EFFECTS OF MICRO-OSTEOPERFORATION DEPTH ON THE ORTHODONTIC ACCELERATION: A SYSTEMATIC REVIEW

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ABSTRACT
This systematic review aimed to evaluate the clinical effectiveness of different depths of micro-osteoperforations (MOPs) in accelerating canine in orthodontic patients at one month period. Relevant literature was sought using a pre-specified search strategy until December 2023. Electronic medical and scientific databases included PubMed/MEDLINE, Scopus, EMBASE, and The Cochran's Library (clinical trials). Searches were conducted in the databases for randomized control trials (RCTs) that used MOPs. The primary outcome was canine retraction rate. 14 randomized controlled trial studies were included. From all the included articles, reported depths of MOPs range from 1 to 7 millimeters. MOPs accelerate tooth movement more effectively compared to conventional orthodontic treatment, with canine retraction rates varying from 1.1 to 1.75 times the conventional rate. In conclusion, increasing the depth of MOPs did not impact tooth movement acceleration at one month after MOPs.
Keywords: Micro-osteoperforations, MOPs, Tooth Movement, Systematic Review

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INTRODUCTION

Over the years, several surgical procedures have been developed to accelerate orthodontic tooth movement. Several techniques of cortical bone penetration are aimed at cutting the cortical bone through the cancellous bone. This initiates transient osteopenia, indicated by a reduction in bone density, consequently resulting in diminished resistance to tooth movement. Regional Acceleratory Phenomenon (RAP) was first identified in 1983 (Frost, 1983).

Nevertheless, conventional corticotomy is considered as an invasive technique due to flap elevation, leading to patient discomfort. Various surgical approaches have been proposed as minimally invasive surgical techniques, including PiezocisionTM (Dibart et al., 2009), interseptal bone (Leethanakul et al., 2014) reduction, corticision (Park, 2016), and micro-osteoperforations (MOPs) (Teixeira et al., 2010).

MOPs have been proposed as a minimally invasive technique for accelerating orthodontic treatment. The rationale of this technique is that puncturing the alveolar bone can trigger bone remodeling without flap operation. Transmucosal holes of the cortical bone are created using Propel, Lance drill, and mini-implant. (Teixeira et al., 2010) A randomized controlled trial showed the combination of orthodontic treatment with MOPs for canine retraction can enhance tooth movement rates by 2-3 times higher than the conventional orthodontic treatment (Alikhani et al., 2013).

This systematic review aimed to evaluate the clinical effectiveness of different depths of MOPs in accelerating the canine retraction rate compared to conventional orthodontic treatment.

LITERATURE REVIEWS

Micro-osteoperforations (MOPs)

Micro-osteoperforations are a minimally invasive technique to accelerate tooth movement. MOPs can decrease complications from surgical procedures by using Propel (Alikhani et al., 2013; Li et al., 2022), Lance drill (Raghav et al., 2022; Thomas et al., 2021), and mini-screw (Alkebsi et al., 2018; Alqadasi et al., 2019; Alqadasi et al., 2021; Babanouri et al., 2020; Haliloglu-Ozkan et al., 2018; Ozkan & Arici, 2021; Sivarajan et al., 2019) to perform the transmucosal perforation. When using Propel, it is required to penetrate adjacent alveolar bone with a range from 0 to 7 mm from the surface of the alveolar bone. Inserting a propel through the gingiva into bone without flap operation can be done under local anesthesia.

Since 2010, MOPs have been first introduced by Teixeira and colleagues. The study showed an increase in the rate of bone remodeling and tooth movement after arousing the expression of inflammatory cytokines over minute cortical bone penetration of forty-eight rats. The study also reported that osteoperforations increased tooth movement rate (Teixeira et al., 2010). While human experimental study showed canine retraction by orthodontic force combined with MOPs can increase the rate of tooth movement at 2-3 times faster than the conventional method (Alikhani et al., 2013).

Micro-osteoperforations administration

MOPs can be effortlessly performed during a standard orthodontic appointment. Clinicians should plan the application of MOPs to ensure specific tooth movement, considering anchorage needs, bone structure, and other important factors. Applying MOPs in proximity to the target teeth and at a distance from the anchor teeth yields the highest effect. The recommended range is usually two to four perforations per site. If unable to achieve the higher perforations, increasing the depth of the perforations can compensate. The depth of perforation in the cortical plate should be decided based on the thickness of the soft tissue and cortical plate. Generally, it is advised to use MOPs with penetration depths ranging from 3 to 7 mm into the bone. (Sangsuwon et al., 2017)

From the literature review, the conceptual framework can be drawn as shown in Figure 1.

