Comparison of Micro-Osteoperforation and Platelet-Rich Fibrin Methods in Accelerated Orthodontic Tooth Movement

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Abstract

AIM: The purpose of this thesis was to compare two methods of accelerated orthodontic tooth movement (OTM) in adults: Micro-osteoperforation (MOP) and platelet-rich fibrin (PRP/PRF) regarding the speed of canine retraction and other teeth OTM in terms of patient comfort measures.

METHODS: From over 3000 searches in different sources like PubMed, Cochrane Library, and Google Scholar, 21 peer-reviewed articles from 2015 to 2022 were selected. All the studies researched healthy, non-growing humans aged 16-40, diagnosed with Class II div 1 malocclusion with first premolar extraction or molar distalization or incisors crowding.

RESULTS: Both methods accelerated orthodontic tooth movement. The MOP method was slightly faster than the PRP/PRF method but more painful. There were a few reported side effects including root resorption, anchorage loss, and canine tipping more in the MOP studies. More MOPs placed less often were more effective. Higher platelet concentration injected more often had a better result. Both methods had inflammatory markers, particularly IL-1β elevated in the gingival crevicular fluid, which persisted longer in the MOPs. Gingival and plaque indexes showed clinically insignificant differences in MOP trials and were not measured in PRP/PRF studies.

CONCLUSION: Both experimented accelerated OTM methods can help to shorten adult treatment comfortably. Nevertheless, further studies on the PRP/PRF method, are needed.

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1 Introduction

The biological processes of bone remodelling and orthodontic tooth movement are closely interconnected. In adult patients, the natural bone remodelling process may decelerate due to a decrease in the number of osteoblasts, resulting in slower orthodontic tooth movement and longer treatment times. To address this issue, minimally invasive techniques like micro-osteoperforations (MOPs) and platelet-rich fibrin (PRF) injections have the potential to hasten the bone remodelling process and expedite the pace of orthodontic tooth movement.

The keyword "minimally invasive" is central to the study, as it reflects the importance of reducing patient discomfort and complications. While presented studies tried to assess the efficiency of both methods in human trials, there is still not enough systematic evidence showing their clinical capability to shorten treatment for adult patients.

The aim of this thesis was to compare the presented techniques in the latest literature reviews and data analysis from 2015 to 2022 in an effort to contribute to the understanding of minimally invasive techniques and their impact on patients' outcomes. The main findings suggested that the mechanical method is faster, while the biological method is less painful for patients. The implications of these results are discussed in the context of clinical practice and future research.

Accelerated tooth movement by micro-osteoperforation is based on mechanical trauma caused to bone through the mucosa. Transmucosal puncture induces the regional acceleratory phenomenon (RAP), first described in 1983 by Harold Frost (Feizbakhsh et al., 2018), which naturally occurs during bone and soft tissue trauma. RAP is responsible for transient osteopenia and faster bone remodelling. The phenomenon lasts around 4 months (Joy et al., 2021).

The applied perforations create microdamage to the periodontal ligament (PDL), which initiates the remodelling signal. This signal triggers a series of biological processes, including the secretion of various growth factors and cytokines that stimulate the activity of osteoclasts and osteoblasts. These cells work together to resorb and form new bone, which leads to tooth movement (Alikhani et al., 2013). The amount of tooth movement is directly correlated with the levels of the potent pro-inflammatory cytokine IL-1β measured in the crevicular fluid of the PDL (Jaiswal et al., 2021). A study of orthodontic tooth movement (OTM) proved that osteoclasts are rate-limiting in bone resorption (Attri et al., 2018).

Platelet-rich fibrin (PRF) and platelet-rich plasma (PRP) are terms used for a centrifuged blood fraction containing growth factors such as platelet-derived growth factor, transforming growth factor, and endothelial growth factor, etc., and an autologous fibrin matrix that promotes bone remodelling and healing (Ahmad et al., 2019). The difference between the two main types is that PRP contains anticoagulants such as ACD (acid citrate dextrose) as a preservative, whereas PRF produces a higher cumulative release of the growth factor and has no additive except PRGF, which contains $CaCl_2$. These two main types can have derivatives such as L-PRF, L-PRP, P-PRP, P-PRF, etc. Researchers have reported that i-PRF contained the most growth factors, gradually released up to 1 week after the injection to increase tooth movement (Erdur et al., 2021).

PRP/PRF induces the RAP effect through transmucosal injection with already present inflammatory mediators and the fibrin matrix (Zeitounian et al., 2021). PRF, as a source of growth factors, reduces bone density and speeds up bone remodelling (Abrar et al., 2022). According to Liou et al. (2016), "a single injection of PRP activity lasts for 5-6 months clinically, and the fastest rate of acceleration is during the second and fourth months after the injection".

This literature review aims to comprehensively compare the effectiveness, patient comfort, pain levels, side effects, and other relevant research findings of two accelerated orthodontic tooth movement (OTM) methods—micro-osteoperforation (MOP) and platelet-rich fibrin (PRF)—in adult patients.

