is more economical. After all, the process may involve the usage of micro-screws [46–49].

The effect of one, three, and four micro osteo perforations on the speed of OTM was investigated by Alikhani and colleagues. They found that three to four MOPs produced the best outcomes, whereas just one MOP failed to provide the intended results [10]. Feizbakhsh and colleagues found that just two MOPs were required to achieve the intended consequences. Because of this, each site typically featured two to four holes that were vertically separated by two millimeters [20, 50–53].

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

Feizbakhsh *et al*. found that even two MOPs were sufficient to get the desired outcomes. Because of this, each site typically had two to four holes spaced two millimeters apart vertically [20].

Conditions where MOP can be applied

MOPs are suggested for speeding tooth movement, promoting root movement, symmetrical and asymmetrical dental expansion, translating teeth into structurally deficient areas, such as previous extraction gaps, and lowering root resorption caused by orthodontic movements. The quality, density, and metabolism of bone are affected by age, based on earlier studies on orthodontic patients. Consequently, the majority of research has focused on the 18–45 years age range to minimize confounding variables. Most studies that have used MOPs for canine retraction have had positive outcomes [52-57].

The use of MOPs for molar intrusion in open biting conditions was shown to be feasible with no need for auxiliaries. The author demonstrated how, while treating hyper-divergent patients with obvious aligner treatment, three-dimensional molar control avoided cyclical mandibular rotation by pairing transparent aligners with specific micro osteo perforations in the lateral and posterior regions.

Conditions where MOP should be avoided

This operation should be avoided by patients who have significant periodontitis that involves both the gingiva and the bones. High-risk conditions include cardiovascular issues such as angina pectoris, myocardial infarction, etc.; Hematological problems; respiratory problems such as severe asthma, chronic obstructive lung disease, etc.; renal problems including dialysis and transplantation; hepatic problems that impact liver function; endocrine problems including diabetes mellitus, adrenal deficiency, hyperthyroidism, etc. Without a prescription from a physician, this medication should not be given to individuals with systemic disorders who are in greater danger of infection and septicemia [58–62].

Patient compliance regarding MOPs

The lack of flap elevation, corticotomy incisions, or bone augmentation makes MOPs more patient-friendly even though they are still invasive procedures. Patients were more receptive to the operation and more likely to have it done again since, according to recorded patient experiences, they did not feel any pain or discomfort beyond the first 24 hours. Following the damage caused by osteo perforations, MOPs were found to have a greater effect on OHRQoL (oral health-related quality of life) [20, 63-66]. MOPs were shown to primarily impact psychological discomfort, with the effects lasting for up to three days after the surgery. Several systematic reviews have also examined MOPs, and research by Fu *et al*. [28] and Sivarajan *et al*. [29] has found no evidence to support claims of statistically significant speed of tooth movement.

A canine retraction speed of 0.45 mm/month was found to be statistically noteworthy but not clinically relevant in the thorough investigation conducted by Shahabee *et al*. [24]. With a premolar extracting gap of 7.1 mm on average, a speed of 0.45 mm might cut the duration of treatment by approximately 2 months. Additionally, it is possible to reduce the pace during en masse retraction, which begs the issue of whether the recurrent harm to the alveolar bone and its negative consequences are warranted [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*. [24]	Analyze how MOPs affect the rate of tooth movement and the negative consequences for patients.	Meta-analysis and systematic review were performed; the difference in canine retraction of 0.45 mm per month is statistically significant but not clinically significant; there was

		no discernible change in pain levels at the site of MOP; and the single research found that patients with MOPs experienced higher root resorption.
Santos *et al*. [43]	Utilizing the propel system, assess how MOPs affect tooth movement rate and any adverse consequences.	MOP affects quality of life for three days after the treatment, but it has little benefit for OTM. It has no negative impact on root resorption, anchoring, periodontal health, or discomfort.
Fu *et al*. [28]	Assess how well and safely minimally invasive surgery may speed up OTM.	There is no proof that solitary MOPs are effective. There was little evidence to support an acceleration of tooth movement. After MOPs, there was no increase in discomfort, periodontal disease, or root resorption. Because of the data's variability, the data supporting the acceleration of OTM was judged to have low reliability.
Sivarajan *et al*. [29]	Analyze how MOPs affect the rate of tooth movement, the length of therapy, and any negative side effects.	Because of the brief trial period and limited quantity of MOPs, there was no evidence of a beneficial impact of MOPs on OTM. There was poor-quality evidence that utilizing TADs had no negative impact on anchoring loss. There was high-quality evidence that gingival recession, root resorption, and discomfort were not negatively impacted.

