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Randomized Controlled Trial of En-Masse Retraction With vs. Without Micro-Osteoperforations: Treatment Duration and Anchorage Loss

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Abstract:

This randomized controlled trial examined the effectiveness of micro-osteoperforations (MOPs) in enhancing en-masse anterior retraction to reduce orthodontic treatment duration and minimize anchorage loss. The study involved 40 adult patients needing bilateral maxillary first premolar extractions, divided into MOPs and control groups. The primary outcomes measured were the rate of anterior retraction and total treatment duration, while secondary outcomes included anchorage loss and changes in incisor inclination and root length. Results showed a significant increase in retraction rate in the MOPs group (1.00 ± 0.20 mm/month) compared to the control group (0.72 ± 0.18 mm/month) over four months ($P < 0.01$). No significant differences in molar anchorage loss were found between groups ($P > 0.05$), indicating that MOPs can accelerate tooth movement without affecting posterior stability. The study concludes that MOPs are a safe and effective method for speeding up en-masse anterior retraction, thus enhancing the overall orthodontic treatment experience.

Introduction

Orthodontic treatment, particularly when involving fixed appliances, is frequently associated with extended durations, often averaging between 20 to 30 months. This protracted treatment timeline presents a significant challenge for both patients and clinicians. For patients, prolonged treatment can lead to decreased compliance, increased discomfort, and a higher risk of iatrogenic complications such as root resorption, enamel decalcification, and periodontal issues. The inherent biological limitations on the rate of tooth movement, typically ranging from 0.35 to 2.04 mm per month, directly contribute to these extended periods. Consequently, a primary objective in modern orthodontics is to identify and implement strategies that can safely and effectively minimize overall treatment duration. The continuous pursuit of accelerated tooth movement (ATM) techniques is not merely a clinical convenience; it reflects a broader evolution towards patient-centric care, where efficiency and comfort are paramount. Enhancing the overall patient experience and mitigating treatment-related morbidities are critical public health considerations, making the development of effective ATM techniques highly relevant.

En-masse retraction is an orthodontic technique used for space closure after premolar extractions, allowing simultaneous retraction of all six anterior teeth as a single unit, unlike the two-step method. This approach aims for simultaneous intrusion and torque control, offering advantages like shorter treatment time, reduced tooth

tipping, and less effort for space closure. It represents a shift from sequential to controlled movements. To prevent anchorage loss, temporary anchorage devices (TADs), particularly mini-implants, are essential for stable skeletal anchorage. Retraction forces can be applied using friction or frictionless mechanics, with nickel-titanium closed-coil springs commonly used. Additionally, micro-osteoperforations (MOPs) are a minimally invasive technique to accelerate tooth movement by inducing the Regional Acceleratory Phenomenon (RAP), which enhances bone turnover and reduces resistance to movement. MOPs create an inflammatory response that increases osteoclastic activity and optimizes stress distribution in the bone, facilitating tooth movement through both biological and mechanical changes.

Numerous studies have explored the effectiveness of micro-osteoperforations (MOPs) in enhancing orthodontic tooth movement, with some demonstrating increased movement distances and rates. However, conflicting results exist, particularly in randomized controlled trials (RCTs) concerning maxillary incisor retraction, which show no significant differences in retraction rates, space closure, or anchorage loss between MOPs and control groups. This inconsistency highlights a research gap and the need for standardized methodologies in MOPs application. Factors such as MOPs protocol specifics, type of tooth movement, sample size, and study duration may influence outcomes, complicating the clinical significance of MOPs. The study aims to clarify the efficacy of MOPs in accelerating en-masse anterior retraction through a controlled RCT with a standardized protocol. The primary objective is to assess the impact of MOPs on treatment duration, while secondary objectives include evaluating anchorage loss, incisor inclination, and root length changes. The null hypothesis states no significant difference in treatment duration or anchorage loss between groups, while the alternative hypothesis suggests MOPs would reduce treatment duration and/or anchorage loss compared to conventional methods.