2 Methods

The literature search included multiple databases: PubMed, Google Scholar, ScienceDirect/Elsevier, and the Cochrane Library. The PICO elements utilized in this search strategy were defined as follows:

The population (P) consisted of adult patients undergoing orthodontic treatment, specifically those aged 16-40, who were healthy and exhibited Class II Division 1 malocclusion with first premolar extraction, molar distalisation, or incisor crowding. The intervention (I) included terminologies related to micro-osteoperforations, such as micro-osteo perforations, micro-osteoperforations, micro-osteoperforation, MOPs, and MOP. The comparison (C) focused on platelet-rich fibrin injections and its associated terms, which include platelet-rich fibrin (PRF), platelet-rich plasma (PRP), leukocyte-and-platelet rich fibrin (L-PRF), among others. The outcomes (O) of interest were faster tooth movement and accelerated orthodontic treatment, as well as related aspects like comfort and pain levels, including pain and swelling, and side effects like anchorage loss, canine tipping, and root resorption.

The inclusion criteria for the literature review demanded that the selected studies be randomized split-mouth clinical trials or two-arm controlled clinical trials. The studies had to be published within the years 2015 to 2022 and written in English to ensure relevance and accessibility.

On the other hand, the exclusion criteria eliminated single case studies, animal studies, meta-analyses, and systematic reviews from consideration. Additionally, studies featuring fewer than 15 participants were also excluded to maintain a sufficient sample size for meaningful analysis. Subsequently, 21 peer-reviewed journal articles were selected concerning MOPs and PRF/PRP methods for accelerating tooth movement.

2.1 Statistics

Descriptive statistics, frequency analysis, and content analysis were employed as part of the qualitative methodology to systematically analyze the textual content of the included studies. It is important to note that, given the narrative nature of this study, regression analysis and meta-analysis techniques were not deemed suitable for the analytical framework.

3 Results

3.1 Micro-osteoperforation

In the review of 11 MOPs articles, several similarities stand out. All trials were randomised clinical studies—either split-mouth or parallel two-arm—performed on 16 to 46 healthy adults with a mean age of approximately 30 years, comprising both males and females. All selected patients had a Class II Division 1 malocclusion, which was treated with extractions of the maxillary and mandibular first premolars. While the studies were randomised at the outset, complete blinding was not feasible due to the same provider's intervention.

The first treatment modality involved levelling and aligning teeth until stainless steel wire size 019/025 was reached. The extraction sites were permitted to heal for at least 4 to 6 months prior to the initiation of the trial to ensure that no Regional Acceleratory Phenomenon (RAP) effects from the extractions interfered with the sole influence of micro-osteoperforation on the experiment.

A temporary anchorage device (TAD) with a nickel-titanium (NiTi) coil was employed, measuring a force of 150 to 200 g, to prevent molar movement and to distalise the canines. Noteworthy exceptions in the research include Gulduren et al. (2020), who utilised a distalisation appliance; Kundi et al. (2020), who anchored the first and second molars together; Sharin et al. (2021), who examined incisor unraveling on 0.18 NiTi wire; and Shivarian et al. (2018), who employed an elastomeric chain instead of the coil.

The typical number of MOPs in the trials was three, with a depth of 3 to 4 mm into cancellous bone, except in the study by Gulduren et al. (2020), who used six MOPs with a depth of 5 to 6 mm, and in the research by Feizbahsh et al. (2018), who utilised only two for both jaws. The devices used to create punctures included the Propel Execellerator Driver or a temporary anchorage device (TAD). Gulduren et al. (2020) employed a 14 mm drill to create the perforations.

The usual location for micro-osteoperforation was distal to the maxillary canine, performed through the gingival mucosa without creating a flap (**Figure 1**). Two studies that investigated molar distalization (Guldren et al., 2020) and the resolution of maxillary incisor crowding (Sharin et al., 2021) represented exceptions to this practice. In the case of molar distalization, researchers employed punctures between the first and second molars and the premolars. For maxillary incisors, micro-osteoperforations (MOPs) were completed between the roots.

The time required to incorporate MOPs into the experimental group varied across clinical trials (**Table 1**), ranging from a single treatment consisting of three MOPs (Alikhani et al., 2013; Kundi et al., 2020) to a monthly treatment involving perforations, with a total of fourteen performed (Sharin et al., 2021).

Table 1. Summary of clinical trials evaluating micro-osteoperforation and temporary anchorage devices (TADs) for orthodontic treatment. Data from various randomized controlled trials (RCTs) involving patients aged 15 to 45. Key columns include: Source (1st author, date), Trial type (e.g., "2-arm" or "split mouth" RCT), Age (in years), Number of patients (N), Tools used (e.g., TADs, Niti coils), Measurement (method and point), Treatment interval (in days), Affected areas (e.g., maxillary or mandibular canines), and the number of Mandibular Opposing Planes/Devices (MOPs).