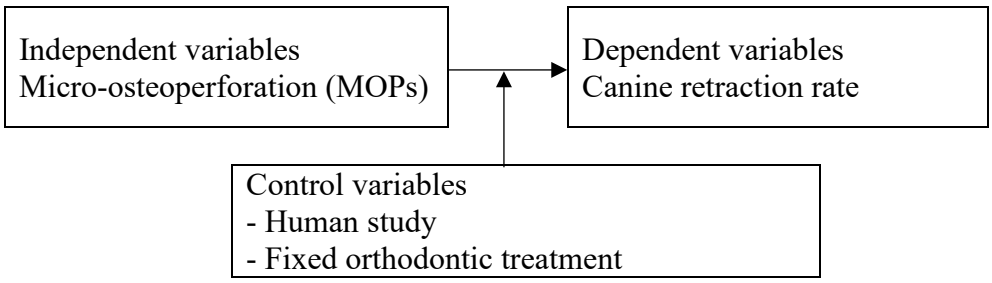

Figure 1 Conceptual Framework

RESEARCH METHODOLOGY

Searches

Relevant literature was sought using a pre-specified search strategy from 2013 to December 2023. Electronic medical and scientific databases include PubMed/MEDLINE, Scopus EMBASE, and The Cochran's Library (clinical trials).

Table 1 Search strategy

Concept	Keywords
Orthodontics treatment	- Orthodontic* - Malocclusion
Surgical procedures	- Micro-osteoperforation* - Osteoperforation* - Osteopuncture
Outcomes	- Retraction rate - Canine movement - Tooth movement

Condition or domain being studied: Orthodontic patient
Participants/population: Orthodontic patients of all ages
Intervention(s): Micro-osteoperforations (MOPs)
Comparator(s)/control: Conventional orthodontic treatment
Main outcome: Canine retraction rate
Inclusion criteria
- randomized controlled trials (RCTs)
- patients of all ages undergoing orthodontic tooth movement acceleration with micro-osteoperforations (MOPs) with any appliances
- patients who required premolars extraction and subsequent canine retraction
Exclusion criteria
- non-English publication
- non-randomized study, controlled clinical trials, observational studies such as cross-sectional, case-control, cohort study, and descriptive study
- including trials on mixed populations of intervention and control

Data extraction (selection and coding)

The search involved screening titles and abstracts of relevant literature found in databases including PubMed/MEDLINE, Scopus, EMBASE, and The Cochran's Library (clinical trials) up to December 2024. Two reviewers applied specific criteria to selected studies for inclusion in the systematic review. Two reviewers will independently screen records for inclusion, and the third reviewer will resolve disagreements between individual judgments. The means of recording data in an Excel spreadsheet.

RESEARCH RESULTS

Study selection

The search results from 4 databases according to the search strategy, consisting of 70 from PubMed, 108 from Scopus, 107 from the Cochrane Library, and 70 from Embase. Initially, 355 articles were discovered in the literature search, and 178 duplicated articles were excluded. However, after reviewing topics and abstracts, 151 articles were found unsuitable for research inclusion criteria. Following the reading of the 25 remaining full texts and the exclusion of those not meeting the inclusion criteria, 14 studies were deemed eligible for consideration.

