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Original Article

Impact of micro-osteoperforations on root resorption and alveolar bone in en-masse retraction in young adults: A CBCT randomized controlled clinical trial

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Keywords
Micro-osteoperforations
Root resorption
Bone Thickness
En-masse retraction
CBCT

Summary

Background > Micro-osteoperforations (MOPs) as a surgical technique is increasingly being used as a method to enhance orthodontic tooth movement. However, its iatrogenic effects on root and alveolar bone morphology have been less studied.

Objective > This parallel-groups single-centered trial aimed to assess the impact of micro-osteoperforations (MOPs) on orthodontically induced inflammatory root resorption (OIIRR) and alveolar bone during en-masse retraction stage of maxillary and mandibular anterior teeth.

Methods > Fifty-two patients (mean age 21.35 $\pm$ 2.2 years) with Class I bi-dentoalveolar protrusion, requiring all 1st premolar extractions and miniscrews for anchorage, were randomly distributed into two groups ($n = 26$ each): MOP group treated using single application of MOP's and control group treated with routine sliding mechanics, for en-masse retraction. The primary outcomes were assessed using CBCT-based measurements.

Results > Anterior teeth in MOP group showed increased mean OIIRR than control group, though the difference was statistically non-significant [maxillary anteriors, MOP group – OIIRR = 0.78 $\pm$ 0.29 mm and control group OIIRR = 0.73 $\pm$ 0.36 mm; mandibular anteriors, MOP group – OIIRR = 0.733 $\pm$ 0.20 mm and control group OIIRR = 0.70 $\pm$ 0.24 mm]. Levander and Malmgren's Index for objective scoring of OIIRR revealed only mild resorption with most teeth in both the groups (47% and 51%, respectively). Lateral incisors showed highest OIIRR followed by central incisors and canines in both groups. Lingual side bone thickness and height decreased significantly, however, the differences between the two groups were non-significant ($P > 0.05$).

Conclusion > Within the settings of the current RCT, en-masse retraction when combined with single application of micro-osteoperforations did not pose an increased risk of root resorption or alveolar bone changes compared to routine sliding mechanics.

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Introduction

Comprehensive orthodontic treatment usually lasts for around 24 months, which could be even longer depending on case complexity, treatment plan, and patient characteristics [1].

Long duration of orthodontic treatment may add the risk of adverse effects of pain, discomfort, periodontal diseases, white spot lesions, and orthodontically induced inflammatory root resorption (OIIRR) [2]. Therefore, methods that can accelerate orthodontic tooth movement and reduce treatment time will also be beneficial to minimise the adverse effects. In 2013, Alikhani et al. introduced flapless MOPs in cortical bone as a minimally invasive procedure for accelerating tooth movement and reducing treatment time. Their results reveal a slightly greater than two-fold increase in single tooth canine retraction [3]. Recent clinical study on MOPs in en-masse retraction cases have shown to increase the rate of tooth movement, especially in the first 4–6 weeks following surgical intervention [4]. However, the iatrogenic effects of MOPs on structures close to the surgical site (e.g., root and alveolar bone) has not been clearly evaluated. OIIRR is the most common iatrogenic effect occurring at variable extents in many fixed appliance cases [5]. OIIRR is associated with complex remodelling changes in the periodontal ligament and the removal of hyalinized necrotic tissue by the osteoclastic cells following a heavy force-induced injury [6]. Additionally, increase in levels of cytokines has been noted in MOP's affected area [7]. These cytokines have also been associated with the root resorption process [8]. Hence, it's important to assess the impact of MOPs on root morphology.

Most studies involving MOPs have only assessed OIIRR for the canine tooth. It was concluded that MOP did not exacerbate canine root resorption compared to controls [9–13]. Shahrin et al. applied the MOPs during the alignment phase bilaterally in the anterior interradicular region of the maxilla, excluding the midline. On intraoral periapical (IOPA) examination, the authors did not note any exacerbation of OIIRR in the MOPs group [14]. In terms of alveolar bone, Thomas et al. observed a slight decrease in alveolar bone height on the side closer to the MOPs, whereas Bansal et al. observed no significant height changes [12,15]. There is therefore a lack of clear data on changes in the alveolar bone.