SOURCE	TRIAL	AGE	N	TOOLS	MEASUREMENT	INTERVAL	AREA	MOPS
Abrar, 2022	2-arm	18-26	50	TAD Niti 150g	3D, gingival incisor-canine	28	Distal max canine	3/Mini
Alikhani, 2013	RCT	18-45	20	TAD TPA Niti 150g	Plaster, caliper, canine-lateral	1	Distal max canine	3/propel
Alkebsi, 2018	RCT	>16	32	TAD Niti 150g	3D, rugae canines	180	Distal max canine	3/Mini
Attri, 2018	2-arm	17-20	60	TPA Niti 150g	3D, movement	28	Distal canine	3/propel
Fattori, 2020	2-arm	18-27	24	TAD 10mm, Niti 200g	3D, space	1	Distal max canine	3/7
Feizbakhsh, 2018	RCT	28	20	TAD SS Niti 150g	3D, TAD-canine dist	180	Max & mand canine	2/Mini
Gulduren, 2020	RCT	16-24	18	TAD dist. appliance	3D, Y-axis	21	Betw. 1st & 2nd molar	6/1.4mm
Jaiswal, 2021	RCT	15-25	16	TAD Niti 150g	3D, canine tips	1	Distal max canine	3/propel
Kundi, 2020	RCT	27-33	30	Ni TI 100g	3D, canine - incisor tips	1	Distal max canine	3/propel
Shahrin, 2021	2-arm	18-45	30	0.018 Niti, SS	Plaster, incisors dist	30	6 max incisors	3/propel 14
Sivarajan, 2018	RCT	18-26	30	TAD SS chain 140-200g	Intraoral caliper, premolar-canine	28	Over extraction	3/Mini

The tooth most frequently observed in the majority of experiments was the maxillary canine; however, Guldren et al. (2020) evaluated maxillary molar distalization, while Kundi et al. (2020) measured both canine distalization and molar mesialization. Additionally, Sharin et al. (2021) investigated maxillary incisor unraveling. Feizbaksh et al. (2018), Attri et al. (2018), and Sivarajan et al. (2018) further observed the mandibular canine to assess any differences in the speed of movement between the upper and lower canines.

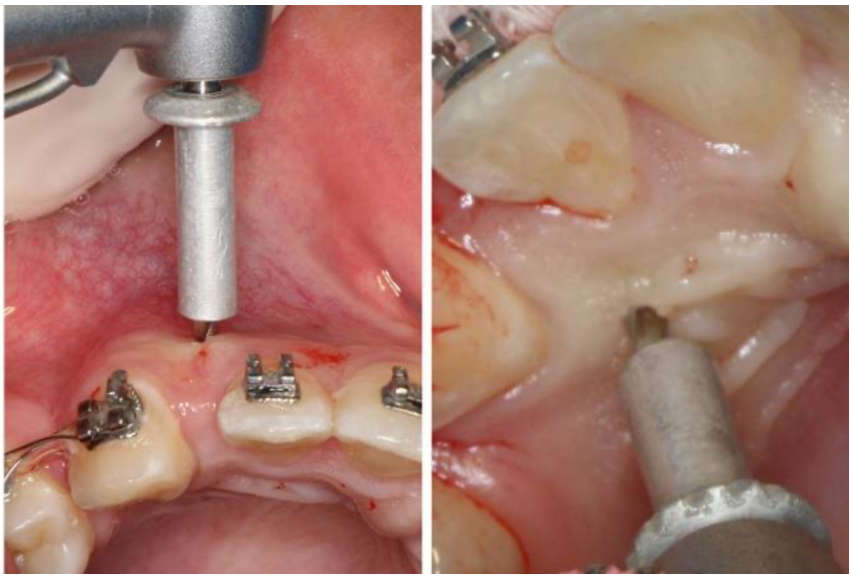

Figure 1. Micro-osteoperforations (MOPs) on the buccal and palatal surfaces. Image source (CC BY 4.0): Mordente et al., 2024)

The duration of observation varied from 28 days (Alikhani et al., 2013; Feizbakhsh et al., 2018) to full gap closure (Attri et al., 2018). Movement speed was measured using superimposed 3D models and motion calculation software, with the exception of Alikhani et al. (2013) and Sharin et al. (2021), who employed plaster models and 3D calipers to evaluate tooth movement. The measurement points for tooth movement varied from trial to trial (**Table 1**).

3.2 Platelet-rich plasma/fibrin

In the selected PRP/PRF articles, all the trials were randomised clinical split-mouth or two-arm studies performed on healthy adults aged 18 to 40 years, diagnosed with a Class II Division 1 malocclusion with planned extraction of the first maxillary and mandibular premolars. Both males and females participated in the study, except for El-Timamy et al. (2020), where the experimental group consisted solely of females.

All studies were randomised; however, complete blindness was not possible due to interactions between practitioner and patient. Teeth were levelled and aligned before the initiation of the experiment until stainless steel wire 0.019/0.025 was achieved. Tehranchi et al. (2018) and Pacheco et al. (2020) used 0.016/0.022 and 0.020 stainless steel wires, respectively (**Table 2**).

Maxillary canine retraction was observed in most of the trials, except for Joy et al. (2021), who assessed mandibular canines, and Tehranchi et al. (2018), who compared both maxillary and mandibular canines. Karakasli et al. (2021) experimented with maxillary incisor retraction.

Table 2. PRP/PRF study characteristics. The data presents the source, trial type, patient age range, number of patients (N), Measurement (method and point), wire specifications, treatment time, affected area/site, and injection details (number, volume, and type). Abbreviations used include N for number of patients, Age for years, inj. (N/vol./type) which denotes number of injections, volume, and type (where PRP stands for platelet-rich plasma, i-PRF for injectable platelet-rich fibrin, and L-PRF for leukocyte- and platelet-rich fibrin), tx for treatment, dist. for distance, wks for weeks, mths for months, U for units, SS for stainless steel, TAD for temporary anchorage device, submuc. for submucosal, intra-lig. for intra-ligamental, and mem. for membrane.