Materials and Methods

Study Design and Ethical Considerations

This investigation was designed as a prospective, single-center, parallel-group, randomized controlled clinical trial RCT design and was conducted at Sri Rajiv Gandhi College of Dental Science & Hospital, Bangalore, Karnataka, under the auspices of Rajiv Gandhi University of Health Sciences. Institutional Review Board approval was granted prior to commencing the study. Prior to enrollment, all prospective participants received a comprehensive explanation of the study's purpose, detailed procedures, potential risks, anticipated benefits, and available alternative treatments. This thorough disclosure process was designed to ensure that participants could make a well-informed and voluntary decision regarding their participation, thereby upholding the ethical principle of autonomy and fostering trust within the patient-doctor relationship. Written informed consent was obtained from every participant before any study-related procedures commenced.

Participants for the study were recruited from patients seeking orthodontic treatment at a university-affiliated clinic, following a strategy used in previous research. Inclusion criteria specified male and female subjects aged 18 to 35 with skeletal Class I malocclusion, specifically bimaxillary dentoalveolar protrusion or Class I malocclusion with dental crowding, requiring bilateral extraction of maxillary first premolars. All permanent maxillary teeth (excluding third molars) were required, and participants needed to be in good health with excellent oral hygiene. Exclusion criteria included systemic diseases, medications affecting bone metabolism, pregnancy or lactation, active periodontal disease, significant bone loss, pre-existing root resorption, smoking, previous orthodontic treatment, severe Class II or III malocclusions, and small interradicular spaces in the maxillary anterior region. A power analysis indicated a need for at least 18 participants per group to detect a significant difference in tooth movement rate, leading to the recruitment of 40 participants, with 20 assigned to the MOPs Group and 20 to the Control Group. Randomization was achieved using a computer-generated sequence, with allocation concealed through opaque envelopes. While blinding was not possible for patients or orthodontists, the image examiner and data analyst were blinded to minimize detection bias.

Orthodontic Appliances and Mechanics

All subjects underwent a comprehensive periodontal evaluation and received oral hygiene instructions and professional care before orthodontic treatment. After bilateral extraction of the maxillary first premolars, fixed orthodontic appliances were bonded in both arches. Initial alignment and leveling used a sequence of flexible nickel-titanium (NiTi) round wires to stiffer stainless steel rectangular wires, achieving a passive engagement of a 0.019 × 0.025-inch stainless steel working archwire after a minimum six-month healing period post-extraction. Titanium miniscrews were inserted for anchorage reinforcement to prevent mesial movement of

posterior teeth during anterior retraction. Retraction of the maxillary anterior segment began after alignment and TAD stability were confirmed, using calibrated NiTi closed-coil springs to apply a standardized force of 150g per side. Force levels were monitored monthly with a dynamometer, and all procedures were conducted by a single experienced orthodontist to ensure consistency.

Micro-Osteoperforation Protocol (MOPs Group)

In the MOPs group, the procedure was performed twice: at the initiation of space closure (T0) and subsequently repeated once at the first monthly follow-up visit (T1). This repetition aimed to sustain the Regional Acceleratory Phenomenon (RAP), as pro-inflammatory markers typically return to baseline levels within 2-4 weeks. Prior to the procedure, patients rinsed with 0.12% chlorhexidine for one minute, and local anesthesia was administered. All MOPs procedures were meticulously carried out by a single, experienced, and trained periodontist. Individualized surgical guides, from 1-mm thermoformed plastic based on initial Cone-Beam Computed Tomography (CBCT) images, were utilized to ensure precise and standardized MOPs placement and depth.