En-mass teeth movement is a common method of retraction. No studies have yet evaluated the effects of MOPs placed in all anterior interradicular areas on the root and alveolar bone of maxillary and mandibular anterior teeth during en-masse retraction.

Specific objective

The objective of this CBCT-based randomized controlled trial was to investigate the effects of MOPs on OIIRR and alveolar bone to aid en-masse retraction.

Materials and methods

Trial design, registration, ethics approval

This study was a single-centre; prospective, 2-arm parallel-group, single-blinded randomized controlled clinical trial to assess the impact of MOPs on OIIRR and alveolar bone during the en-masse retraction stage of anterior teeth in comparison with conventional sliding mechanics. The trial was registered at ctri.nic.in database (CTRI No. CTRI/2018/05/013550). Ethical clearance was obtained from the institutes' ethics committee (NO. EC-PhD-02/Ortho-02/2018). Participants took part in the trial voluntarily and were allowed to withdraw from the trial, if need be, without affecting the patient's orthodontic treatment outcome.

Participants, setting, and eligibility criteria

This trial was conducted at the Institute's Department of Orthodontics. All subjects met the following inclusion criteria: (1) aged 18 to 30 years; (2) class I bi-dentoalveolar protrusion ($1^\circ < ANB < 4^\circ$) requiring all first premolars extraction; (3) high anchorage case; (4) average growth pattern ($30 < SN\text{-}GoGn < 34$); (5) no or mild crowding (tooth size − arch length discrepancy < 4 mm; (6) no systematic diseases or drug uses that would affect bone and tooth movement rate; and (7) good oral hygiene and healthy periodontium. Participants with a history of smoking, pregnancy, facial asymmetry or skeletal abnormalities were also excluded. Information sheets were provided to all participants, and informed consent was obtained from all included patients before enrolment.

Sample size calculation

Sample size was estimated based on an earlier trial investigating root resorption and alveolar bone changes of anteriors after en-masse retraction using CBCT [16]. Statistical analysis with G-Power software yielded a total sample size estimate of 52 participants with 26 per group at a conventional alpha-level ($P = 0.05$) and desired power ($1-\beta$) of 0.80. The sample size was raised to 60 subjects to further increase the power of the study and attrition.

Randomization and allocation concealment

Sixty participants were allocated in the MOP group ($n = 30$) and control group ($n = 30$) in 1:1 ratio. The allocation was based on the block randomization method using Cochran and Cox's (1957) 20 sets of random permutations of the first 16 integers [17]. Every participant randomly picked one sealed envelope

Glossary

- **OIIRR** Orthodontically induced inflammatory root resorption
- **MOPs** Micro-osteoperforations
- **RAP** Regional acceleratory phenomenon
- **CBCT** Cone-beam computed tomography
- **IOPA** Intraoral periapical radiograph
- **CEJ** Cementoenamel junction

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containing treatment code cards. Another researcher from the institute carried out randomization. The principal investigator of this trial was kept unaware of the randomization.

Blinding

Blinding of either the principal investigator performing the clinical procedures or patients was not possible; however, data assessment was blinded. The principal investigator was involved in recruiting the subjects, collecting records, providing orthodontic treatment, and MOPs procedure. Another investigator carried out all CBCT measurements and was blinded for both groups.

Interventions

Orthodontic treatment

All subjects were treated with a 0.018'' slot appliance with an MBT prescription (Dentos Pvt. Ltd.). Extractions of the first premolars were done at the beginning of treatment. Alignment and levelling were continued until the 0.016 × 0.022-inch SS wire seated inside the brackets was completely passive. Anchorage was obtained using mini-implants (FavAnchor™SAS, India, 1.6 × 8 mm) placed bilaterally between maxillary and mandibular 2nd premolars and 1st molars. Mini-implants were placed at least two months before retraction. En-masse anterior retraction was carried out on 0.016 × 0.022-inch SS wire. 9 mm NiTi closed coil spring (G&H Orthodontics) with a force of 250 gm per side was used for retraction. The NiTi closed coil spring was attached from 8- to 10-mm long hooks distal to the lateral incisors to the mini-implants. Retraction force was calibrated and readjusted whenever necessary using a dontrix gauge (Dentaurum).