SOURCE	RCT	AGE	N	MEASUREMENT	WIRES	TX TIME	AREA	INJ. (N/VOL./TYPE)
Abrar, 2022	2-arm	18-26	50	3D models, ging. contour canine	TAD Niti 150g, 019/025 SS	Pre-retraction	Buccal & ling.	2 x 0.3 ml PRP
Ahmad, 2019	Split mouth	18-28	28	Plaster, digital photo, canine dist.	TPA 019/025 SS Niti 150g	Post-extraction	Submuc.	2 x 0.7 ml PRP
El-Timamy, 2020	Split mouth	18-22	16	3D models, canine dist.	TAD Niti 150g, 017/025 SS	3, 6 wks post-extr.	Submuc.	3 x 25 U (0.25 ml) PRP + 10% CaCl2
Erdur, 2021	Split mouth	21-24	20	Plaster, caliper, canine dist.	TAD Niti 150g	2 wks	Intra-lig.	2 x 2 ml i-PRF
Joy, 2021	Split mouth	21-25	15	Plaster, canine-molar dist.	TAD Niti 150g	4 mths	Submuc.	2 x 1 ml PRP
Karakasli, 2021	Single-center	18-22	40	Plaster, lat. incisor-canine dist.	TAD Niti 150g, 019/025 SS	2 wks	Intra-lig.	2 x 2-3 ml i-PRF
Pacheco, 2020	Split mouth	20-40	17	Flexible ruler, midline-canine	0.008 ligature, 0.20 SS	Post-extr.	Alveoli	L-PRF mem.
Tehranchi, 2018	Split mouth	12-25	30	Plaster, adjacent teeth dist.	TAD Niti 016/022 SS	Post-extr.	Alveoli	L-PRF plug
Zeitounlouian, 2020	Split mouth	16-24	21	Plaster, measurements	Niti 150g, 019/025 SS, TPA	Post-extr. & 1 mth	Submuc.	2 x 3 ml i-PRF

Temporary Anchorage Devices (TADs) were used as molar anchorage, except in the studies by Ahmad et al. (2019) and Zeitounlounian et al. (2020), who utilised TPA arches. Pacheco et al. (2020) applied a 0.008 ligature laced back for molars and premolars. PRP/PRF was injected submucosally (**Figure 2**) and intra-ligamentally. Tehranchi et al. (2018) and Pacheco et al. (2020) utilised L-PRF membranes or plugs directly into extraction sockets for site preservation. The number of injections varied between 1 to 3 per side. Each experiment employed a different volume of PRP/i-PRF, ranging from 0.3 ml to 5 ml. The injection timing differed in each experiment, starting immediately after extraction or at varying time intervals (**Table 2**).

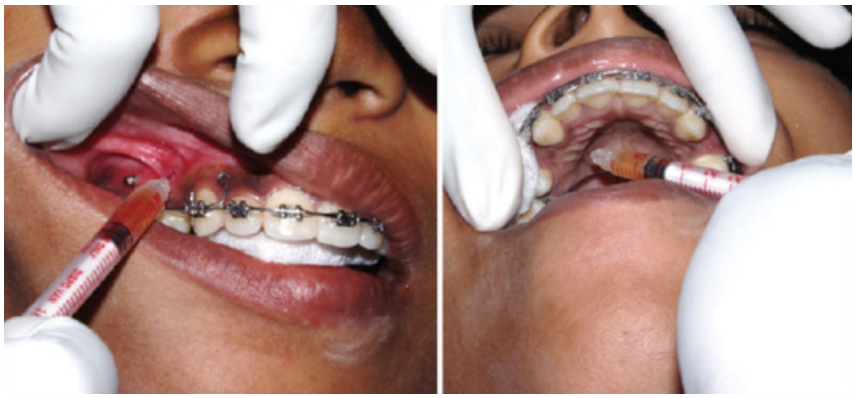

Figure 2. Submucosal injection of platelet rich plasma. Image source (CC BY-NC-SA 4.0): Desai et al., 2023.

The measurement methods demonstrated a wide variety, with each test employing a different approach to analysing tooth movement, from 3D model software support to linear distance measurement on plaster models. The points at which the movement was evaluated were even more diverse. Three of the studies used the third palatal rugae as a stable point of evaluation, while the remainder measured the distance from the lateral incisors to the

mesial aspect of the canines. Each study provided its own unique assessment.

3.3 Speed of tooth movement with MOP

All reviewed studies involving maxillary canine retraction, except for Alkebsi et al. (2018), Fattori et al. (2020), and Sharin et al. (2021), demonstrated a statistically significant acceleration in tooth movement within the experimental groups that employed micro-osteoperforations (MOPs), with a P-value of less than 0.05 (**Table 3**).

Table 3. PRF/PRP observation period, methods of measurement, and movement in millimeters. Abbreviations: "mos" means months, "wks" refers to weeks, and "d" indicates days. "Gap closure" denotes the period until full gap closure. "Max" stands for maxillary, "mand" for mandibular, "inc." for incisors, "retr." for retraction, "Molar mes." for molar mesialization, and "distal." for distalization.