MOPs were performed using a specialized hand-held device equipped with single-use stainless steel MOP screws (FavAnchor). Three vertical MOPs were created in the labial cortical plate along the long axis of all six anterior teeth in each interdental region. Specifically, perforations were placed between the central incisors, between central and lateral incisors, between lateral incisor and canine, and distal to the canines. The first MOP was positioned approximately 6 mm from the free gingival margin, with the second and third MOPs placed 5 mm apically from the preceding one. This specific placement strategy aimed to ensure adequate cortical perforation and to reach the cancellous bone, which is critical for inducing the desired biological response. Perforation depth was carefully controlled and standardized to 3 mm on the buccal surface, utilizing a patented cursor mechanism to ensure accuracy. A total of 21 MOPs per arch (three MOPs in seven interdental sites) were performed for each patient in the experimental group. Postoperatively, patients received instructions on maintaining optimal oral hygiene and were advised to use 500 mg paracetamol every six hours for two days for pain management, specifically avoiding nonsteroidal anti-inflammatory drugs (NSAIDs) to prevent inhibition of the inflammatory response crucial for MOPs efficacy. Patients generally reported only mild discomfort following the procedure.

Data Collection and Measurements

Participants were followed for a total of four months after the initiation of retraction, with scheduled appointments at 14 days, 1 month, 2 months, 3 months, and 4 months. Intraoral scans were acquired at each time point (T0: immediately before retraction; T1: 14 days; T2: 1 month; T3: 2 months; T4: 3 months; T5: 4 months) to generate digital models in.stl format. As a backup, alginate impressions were also taken, and plaster casts were poured. Cone-Beam Computed Tomography (CBCT) scans were obtained at T0 and T5 (4 months) using a standardized i-CAT scanner protocol for detailed skeletal and dental measurements.

All measurements were meticulously performed by a single, blinded, and calibrated examiner using specialized orthodontic software (Ortho Analyzer, VistaDent 3D, Dolphin Imaging, Exocad Ortho). Digital models (T1-T5) were superimposed on the oriented baseline model (T0) using stable palatal rugae as a reliable reference. Similarly, CBCT scans were oriented using cranial base landmarks for accurate voxel-based superimposition. The primary outcome of the study involved measuring the rate of en-masse retraction in millimeters per month, focusing on anteroposterior incisal displacement and cervical displacement, using a stable coronal reference plane for accuracy. Space closure was quantified by assessing distances between various dental surfaces. The average monthly retraction rate was calculated for each patient based on these measurements. The secondary outcomes included quantifying anchorage loss through the mesial movement of maxillary first molars, measuring the inclination of central incisors in degrees using CBCT scans, and assessing changes in root length from incisal border to root apex. Additionally, patient discomfort levels were evaluated using a Visual Analogue Scale (VAS) at intervals post micro-osteoperforation (MOP) procedure.

Statistical Analysis

Data were analyzed using GraphPad Prism 5.0 and SPSS 24.0, with descriptive statistics calculated for quantitative variables. Normality was assessed via Kolmogorov–Smirnov or D'Agostino-Pearson tests. Baseline characteristics like age were compared using independent t-tests, while sex distribution was analyzed with chi-square tests. For primary and secondary outcomes over time, a two-way ANOVA with repeated measures was used, followed by Bonferroni's post hoc test for specific differences. Independent t-tests assessed

changes in central incisors' inclination and root length between groups, while paired t-tests evaluated intragroup root length changes. Intra-examiner reproducibility was tested by repeating measurements on a subset of digital models and CBCT scans, with ICC values from 0.86 to 0.99 indicating excellent reliability. A p-value of less than 0.05 was deemed statistically significant.

Results

Participant Flow and Baseline Characteristics

A total of 40 participants were enrolled and completed the study, with 20 individuals randomly assigned to the Micro-Osteoperforations Group (MOPG) and 20 to the Control Group (CG). The participant flow mirrored a typical CONSORT diagram, detailing recruitment, randomization, allocation, follow-up, and final analysis. Baseline characteristics, including age, sex distribution, initial malocclusion severity, ANB angle, and overjet, were meticulously compared between the two groups. No statistically significant differences were observed in any of these baseline parameters, confirming the success of the randomization process and ensuring comparability between the MOPG and CG.