Micro-osteoperforation procedure

A single application of MOPs was performed just before the initiation of en-masse retraction. A mini-implant (FavAnchor™SAS, India) of 1.6 × 8 mm size was used for MOPs placement. Each micro-osteoperforation of approx. 1.6 mm in width and 5 mm in depth was placed after local anaesthesia (2% lidocaine with 1:80,000 epinephrine) infiltration. Three holes were made at equidistance in each interradicular alveolar bone of all six anterior teeth, including the extraction area distal to canine. A total of 21 MOPs were placed per arch with 0–3 day intervals between MOPs for both the arches (*figure 1*). Care was taken to avoid root damage. All patients were prescribed 0.12% Chlorhexidine mouthwash twice a day for 1-week use and analgesic (tablet Aceclofenac 100 mg + Paracetamol 325 mg) if necessary.

CBCT imaging

CBCT imaging (Carestream, Kodak 9000 C 3D with limited FOV, voxel size 76.5 × 76.5 × 200 µm, 7–12 mA, 9 s) was carried out just before en-masse retraction (T1) and after the end of space closure (T2). The CBCT slices were oriented to provide maximum root length using Carestream 3D imaging software. Radiation doses from the selected imaging machine were in the range of 5–19 µSv which are similar to those of panoramic radiographs [18].

Primary outcomes

Measurement of OIIRR

The root length was measured as the perpendicular distance from the CEJ line (mesial to distal cement-enamel junction) to the root apex (*figure 2*) with the virtual measurement tools on CBCT images. Root resorption was calculated by subtracting T2

FIGURE 1

MOPs placed interradicular region in maxillary & mandibular arches

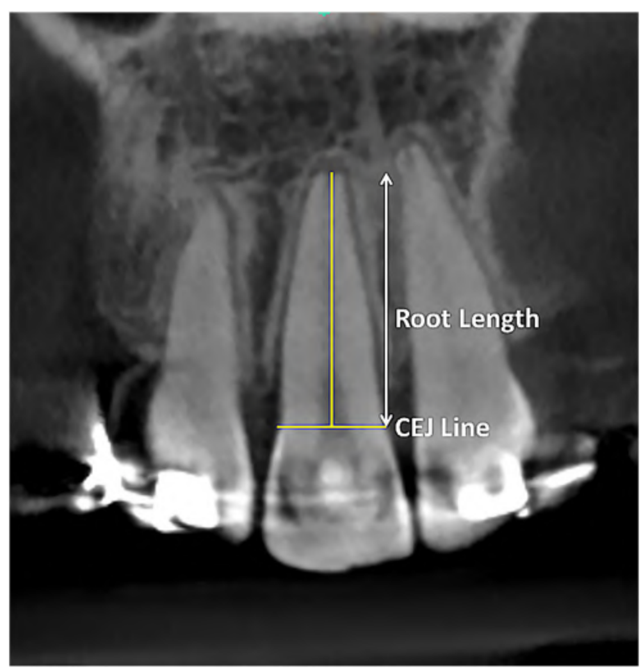

FIGURE 2

Measurement for root length (from cementoenamel junction (CEJ) line to root apex)

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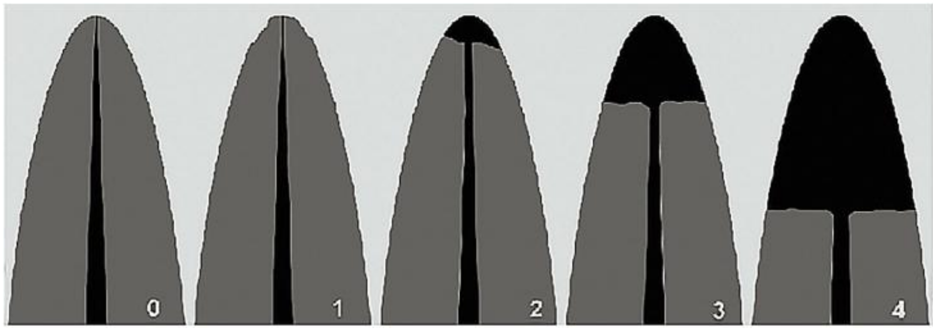

FIGURE 3

Degrees of OIIRR based on Levander & Malmgren Index. Score 0: absence of changes in the root apex; 1: irregular root contour; 2: OIIRR < 2 mm; 3: OIIRR from 2 mm to one-third of the original root length; 4: OIIRR > one-third of the original root length

measurements from T1 measurements. Apical root resorption was further graded objectively using Levander and Malmgren scoring system (*figure 3*) [19]. No other radiographic examinations were carried out to minimize radiation doses.