SOURCE	TOOTH	CONTROL	EXPERIMENTAL	P-VALUE
Abrar, 2022	Canine maxillary	B: 6.2; 4w: 6.5; 8w: 6.7	B: 6.06; 4w: 6.7; 8w: 7.2	0.05; 0.038; 0.00
Ahmad, 2019	Canine maxillary	4w: 0.9; 8w: 1.1; 12w: 1.7	1.3; 1.2	<0.001
El-Timamy, 2020	Canine maxillary	4w: 1.3; 12w: 1.1	1.55; 0.59	0.049; 0.020
Erdur, 2021	Canine maxillary	0.35; 1.08; 1.23	0.73; 1.56; 1.88; 1.90	<0.001
Joy, 2021	Canine mandibular	0.7	0.87	<0.001
Karakasli, 2021	Max incisors retraction	0.081; 0.136; 0.073; 0.109	0.072; 0.138; 0.077; 0.105	<0.001
Pacheco, 2020	Canine maxillary	0.90	0.67	0.004
Tehranchi, 2018	Max and mandibular canine	2.08	4.12	0.006
Zeitounlouian, 2020	Canine maxillary	1.25; 0.92; 0.97; 1.40; 1.13	1.46; 0.86; 1.14; 1.23; 0.68	>0.05

Mandibular canines included in the studies by Feizbakhsh et al. (2018), Attri et al. (2018), and Sivarajan et al. (2018) also showed significant acceleration in tooth movement with the application of MOPs. According to the authors, maxillary canines exhibit a velocity that is 0.94 mm faster than their mandibular counterparts (Sivarajan et al., 2018).

Sivarajan et al. (2018) explored variable durations of MOP application, ranging from 4 to 12 weeks between the first and second applications. The most favourable results were observed with a longer interval between the MOP applications. Sharin et al. (2021) conducted an experiment involving the unraveling of 6 maxillary incisors, which revealed only a 4-day difference between groups, favouring the experimental group. Gulduren et al. (2020) analysed maxillary molar distalisation over a period of three months and found a significant acceleration in tooth movement in the study group that received MOPs.

Kundi et al. (2020) identified, as a side effect of canine distalisation in the maxilla, a reduced forward molar movement (better anchorage) in the experimental MOP group (**Table 3**). No effects could be determined based on wire thickness, patient age, or anchorage methods, as these variables were consistent across studies. The differing variables in the trials included the points and methods of measurement, as well as the number of micro-osteoperforations (**Table 2**).

3.4 Speed of tooth movement with PRP/PRF

Results from studies on Platelet-Rich Plasma (PRP) and Platelet-Rich Fibrin (PRF) demonstrated considerable diversity. Some research papers reported a significant tooth movement of 1.7-fold compared to the control group (Liou et al., 2016; Tehranchi et al., 2018; Er-

dur et al., 2021; Karakasli et al., 2021; Joy et al., 2021), with a p-value of less than 0.05. Other studies (El-Timamy et al., 2020; Ahmad et al., 2019) indicated a faster rate of tooth movement during the first four weeks, which subsequently declined. Conversely, Zeitounian et al. (2020) observed slower tooth movement during the second month. Pacheco et al. (2020) demonstrated that the experimental group exhibited a generally slower rate of tooth movement. The amount of tooth movement per month ranged from 0.68 mm to 1.90 mm (**Table 4**).

Table 4. MOPs treatment, tooth observed, movement in millimeters. Abbreviations: "B" = Baseline, "w" = weeks, and "Max" = maxillary. "TX TIME" indicates Treatment Time, "Control" signifies values for the control group, and "Experimental" denotes values for the experimental group. "Mean P" indicates P value significance.

SOURCE	TOOTH	CONTROL	EXPERIMENTAL	P-VALUE
Abrar, 2022	Canine maxillary	B: 6.2; 4w: 6.5; 8w: 6.7	B: 6.06; 4w: 6.7; 8w: 7.2	0.05; 0.038; 0.00
Ahmad, 2019	Canine maxillary	4w: 0.9; 8w: 1.1; 12w: 1.7	1.3; 1.2	<0.001
El-Timamy, 2020	Canine maxillary	4w: 1.3; 12w: 1.1	1.55; 0.59	0.049; 0.020
Erdur, 2021	Canine maxillary	0.35; 1.08; 1.23	0.73; 1.56; 1.88; 1.90	<0.001
Joy, 2021	Canine mandibular	0.7	0.87	<0.001
Karakasli, 2021	Max incisors retraction	0.081; 0.136; 0.073; 0.109	0.072; 0.138; 0.077; 0.105	<0.001
Pacheco, 2020	Canine maxillary	0.90	0.67	0.004
Tehranchi, 2018	Max and mandibular canine	2.08	4.12	0.006
Zeitounlouian, 2020	Canine maxillary	1.25; 0.92; 0.97; 1.40; 1.13	1.46; 0.86; 1.14; 1.23; 0.68	>0.05

The rate of tooth movement was dependent on the dosage and platelet concentration, with values ranging from 2.45 to 6.6 times that of whole blood. The observation period varied from 3 to 18 months, significantly influencing the results of the experiments.