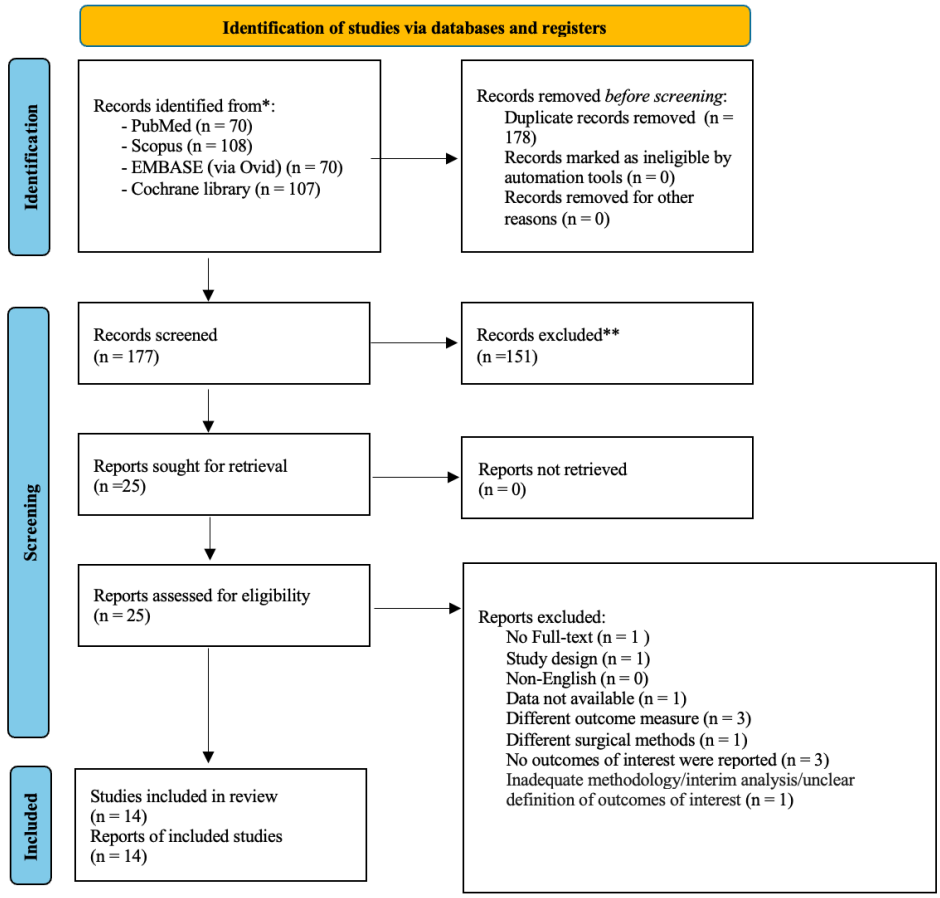

Figure 2 Flow diagram

The rate of canine movement

The rate of canine movement was investigated in 14 studies. The average age of the sample group ranges from 12.56 to 40 years old. From all the included articles, reported depths of MOPs range from 1 to 7 millimeters.

Table 2 Characteristics of the studies of randomized controlled trials

Study	Age (year)	Sample size	Surgical methods	Rate of canine retraction
Alikhani et al. (2013) (2013)	19.5-33.1	20	- maxillary canine retraction - using Propel - 3 mm in depth	1 months MOPs : 1.27 ± 0.15 mm Control : 0.55 ± 0.15 mm
Haliloglu-Ozkan, Arici, and Arici (2018) (2016)	MOPs; 15.27 ± 1.62, Control; 16.13 ± 1.28	32 (19 M, 13 F)	- maxillary and mandibular canine retraction - using mini-screw - 5 mm in depth	1 months MOPs : 1.76 ± 0.66 mm Control : 1.36 ± 0.81 mm
Babanouri, Ajami, and Salehi (2020) (2020)	16.3- 35.2	25 (11 M, 14 F)	- maxillary canine retraction - using mini-screw - 1 mm in depth	1 months MOPs : 0.94 ± 0.31 mm Control : 0.64 ± 0.12 mm
Alkebsi et al. (2018)	19.26 ± 2.48	32 (8 M, 24 F)	- maxillary canine retraction - 3-4 mm in depth	1 month MOPs : 0.65 ± 0.26 mm Control : 0.67 ± 0.34 mm
Abdelhameed and Refai (2018)	15-25	30	- maxillary canine retraction - using mini-screw - 6 mm in depth	1 month MOPs : 2.16 ± 0.27 mm Control : 1.31 ± 0.23 mm
Sivarajan et al. (2019)	22.2 ± 3.72	30 (7 M, 23 F)	- maxillary and mandibular canine retraction - using mini-screw - 3 mm in depth	1 month MOPs : 1.04 ± 0.40 mm Control : 0.76 ± 0.41 mm
Alqadasi et al. (2019)	15-40	8 (4 M, 4 F)	- maxillary canine retraction - using mini-screw - 5-7 mm in depth	1 month MOPs : 1.11 ± 1.26 mm Control : 1.17 ± 0.72 mm
Alqadasi et al. (2021)	20.89 ± 4.46	10 (4 M, 6 F)	- maxillary canine retraction - using mini-screw - 5-7 mm in depth	1 month MOPs : 1.07 ± 1.2 mm Control : 1.15 ± 0.7 mm
Thomas et al. (2021)	19-25	30	- maxillary canine retraction - using a Lance drill - 4 mm in depth	1 month MOPs : 1.32 ± 0.4 mm Control : 0.86 ± 0.4 mm
Ozkan and Arici (2021)	MOPs; 17.27 ± 1.22, Control; 18.13 ± 1.28	24 (12 M, 12 F)	- maxillary canine retraction - using mini-screw - 4 and 7 in depth	1 month MOPs (4 mm) : 1.22 ± 0.29 mm MOPs (7 mm) : 1.3 ± 0.31 mm Control : 0.88 ± 0.2 mm
Golshah, Moradi, and Nikkerdar (2021)	16-25	25 (14 M, 11 F)	- maxillary canine retraction - using mini-screws with handpiece - 3-4 in depth	1 month MOPs : 1.45 ± 0.65 mm Control : 1.23 ± 0.73 mm
Venkatachalapathy et al. (2022)	15-25	20	- maxillary and mandibular canine retraction - 3 mm in depth	1 month MOPs : 0.65 ± 0.21 mm Control : 0.37 ± 0.09 mm
Raghav et al. (2022)	20.32 ± 1.96	30	- maxillary canine retraction - using the Lance pilot drill - 5 mm in depth	1 month MOPs : 1.12 ± 0.49 mm Control : 0.82 ± 0.42 mm
Li et al. (2022)	12.56-25.89	20 (9 M, 11 F)	- maxillary canine retraction - using Propel - 5 mm in depth	1 month MOPs : 1.28 ± 0.56 mm Control : 1.16 ± 0.66 mm