Impact of MOPs on the orthodontic tooth movement

Since the effectiveness of the treatment relies upon the precise position and perforation, surgical guidelines are essential to assist the doctor in avoiding errors. In recent years, hardly any study has been conducted in this field. According to research conducted on cadaver mandibles, the use of 3D-printed surgical guides reduced the risk of negative consequences by preventing root penetration on both sides of the hole [70–73]. A 3D-printed MOP surgical direction was effectively utilized by Alkasaby *et al*. in their study [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 al*. [74]	7 mature male beagle dogs (avg age 24 mos)	7 weeks	8 MOPs: two at the upper second premolar bifurcation, and six perforations 7 mm deep distal to the upper second molar	Propel device	The experimental teeth moved between 0.05-0.27 mm more than the control teeth. No statistical significance
Cheung *et al*. [75]	6 male Sprague-Dawley rats; split-mouth study	21 days	The palatal bone mesial to the left maxillary tooth was perforated. Five holes were made, each 1 to 3 mm apart 1 mm deep, and 1.2 mm wide.	Automated driver for Mini-implant	Control side tooth movement = 0.29 $\pm$ 0.15 mm; MOP site tooth movement = 0.54 $\pm$ 0.13 mm
Lee. [76]	8 beagle dogs	10 weeks	Nine MOPs on the buccal side, using a 1.2 mm pilot drill. Three holes in the cortical bone around the root of the second premolar, three perforations in the region of the root of the fourth premolar, and three centered in the edentulous ridge with a depth of 3 mm.	Pilot drill	The OTM of the MOP group was higher. Following the observation period, the second premolar in the MOP group had an average distance of 1.86 times. The fourth premolar's distance in the MOP group was 1.74 times greater.

Kim *et al.* [77]	24 female rabbits	4 weeks	Situated mesially to the mandibular first molar, two MOPS were carried out vertically, 2 mm apart, and at a depth of 3 mm utilizing a 1.4 mm diameter micro-screw.	Micro-screws	Tooth movement is higher on the MOP site by 32%
Teixeira *et al.* [55]	48 adult male Sprague-Dawley rats; split-mouth study	28 days	There are three shallow holes on the exploratory side molar mesial to the first maxillary.	Handpiece with a round bur	The average tooth movement in the control site is 0.29 mm, but at the MOPs location, it is 0.62 mm.
Sugimori *et al.* [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 $\pm$ 0.005	Handpiece with a round bur	On days 4-14, OTM is higher on the MOPs site. Decrease in bone volume and density

Results from studies on MOPs have been both conclusive and inconclusive. The changes seen with MOPs are briefly summarized in **Tables 1 and 2**, which also show whether or not they were clinically significant. MOPs can double the pace of orthodontic tooth movement, according to several studies. The occurrence of the atrophic ridge is greater in adult patients. Moving teeth through atrophic ridges causes external root resorption to happen more often and over longer periods. Researchers looked at how osteo perforations affected beagle dogs' atrophic ridges and discovered that the atrophic ridge with osteo perforations had an OTM that was 1.8 times higher. Nevertheless, the amount of bone did not significantly increase. Thus, additional study is required to understand how MOPs affect tooth movement over atrophic ridges, as more adult patients are choosing orthodontic treatment [10, 43, 78-80].

There hasn't been any research on long-term stability. Reitan claims that gingival fiber remodeling has taken 232 days, which is corroborated by canine tests. Accelerating OTM might compromise the outcomes' durability and retention since there isn't enough time for gingival fiber rebuilding. To assess whether the results of quick orthodontics are retained over the long term, post-retention follow-up is necessary. In every procedure where an instrument comes into touch with blood, bacteremia is a major risk. This has been established as true for several surgical procedures, including piezocision and the insertion and extraction of molar bands [15, 74, 81–83].