No effects could be determined based on wire thickness, patient age, or anchorage methods, as these variables were similar across studies. The variability arose from the points and methods of measurement, which differed in each study.

Comparative studies between Platelet-rich plasma/fibrin and micro-osteoperforations indicated that the PRP/PRF method was the most efficient during the first four weeks of treatment, a period characterised by elevated inflammatory markers. In contrast, the MOP technique exhibited acceleration between baseline and eight weeks, with inflammatory markers remaining elevated throughout the duration of tooth movement. Furthermore, repeated PRP/PRF injections were shown to sustain regional acceleration phenomenon (RAP) momentum for an extended period (**Table 5**).

Table 5. Comparative studies between MOPs and PRP/PRF.

SOURCE	OBSERVATION	TOOTH	AMOUNT OF TOOTH MOVEMENT IN MM/MONTH		DIFFERENCE BETWEEN GROUPS
			MOP GROUP	PRP GROUP	
Abrar, 2022	3 months	Canine maxillary	Baseline 6.2 4 weeks 6.5 8 weeks 6.7	Baseline 6.06 4 weeks 6.7 8 weeks 7.2	Baseline 4 weeks 8 weeks

3.5 Side effects

Alkebsi et al. (2018) reported significant root resorption based on periapical X-rays and root length measurements using DIGORA software. The amount of resorption was comparable in both groups. Alikhani et al. (2013), Gulduren et al. (2020), and Shahrin et al. (2021) reported a lack of root resorption in their experiments. Three of the included papers mentioned anchorage loss; however, there was no clinically significant difference between the control and experimental groups (see Table 5). Alkebsi et al. (2018) and Jaiswal et al. (2021) noted clinically significant canine tipping in their articles. The control group exhibited substantially more tipping than the experimental group in both trials. Superimposed X-rays of groups that received one or two MOPS revealed a comparable amount of canine tipping (supplementary **Table S6**).

There are few reports on side effects during accelerated tooth movement with PRP/PRF trials. None of the trials reported root resorption during the experiments. Two opposing reports were submitted regarding anchorage loss in the experimental group versus the control group. Karakasli et al. (2021) reported significantly less anchorage loss using TADs, while Zeitounlouian et al. (2020) reported more anchorage loss with TPA. Additionally, canine tipping and rotation reported by El-Timamy et al. (2020) and Pacheco et al. (2020) were more pronounced on the control side (**Table 7**).

Table 7. PRP/PRF Anchorage loss, canine tipping.

SOURCE	ANCHORAGE LOSS MOLAR		CANINE TIPPING		P-VALUE
	CG	EG	CG	EG	
El-Timamy, 2020			15.46°	14.42°	0.71
Joy, 2021	Reported no anchorage loss				
Karakasli, 2021	0.25°	0.06°			0.134
Pacheco, 2020			8.5°	5.8°	0.35 0.024
Zeitounlouian, 2020	1.41 mm	1.64 mm	22.83°	23.89°	0.335 molars 0.655 canine

The same pattern was observed when assessing pain and discomfort, as well as other aspects of quality of life, such as eating, speech, and sleep. All participants experienced some pain or discomfort on the day of the procedure and the day after, which improved rapidly. In all studies, the experimental group reported more pain and discomfort than the control group. Pain and discomfort were moderate to mild, with only 15% of participants experiencing severe pain (**Table S8**) during the observation period, which ranged from 4 hours to 28 days. There was no pain reported in either group after 28 days.

Alkebsi et al. (2018) added a questionnaire to assess participants' willingness to repeat the procedure (91.2% responded affirmatively), satisfaction with the outcome (8.94 on a scale of 0 to 10), and the perceived ease of the procedure (2.71 on a scale where 0 denotes easy and 10 denotes difficult). Among the selected articles, only three groups of authors reported pain and discomfort using a visual analogue scale (VAS). Participants experienced low-grade pain and discomfort on the day of the procedure, which diminished by the third day. Only 15% of patients reported severe pain (Liou et al., 2016). In the PRP trial involving a control group receiving $CaCl_2$ injections, El-Timamy et al. (2020) found that both groups of participants reported similar levels of pain and discomfort associated with the needle intervention (**Table 9**).

Table 9. PRP/PRF Pain, discomfort and methods of assessment.

SOURCE	PAIN	DISCOMFORT	MEASUREMENT
Abrar, 2022	1.62 day 1 0.424 day 2 0.15 day 3	Day of the procedure	VAS
El-Timamy, 2020	Both CG and EG same level	Day of injection Week1,4,7	VAS
Liou, 2016	15 % severe pain	6-12 h post op 85% patients slight discomfort dose dependent	

3.6 Inflammation-related oral parameters

Alikhani et al. (2013) and Jaiswal et al. (2021) conducted measurements of gingival crevicular fluid (GCF) to evaluate cytokine levels prior to and following the procedure. The enzyme-linked immunosorbent assay (ELISA) indicated a significant increase in cytokine expression, particularly IL-1β, in both the controlled and experimental groups, especially on the first day after the insult. In the MOP group, cytokine levels remained elevated throughout the entire study ($p < 0.05$). Alikhani et al. (2013) reported cytokine levels of 0.25 pg/µL in the controlled group and 0.80 pg/µL in the experimental group, while Jaiswal et al. (2021) found levels of 245 pg/mL in both the 1 MOP and 2 MOP groups.