Measurement of alveolar bone thickness and height

The buccolingual CBCT imaging section was used to determine the alveolar cortical bone thickness and bone height (*figure 4*).

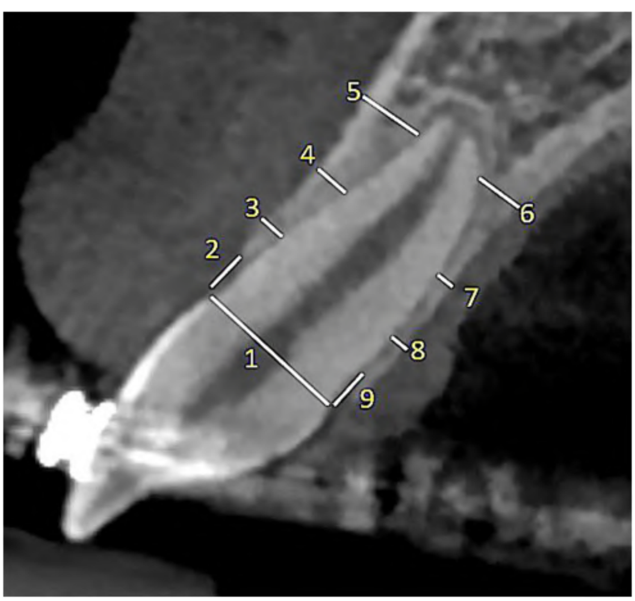

FIGURE 4

Measurement of alveolar bone thickness and height. 1: CEJ line; 2: labial crest height (distance from alveolar crest to CEJ line); 3: labial bone thickness at cervical root level; 4: Labial bone thickness at mid-root level; 5: labial bone thickness at apical root level; 6: lingual bone thickness at apical root level; 7: lingual bone thickness at mid-root level; 8: lingual bone thickness at cervical root level; 9: lingual crest height (distance from alveolar crest to CEJ line)

Alveolar bone thickness

The buccal and palatal/lingual cortical bone thickness was measured at the cervical, mid and apex root levels of all anterior teeth (*figure 4*). The overall mean was then calculated for each side for further comparisons.

Alveolar crest height loss

Alveolar crest height was determined as shown in *figure 4*. The crest height loss was measured as the difference between T1 and T2 values.

Statistical analysis

All statistical tests were performed using SPSS version 24 software (IBM Co., Armonk, NY, USA). Descriptive statistics, mean, and SD were calculated for continuous variables. The distribution normality of data was studied using the Shapiro-Wilk test and appropriate parametric tests were used. Unpaired *t*-tests were applied for intergroup mean comparisons. Comparisons among anterior teeth between groups were evaluated using the ANOVA test. *P*-value < 0.05 was considered significant. The reliability of the measurement technique was assessed by re-measurements on randomly selected 20 CBCT records.

Results

Participant flow

Sixty-six participants were selected based on the set inclusion criteria. Six participants declined to participate. Sixty participants were enrolled in the trial. Two participants moved away during the pandemic. Six more participants' timely follow-up records could not be collected (complete orthodontic treatment was provided). 52 participants completed the trial. An equal number of participants were maintained in both groups during the observation period (*figure 5*).