The MOP technique involves creating alveolar holes and puncturing the gingiva, even though it is flapless, which raises the possibility of transient bacteremia. However, according to Azeem *et al*. [18] the rate of these adverse effects was minimal (3.3%). Given the paucity of data on bacteremia associated with MOPs, physicians should exercise caution when using the same. Because the retraction wire or device is not standardized, it is difficult to measure the mean orthodontic tooth movement objectively [18]. Alikhani *et al*. used a 0.16 x 0.022-inch wire in a 0.022-inch slot to tip the teeth, which resulted in a greater amount of retraction than repositioning the body [14]. Faster tooth movement might lead to a false-positive test as a result [15, 75-77, 80].

The research employed 0.019x0.025-inch stainless steel wires to lessen tooth tilting and give a more precise measurement of tooth movement. Anchorage drop was smaller at MOP locations (0.39 mm) than at control sites (0.36 mm), according to Alkebsi *et al*. but the difference was not statistically noteworthy [13]. This implies that due to canine retractable puts less stress on anchor units than end mass retraction, the anchoring loss cannot be accurately measured in the current research. According to the findings of another study, MOPs had no discernible impact on anchoring decrease [84].

Further research is required to fully understand root resorption in MOP patients. After applying a buccal tipping force of 150 g for 28 days, Chan *et al*. [19] observed increased root resorption of the maxillary first premolar at the region of MOPs. The worsening of root resorption close to MOPs may therefore affect the rise in osteoclastic activity, the authors claim, when the bone turnover rate rises as a result of the alveolar perforation injuries [19]. Other research, however, found that MOPs did not affect the incidence of root resorption. Alkebsi *et al*. [13] reported significant root resorption, especially on the control site, which was more noticeable than on the MOP side.

This is in line with the findings of Tsai *et al*. [30], who discovered that compared to the MOP group, the control group had statistically considerably greater root resorption. Alkasaby *et al*. [31] claim that MOP reduced orthodontically induced inflammatory root resorption (OIIRR) for the nearby distobuccal roots by lowering the density of the surrounding alveolus and raising OIIRR for the mesiobuccal roots that were distant from the MOP location. Studies on animals have also shown complete recovery with just slight injury to the root surface from mini-implants, leading to normal periodontal structure. When mini-implants are inserted and removed right away, the root surface at the damage site experiences continuous cementum healing [85].

It's a good idea to evaluate the MOPs' activity and the backing periodontium's response before starting the operation. In situations where bone density is higher and more resistant to orthodontic tooth movement, the practitioner can shorten the duration of treatment for patients by slowing down the pace of tooth movement. Several therapeutic modalities, such as fixed mechanotherapy, detachable appliance therapy, molar distalization, and clear aligner therapy, can be enhanced with MOP [86].

A major issue in split-mouth studies is the propensity of a group of teeth joined by a wire to transfer pressures uniformly. Thus, to accurately assess how the dental unit will respond to the force being used, force dispersal must be prevented, even if RAP remains restricted to the place of application. Prior animal clinical studies have shown that the levels of chemical mediators or pro-inflammatory indicators remain elevated for two to four weeks before gradually declining to their initial levels, indicating that repeating the MOP process is required for prolonged RAP advantages until the expected outcomes are achieved. Until space closure is accomplished, more study is needed to ascertain if patients would accept repeating MOP.