Erdur et al. (2021) assessed cytokine levels in the GCF, collecting samples before premolar extraction and at two additional time points for comparison. They examined four distinct inflammatory markers and their relationships with tooth movement. The findings revealed an increase in the activity of three markers within the experimental group, alongside a decrease in the OPG marker, which inhibits osteoclast differentiation. This reduction correlated with heightened osteoclast activity, as the marker binds to RANKL, resulting in diminished bone density (**Table 10**).

Table 10. PRP/PRF Inflammatory markers in GCF and correlation with tooth movement.

TIME POINT	IL-1B		MMP-8		RANKL		OPG	
	CG	EG	CG	EG	CG	EG	CG	EG
T0	20.98	20.33	13.03	13.03	30.28	30.49	1.02	1.03
T1	39.79	92.85	40.78	70.88	62.90	150.23	0.80	0.50
T2	30.50	60.71	32.51	54.69	52.23	120.93	0.88	0.61
Correlation with Tooth movement	0.917	0.987	0.989	0.988	0.962	0.925	-0.968	- 0.993
P-Value		< 0.001		<0.001		<0.001		<0.001

Furthermore, Alkebsi et al. (2018), Gulduren et al. (2020), and Jaiswal et al. (2021) evaluated the gingival and plaque indices. Their results indicated no clinically significant differences between the controlled and experimental groups across all selected trials (**Table 11**). It is important to note that the gingival and plaque indices were not assessed in the included PRP/PRF studies.

Table 11. MOPs gingival and plaque index.

SOURCE	GINGIVAL INDEX		PLAQUE INDEX		P-VALUE
	CG	EG	CG	EG	
Alkebsi, 2018	1.38	1.44	1.25	1.28	0.81
Gulduren, 2020	0.139	0.56	0.933	0.727	0.842
Jaiswal, 2021	0.58 1MOP	0.154 2MOP			0.583

4 Discussion

Acceleration of tooth movement is an intriguing topic for both practitioners and patients, representing the final frontier for many innovative orthodontic techniques developed in recent years. New breakthroughs aimed at accelerating orthodontic treatment are strongly desired to reduce the duration of fixed appliance therapy and minimise unwanted side effects such as root resorption, enamel demineralisation/caries, periodontal complications, and burnout.

This literature review constitutes the first attempt to compare accelerated tooth movement between two cutting-edge technologies: micro-osteoperforations (MOPs) and platelet-rich plasma/fibrin (PRP/PRF). The objective is to address an important question: which method is faster and easier to implement while incurring minimal side effects?

Based on the studies reviewed, statistically significant tooth movement was observed in both the MOP and PRP/PRF studies compared to the control group, which adhered solely to standard orthodontic protocols. In the only study to date that directly compared tooth movement speed between both methods simultaneously (Abrar et al., 2022), PRP/PRF demonstrated greater efficacy in the first four weeks following injection, whereas MOPs showed superior performance after eight weeks, with their effects enduring for a longer duration.

The variability in the results concerning the speed of tooth movement associated with MOPs and PRP/PRF was comparatively high. In the case of micro-osteoperforations, this variability may be attributed to differences in the surgical techniques employed, the amount and frequency of micro-osteoperforations administered to patients, the specific mechanics of tooth movement investigated, and the methods and reference points used for measurement.

In the context of PRF, the efficacy of tooth movement is significantly dependent on the concentration of platelets within the sample. Due to the numerous variables present in the existing trials, along with the absence of long-term follow-up studies, drawing definitive conclusions remains challenging. The inconsistencies arising from the multitude of variables render it difficult to identify a reliable formula within both techniques that would consistently facilitate faster tooth movement over a specified distance within an exact time frame.

The overall effectiveness of MOP methods demonstrated a 2.3-fold increase in tooth movement in the experimental groups across most trials, particularly from maxillary and mandibular canines to the distalisation of maxillary molars. For PRF, this rate was observed to be 1.7-fold faster than that of the control group. When comparing the two methods, the MOP group exhibited a significantly more efficient acceleration of tooth movement than the PRF group, although the latter group showed greater speed at the onset of the procedure. In both experimental methods, maxillary canines moved faster than mandibular canines, despite both tooth types being accelerated.

The experiments yielded the most efficient results in the distalisation of canines and molars; however, the differences observed in the maxillary incisors were not clinically significant.

MOPs, as a surgical intervention, induced trauma that stimulated the bone to remodel by creating transient osteopenia. Optimal results were attained with infrequent administration of multiple MOPs, specifically every 12 weeks; excessive application of MOPs was found to hinder the process of bone remodelling.

In contrast, PRP/PRF represented a more biological approach, utilising inflammatory markers and stem cells derived from the patient's blood to leverage pro-inflammatory mediators at the injection site and in the gingival crevicular fluid (GCF), particularly OPG, which is responsible for reducing bone density and promoting faster tooth movement. The addition of an L-PRF membrane or plug into an extraction site was found to delay the tooth movement process due to enhanced healing, regeneration, and minimisation of inflammation.