Note: M refers to the items for male, F refers to the items for female

Fourteen articles included in the analysis evaluated the impact of different depths of MOPs on the rate of canine retraction over a period of one month. MOPs accelerate tooth movement more effectively compared to conventional orthodontic treatment, with canine retraction rates varying from 1.1 to 1.75 times the conventional orthodontic treatment.

Only one study examined MOPs at a 1 mm depth within the cortical bone (Babanouri et al., 2020). The outcomes indicated the efficacy of the MOP technique in accelerating orthodontic tooth movement, although the amount of acceleration was not clinically significant in terms of canine retraction.

Research on MOPs at a depth of 3 mm focused on measuring the extent of canine retraction over a period of 16 weeks. The results showed that all MOP groups demonstrated significantly greater canine distalization compared to the control group. (Sivarajan et al., 2019)

Ozkan's (Ozkan & Arici, 2021) experiment, which underwent three MOPs at depths of 4 mm and 7 mm, showed no significant difference in the rate of canine retraction between the 4 mm MOP (1.22 ± 0.29 mm/month) and the 7 mm MOP (1.29 ± 0.31 mm/month).

DISCUSSION & CONCLUSION

Participants in the studies were aged range from 12 to 40 years, showing that the results were relevant for both adolescents and adults. According to this systematic review, MOPs achieved greater tooth movement acceleration compared to conventional orthodontic treatment, with rates varying from 1.1 to 1.75 times the conventional rate based on the surgical methods employed. Similar to the recent systematic review and meta-analysis, which analyzed ten studies on the effect of MOPs on the tooth movement rate in canine retraction, a significant difference was observed between the MOPs and control groups (Mohaghegh et al., 2021).

Noxious stimuli can enhance tissue healing, making it up to ten times faster than usual. This phenomenon termed the regional acceleratory phenomenon (RAP), was presented by Frost in 1983 (Frost, 1983). The onset of RAP usually occurs a few days after surgery, where the site of the osseous surgery causes alveolar bone demineralization, leading to decreased regional bone density and an increase in bone turnover (Frost, 1989; Schilling et al., 1998). Increasing the level of trauma can amplify the inflammatory response. This can be achieved using MOPs by either increasing the number of perforations or extending the depth of each perforation.

From all the included articles, reported depths of MOPs range from 1 to 7 millimeters. As for the study by Golshah (Golshah et al., 2021), which involved MOPs at depths of 3-4 mm, similar to Alkebsi's study (Alkebsi et al., 2018), conflicting results were found. This may be influenced by other factors besides the depth of the MOPs, such as force application, orthodontic protocol, intervention protocol, number of perforations, site of perforations, width of the appliance, and timing of activation, which affect tooth movement.

Even though the length of the MOPs was extended to 5-7 mm, the total tooth movement rate in the MOPs group did not show an increase (Alqadasi et al., 2019; Alqadasi et al., 2021). Similar to the clinical trial study, the experimental group, which underwent three MOPs at depths of 4 mm and 7 mm, showed no significant difference in the rate of canine retraction between these two groups (Ozkan & Arici, 2021).

There was no statistically significant difference in tooth movement rates between the MOP and control sides for MOPs at depths of 3-4 mm and 5-7 mm over one month (Alqadasi et al., 2019) (Alkebsi et al., 2018). MOPs at a depth of 5-7 mm resulted in a significantly higher tooth movement rate on the experimental sides compared to the control sides after three months. However, the overall tooth movement rate in the MOPs group did not increase (Alqadasi et al., 2021).

Therefore, increasing the length of MOPs does not impact the acceleration of tooth movement. The study should further explore other factors of MOPs, such as gingival phenotype, bone thickness, or location that may influence tooth movement.

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