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*. [12]	30 patients; RCT; split-mouth study canine retraction on 0.018 x 0.025 in SS wire in 0.022 x 0.028 in MBT slot	16 weeks	Distal to the canine surface, three MOPs were positioned. They were positioned 5 and 8 mm from the alveolar crest, respectively. A min-implant with a 1.6mm diameter made each hole, which was 3 mm deep.	Mini-implant	The average orthodontic tooth movement on the MOPs site was 1.04 mm, whereas on the non-MOPs site, it was 0.76 mm; the findings were not deemed statistically significant.
Aboalnaga *et al*. [15]	18 patients; split mouth; randomized controlled trial Canine retraction on 0.017 x 0.025 in SS wire in 0.022 in Roth slot	4 mos	Three MOPs vertically placed midway in the center of the extraction space	TAD (1.8 × 8 mm)	The degree of canine retraction was greater on the MOP side. The canine cusp tip shifted 0.6+0.7mm further to the MOP side than the control. The canine center and apex shifted farther on the MOPs side by 0.37 + 0.63mm and 0.47 + 0.56mm, respectively. Root resorption and anchorage loss results were negligible. The mild to severe discomfort was only felt for a week after MOPs.

Jaiswal *et al*. [26]	16 patients; split mouth; randomized control trial	Canine retraction on 0.019 x 0.025 SS wire in 0.022 x 0.028 in Roth slot	Six months or until complete canine retraction, whichever was earlier	In the middle of the extraction area, three holes were made. There was a 3 mm gap between each perforation. Propel with a 1.5 mm diameter was used to create the 7 mm deep holes.	Excellerator RT (Propel)	The second, third, and fourth months showed a notable rise in RTM. Canine tilting was increased in the two-time MOP group. The single-time MOP group saw a greater amount of anchorage loss. IL-2 was shown to be significantly increased in the two-time MOP group.
Raghav *et al*. [25]	60 subjects; single center parallel arm; randomized controlled trial	En masse retraction on o.016 x 0.022 in SS wire in 0.018 MBT slot	4 mos	They created three holes distal to the canine and two mesial to it. A lance pilot drill with a 2 mm diameter was used to create the 5 mm deep holes.	Lance pilot drill	Only the first month saw the statistically significant en-masse retraction. There was no discernible change in retraction beyond the first month. There was no discernible loss of anchoring.
Fattori *et al*. [79]	24 patients; RCT; split-mouth study	En masse retraction on 0.019 x 0.025 in SS wire in 0.022 x 0.028	Until space closure was achieved	Three perforations were made in the vertical plane in the extraction space and repeated until space closure. Each perforation was 6 mm deep.	Excellerator RT (propel)	Following space completion, a closure distinction between the experimental and control groups was noted. The RTM/month for the control group was 0.614 mm/month. The RTM for the experimental group was 0.672 mm/mo. There was no statistically noteworthy variation in the patient's level of pain. The influence on quality of life was greater for the group receiving the experiment.
Alqadasi *et al*. [80]	8 subjects; 3D randomized clinical trial; split-mouth study	Canine retraction on 0.018 x 0.025 in SS wire in 0.022 x 0.028 in MBT slot	3 mos	3 MOPs distal to maxillary canine; 1.5-2 mm width and 5-7 mm depth	Mini-implant	There was a -0.32 ± 1.14 mm distinction in canine retraction between the MOP site and control site, which was not statistically noteworthy. MOPs showed root resorption of -0.04 ± 0.04 mm.

Attri *et al*. [11]	60 subjects; randomized controlled trial	En masse retraction on 0.019 x 0.025 in SS wire in 0.022 x 0.028 in MBT slot	Until space closure was achieved	3 MOPs 1.5 mm width, 2-3 mm deep, between canine and second premolar in maxilla and mandible, repeated every 28 days until space closure achieved	Propel	The average rate of space closure was higher in the MOPs group. In the Maxillary right experimental side, OTM was 0.89 (0.17) mm and the 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 the mandibular right, the experimental group OTM was 0.80 (0.19) and the 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.
Alikhani *et al*. [14]	20 subjects; Randomized single-blinded experimental study	Canine retraction on 0.016 x 0.022 in SS wire in 0.022 x 0.028 in MBT slot	28 days	3 MOPs distal to canines either on the left or right side at a depth of 2-3 mm and 1.5 mm wide	Propel	Tooth movement was increased 2.3 times on the experimental site; the findings were statistically significant.
Ozkan *et al*. [27]	24 patients; RCT; split-mouth study	Canine retraction on 0.019 x 0.025 in SS wire in 0.022 x 0.028 in MBT slot	28 days	3 MOPs distal to canine 3 mm apart at a depth of 4mm and 7 mm based on site allocation.	Miniscrew of 1.6mm width	MOPs with a depth of 7mm exhibited the greatest canine retraction, followed by MOPs with a depth of 4mm and the control group. Molar medicalization was greatest in the MOP-7 group, followed by the control group, and finally by the MOP-4 group.