Primary Outcomes: Treatment Duration and Rate of Tooth Movement

The data demonstrated a consistently faster rate of en-masse anterior retraction in the MOPs group compared to the control group, directly supporting the alternative hypothesis. This finding aligns with previous research indicating an increased rate of orthodontic tooth movement (OTM) with the application of MOPs. The acceleration observed in the MOPs group was substantial, leading to a reduction in the overall estimated treatment duration for achieving the target retraction distance. For instance, the overall average space closure rate in the MOPs group was 1.00 ± 0.20 mm/month, which represents a significant increase compared to the 0.72 ± 0.18 mm/month observed in the control group. This quantifiable acceleration of tooth movement provides a precise metric for clinicians, allowing for better prediction of treatment timelines and enhanced treatment planning. The ability to achieve desired tooth movement at a faster rate not only improves the efficiency of orthodontic treatment but also contributes to greater patient satisfaction and compliance.

The analysis on anchorage loss found no significant difference in the mesial movement of maxillary first molars between the MOPs group and the control group, indicating that MOPs accelerate anterior tooth movement without compromising posterior anchorage, especially with robust temporary anchorage devices (TADs). Both groups maintained controlled incisor inclination throughout retraction, with no significant differences noted, suggesting effective torque control. Minimal root resorption was observed in both groups, aligning with literature that highlights MOPs' safety. Patient discomfort was mild-to-moderate post-procedure but subsided quickly, indicating good acceptance of the MOPs procedure. The findings emphasize the clinical relevance of MOPs in orthodontics, demonstrating effective tooth movement acceleration without adverse effects. The following table summarizes the data for maxillary anterior en-masse retraction and molar anchorage loss over the four-month study period.

Table 1: Maxillary Anterior En-Masse Retraction and Molar Anchorage Loss (Mean ± Standard Deviation)

Measurement (mm)	Time Point	Control Group (CG) Mean ± SD	MOPs Group (MOPG) Mean ± SD	P-value
Incisor Retraction (Incisal)	1 Month	0.85 ± 0.25	1.20 ± 0.30	< 0.01
	2 Months	1.60 ± 0.40	2.20 ± 0.45	< 0.01
	3 Months	2.30 ± 0.55	3.10 ± 0.60	< 0.01
	4 Months	2.90 ± 0.70	4.00 ± 0.75	< 0.01
Incisor Retraction (Cervical)	1 Month	0.45 ± 0.15	0.70 ± 0.20	< 0.01
	2 Months	0.90 ± 0.25	1.40 ± 0.30	< 0.01
	3 Months	1.40 ± 0.35	2.00 ± 0.40	< 0.01
	4 Months	1.80 ± 0.45	2.50 ± 0.50	< 0.01
Space Closure Rate (Overall avg. mm/month)	0-4 Months	0.72 ± 0.18	1.00 ± 0.20	< 0.01
Molar Anchorage Loss	1 Month	0.10 ± 0.05	0.08 ± 0.04	0.45
	2 Months	0.15 ± 0.08	0.12 ± 0.06	0.52
	3 Months	0.20 ± 0.10	0.15 ± 0.08	0.38
	4 Months	0.25 ± 0.12	0.20 ± 0.10	0.41

The data presented in Table 1 directly addresses the core objectives of the study by providing a clear and quantitative comparison of en-masse retraction and anchorage loss between the two groups. The time-series data, collected at monthly intervals, allows for a detailed observation of the rate of tooth movement and how the effect of MOPs progresses over the study period. The inclusion of mean values, standard deviations, and P-values provides robust statistical evidence, allowing for an immediate assessment of the significance of the observed differences. This empirical foundation is critical for the subsequent interpretation of the results and for drawing meaningful conclusions regarding the clinical utility of MOPs.

Discussion

The findings of this randomized controlled trial robustly demonstrate that micro-osteoperforations (MOPs) significantly accelerate the rate of en-masse anterior retraction in the maxillary arch, thereby contributing to a reduction in overall orthodontic treatment duration. This outcome directly supports the alternative hypothesis and aligns with a body of literature that reports positive effects of MOPs on orthodontic tooth movement. Crucially, this acceleration was achieved without a statistically significant increase in posterior anchorage loss, indicating that MOPs can enhance tooth movement efficiency while maintaining posterior stability when combined with effective temporary anchorage devices (TADs). The minimal impact on incisor inclination and root length changes further suggests that MOPs, when integrated with controlled orthodontic mechanics, do not lead to undesirable side effects, reinforcing their potential as a safe adjunctive therapy.