A singular dose of PRF does not appear to influence tooth movement and may even impede the osteogenic management technique (OMT) process. Repeated injections of PRP/PRF, including dosage adjustments and treatment duration, may bolster the effects of accelerated OMT. Further studies featuring standardised designs are necessary to elucidate the impact on tooth movement.

Both methods were associated with pain and discomfort immediately after the procedure, which then decreased rapidly. MOPs were reported to be more painful than PRP/PRF.

With regard to MOP, mild to moderate pain and discomfort associated with MOP procedures persisted for several hours following the procedure, but resolved quickly within 72 hours. The majority of participants found the process satisfying and straightforward, with 91% expressing a desire to undergo this technique again. Most of the pain and discomfort may have been associated with the number and depth of punctures, as well as the pressure and drilling action involved.

Concerning PRP/PRF, low-grade pain and discomfort observed immediately post-procedure continued for three days. The pain was primarily linked to the needle intervention rather than the procedure itself and was comparable in both groups.

Side effects were reported infrequently for both methods. MOP groups showed increased susceptibility to root resorption, anchorage loss, and canine tipping; however, these effects were comparable to those observed in standard orthodontic groups. In contrast, PRP/PRF did not report any instances of root resorption. Furthermore, TADs represented a better anchorage option than TPA in PRP/PRF groups, as they effectively prevented unwanted molar movements and canine tipping. The cytokine levels were consistently higher in the MOP group throughout the entire experiment, whereas elevated levels in the PRP/PRF group were observed for approximately four weeks following the injections.

In relation to MOP, a limited number of side effects were reported in trials, including root resorption, anchorage loss, and canine tipping. The instances of root resorption noted in one of the trials were comparable to those seen with conventional orthodontic treatments. Minimal anchorage loss was measured during molar mesialisation. The results of the gingival and plaque indices were not clinically significant, indicating no remarkable gum inflammation and average oral hygiene quality. Cytokines and inflammatory markers, particularly IL-1β, showed an increase on the first day post-insult in both control and experimental groups. Throughout the experiment, cytokine levels remained higher in the MOP group.

Concerning PRP/PRF, a few side effects were reported during the trials, with none indicating root resorption. Anchorage loss was noted with the use of a TPA appliance instead of TAD. The canine tipping and rotation on the experimental side were less pronounced, resulting in faster tooth movement through the bone. Gingival and plaque indices were not measured in the included PRP/PRF studies. Experimental groups exhibited increased activity of cytokines and inflammatory markers, such as IL-1β, MMP-8, and RANKL, for

approximately four weeks post-injection. The decreased level of the OPG marker was responsible for the increased activity of osteoclasts, correlating with lower bone density.

When comparing the two methods, while both approaches demonstrated efficacy in accelerating orthodontic treatment for adult patients, the MOP method was slightly faster but more painful than the PRP/PRF method. MOPs potentially presented more side effects than PRP/PRF, particularly concerning root resorption. i-PRF, among all the fractions, contained the highest concentration of growth factors and healing potential. The PRP/PRF method was entirely autologous with minimal side effects. Clinically insignificant gingival and plaque indices were reported for MOPs, while data for PRP/PRF were not measured. Inflammatory mediators were elevated in both methods but exhibited a longer duration in MOPs.

Repeated PRP/PRF injections sustained the momentum of Rapid Alveolar Process (RAP) for an extended period, while the effects of RAP persisted longer in MOPs. The MOP procedures were simpler for both practitioners and patients, requiring merely a basic instrument like the Propel and not necessitating referral to an oral surgeon. This surgery was performed in practice without the need for a flap. In contrast, PRP/PRF involved drawing blood from a patient's vein using a needle, necessitating additional equipment such as a centrifuge to separate platelets from whole blood and multiple injections into the patient's mouth.

4.1 Limitations of the study

One major limitation is that to date, only one study has been conducted comparing the MOPs method to PRF/PRP. All included studies were performed in a younger population, with ages ranging from 18 to 45 years in both the MOPs and PRP/PRF groups. The duration of observation varied from 28 days to 6 months in the MOP group and from 4 weeks to 18 months in the PRP/PRF group. All studies were conducted for a specific type of malocclusion, namely Class II with the extraction of the first premolar.

Longer follow-up periods and broader population diversification with different treatment scenarios are necessary to enhance the generalisability of the results. Further studies on human populations are particularly required regarding the use of PRP/PRF in orthodontic tooth movement (OTM).

Conclusions

Both procedures have the potential to significantly accelerate orthodontic treatment clinically and make the overall patient and practitioner experience more efficient. The MOPs procedure is somewhat simpler and faster method than PRP/PRF but according to current knowledge it is also slightly more painful.

Further studies on both methods, especially on PRP/PRF, are needed to explore the potential opportunities for facilitating tooth movement and other possible benefits.

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Ethical approval

No ethical approval was required for this study as it did not involve human participants, animal subjects, or sensitive data. This study falls under the category of data collection without participant identification.

Consent for publication

Not applicable.

Authors' contributions

The author(s) declare that all the criteria for authorship designated by the International Committee of Medical Journal Editors have been met. More specifically, these are: (a) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (b) Drafting the work or revising it critically for important intellectual content; AND (c) Final approval of the version to be published; AND (d) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

The author(s) declare that there are no competing interests related to this work.

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