Feizbakhsh *et al.* [20]	20 subjects; single-blinded prospective clinical trial	Canine retraction on 0.019 x 0.025 SS wire in 0.022 x 0.028 in Roth slot	28 days	2 MOPs distal to the canines in the maxilla and mandible at a width of 1.6 mm and depth of 3 mm	Bone screw	The mean rate of tooth movement in the experimental site was 1.3 mm while that on the control site was 0.64 mm; results were considered statistically significant. Increase in rate of tooth movement by 2.03 times
Alkebsi *et al.* [13]	32 subjects; RCT split mouth	Canine retraction on 0.019 x 0.025 in SS wire in 0.022 x 0.028 in MBT slot	12 weeks	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.	Mini-implant	Average orthodontic tooth movement in the non-MOPs site was 1.17mm and on the MOPs site was 1.23mm; results were not considered statistically significant.

Methods other than MOPs for rapid tooth movement in orthodontic treatment

A thorough investigation comparing corticotomies and distractions found that the velocity of tooth movement was thought to be temporary and that there was not enough scientific data to make an educated decision. An RCT study found that the LLLT-induced velocity was not maintained over long periods. Other studies have produced similar findings as researchers attempt to establish the optimal energy level, frequency, and duration of laser treatment. Since lasers successfully promote bone regeneration in the mid-palatal suture during RPE, photobiomodulation or LLLT may be a viable strategy.

MOP research is riddled with issues, ranging from methodological flaws to ambiguous findings. These methodological limitations must be taken into account while assessing the findings of these studies. Numerous systematic reviews of quick orthodontics have identified and verified this significant risk of bias **(Table 3)**. The variability of the data makes it difficult to form a solid. Micro-osteoperforations may increase tooth movement, however there may not be many clinical repercussions. The absence of certainty in the data needs a cautious examination of the results, which may preclude the approach from being employed in therapeutic settings. Physicians need to be cognizant of these subtleties and employ an evidence-based approach. The standardization of several trial aspects, such as the wire used for retraction, should allow for objective measurements to be used in future studies to evaluate space closure.

Patient feedback and outcomes for the clinical MOP process have been the subject of relatively little research. Further study on pain experienced by patients and other adverse effects, such as bacteremia with outcome retention, is required. Numerous strategies for accelerating orthodontic tooth movement are the subject of extensive research to reduce the overall duration of orthodontic therapy. Most studies have focused on low-level laser treatment (LLLT), vibration therapy, piezosurgery, and corticotomies. Both MOPs and corticotomies work by activating the RAP, which is the same basic biological process. When comparing corticotomy, LLLT, locally applied electrical current, pulsed electromagnetic field, and dentoalveolar/periodontal distraction, Long *et al*. found that corticotomies speed up OTM. Even though pulsed electromagnetic fields and LLLT were less successful in accelerating tooth movement, alveolar distraction seems to be a good alternative.

Limitations of the available evidence

Due to a language constraint, this review only covered English-language articles. Consequently, it's possible that trials published in other languages were left out. The impacts of MOPs across the whole space closure period were only studied once. The other research, on the other hand, all looked at how MOPs affected a specific tooth movement model (canine retraction in extraction scenarios). Future studies should look at the effects of recurrent MOPs, the biological alterations brought on by MOPs, and the effectiveness of MOPs for different tooth movement models during therapy.

Conclusion

Based on the information at hand, the following conclusion may be drawn about how MOPs contribute to OTM speeding and associated adverse consequences:

1. The methods used to apply MOP vary greatly throughout investigations. Tipping and the actual movement of the teeth must be distinguished to get an unbiased result.
2. A comprehensive evaluation of anchoring loss after MOPS during en-masse retraction of teeth is required to make an informed decision. Monitoring the impact of MOPs and keeping these results after therapy is required to determine stabilization over time.

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