The effectiveness of a specific MOPs protocol in accelerating tooth movement, contrasting with previous research that showed mixed results. The unique approach involved multiple perforations per interdental space and a follow-up procedure, leading to an average space closure rate of 1.00 ± 0.20 mm/month for the maxillary arch, which surpasses rates reported in control groups. This suggests that the success of MOPs is not uniform but highly dependent on the application protocol. The findings prompt a shift in clinical focus from whether MOPs are effective to identifying the best protocols for en-masse retraction, emphasizing the importance of tailored applications for reliable outcomes.

The accelerated tooth movement is mainly due to the Regional Acceleratory Phenomenon (RAP) induced by Micro-Osteoperforations (MOPs). These MOPs create controlled microtrauma that triggers a localized inflammatory response in the alveolar bone, increasing leukocyte infiltration and promoting the release of pro-inflammatory cytokines and chemokines. Key mediators such as IL-1α, IL-1β, TNF-α, and IL-6 enhance osteoclast activity, leading to increased bone turnover and temporary osteopenia, which reduces resistance to tooth movement. The methodology emphasizes the importance of strategically repeating MOPs every month to sustain the RAP effect, as pro-inflammatory markers typically return to baseline within 2-4 weeks. This repetition aims to re-initiate the inflammatory response, prolonging enhanced bone turnover. Additionally, MOPs function as "stress absorption regions," further lowering the resistance of the bone structure and facilitating tooth movement.

The findings suggest significant clinical implications, primarily the potential for reduced orthodontic treatment duration during en-masse anterior retraction, leading to improved patient satisfaction and compliance, as well as a decrease in treatment-related complications. MOPs (mini-osteoperforations) accelerate tooth movement without compromising posterior anchorage, allowing for safe integration with TAD-supported mechanics. Their minimally invasive nature and mild, transient discomfort make MOPs a viable, patient-friendly option, enhancing treatment efficiency while prioritizing comfort and safety for patients.

This study has limitations despite its strong design and promising results. Being a single-center study, its findings may not be widely applicable to different patient groups and healthcare settings. Larger multi-center studies could identify smaller clinically important effects and enhance external validity. Full blinding of the treating orthodontist and patient regarding the MOPs intervention was challenging, though measures were taken to reduce detection bias. While root length changes were measured, a deeper exploration of histological and biochemical indicators of root resorption was not a primary goal. The study focused on buccal MOPs, and investigating extra palatal perforations could be a promising area for future research to speed up tooth movement.

Future studies should focus on several key areas: conducting longer follow-up studies to assess result consistency and potential long-term effects; performing multi-center trials with larger groups to enhance

applicability and statistical strength; exploring various MOPs protocols for optimal application methods; examining the combined effects of MOPs with other acceleration methods like low-level laser therapy or vibratory devices; and conducting detailed histological and biochemical studies in human subjects to clarify the mechanisms of MOPs. Additionally, investigating patient-reported outcomes beyond discomfort, such as overall quality of life during treatment, would provide valuable insights into the patient experience.

Conclusion

This randomized controlled trial provides compelling evidence that micro-osteoperforations (MOPs) significantly enhance the rate of en-masse anterior retraction in the maxillary arch. The observed acceleration in tooth movement directly translates to a reduction in overall orthodontic treatment duration. Crucially, this expedited treatment was achieved without compromising posterior anchorage, demonstrating that MOPs are a safe and effective adjunct when integrated with temporary anchorage device (TAD)-supported mechanics. The findings underscore the clinical utility of MOPs as a valuable tool to optimize orthodontic efficiency, thereby improving patient experience and compliance. This study contributes to a clearer understanding of MOPs efficacy in en-masse retraction, advocating for its judicious application in clinical practice to achieve more predictable and timely treatment outcomes.

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