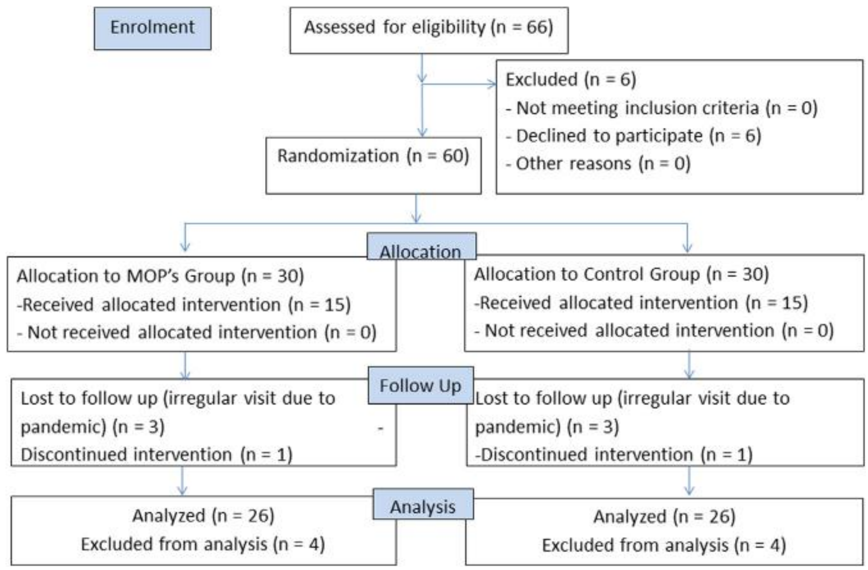

Figure 5
CONSORT flow diagram

Baseline data

The baseline data of the average age of participants and average pre-retraction extraction space have been presented in *table I*.

The error of the method

An intra-class correlation coefficient of 0.91 indicated high intra-examiner reliability for all measurements. Grading for OIIRR was repeated after 1 week on 20 CBCT records and Cohen's kappa intra-rater reliability was 0.801 with 91.67% agreement.

En-masse retraction

The en-masse retraction was completed in an average time of 5.34 ± 1.10 months for the MOP group and 6.01 ± 1.55 months for the control group.

Orthodontically induced inflammatory root resorption (OIIRR)

Overall, all the anterior teeth in the MOP group showed slightly more OIIRR than control group [Maxillary anteriors, MOP group: OIIRR = 0.78 ± 0.29 mm and control group OIIRR = 0.73 ± 0.36 mm; mandibular anteriors, MOP group: OIIRR = 0.733 ± 0.20 mm and control group OIIRR = 0.70 ± 0.24 mm] (*table II*). However, comparison between the MOP and control groups showed no significant difference in OIIRR for both maxillary (P = 0.175, CI = 0.24–1.33) and mandibular anteriors (P = 0.876, CI = 0.23–1.18), respectively (*table II*). Additionally, Levander and Malmgren index's objective scoring of roots (*figure 4*) in both the groups revealed no OIIRR in approximately 45% of the roots, while 50% of the roots showed only mild

Table I
Pre-treatment patient baseline characteristics

	MOP group	Control group
Age	22.5 ± 3.2 years	20.2 ± 1.8 years
Males	10	8
Females	16	18
Pre-retraction Extraction space (mm)	Maxillary right – 4.69 (1.16) Maxillary left – 4.96 (1.15)	Mandibular right – 4.08 (0.90) Mandibular left – 4.39 (1.08)

Table II
Intergroup comparison of OIIRR means of maxillary and mandibular anteriors for T1 and T2 measurements (unpaired *t*-test)

	Group	Mean (mm)	Std. deviation	Mean difference	*P*-value, CI
MaxillaryT1–T2	MOP	0.7885	0.29453	.05513	0.175 (NS), 0.24–1.33
	Control	0.7333	0.20172		
MandibularT1–T2	MOP	0.7103	0.36310	.00769	0.876 (NS), 0.23–1.18
	Control	0.7026	0.24173		

T1-T2 duration: MOP group – 5.34 ± 1.10 months; control group: 6.01 ± 1.55 months; T1 and T2: pre-retraction and post-retraction root length measurements, respectively; CI: confidence interval; NS: not significant $P > 0.05$.

Table III
OIIRR frequency as per Levander and Malmgren scoring system

Grade	Severity	MOP group	Control group
0	No	73 (46%)	66 (42%)
1	Mild	74 (47%)	80 (51%)
2	Moderate	8 (0.05%)	10 (0.06%)
3	Severe	1 (0.006%)	0
4	Extreme	0	0

Table IV
Intergroup comparison of OIIRR means of maxillary and mandibular anterior teeth (ANOVA analysis)

	Maxillary			Mandibular		
Anteriors	Experimental	Control	*P*-value	Experimental	Control	*P*-value
Central incisors	0.79 ± 0.23	0.72 ± 0.21	0.510 NS	0.71 ± 0.31	0.68 ± 0.16	0.531 NS
Lateral incisors	0.82 ± 0.30	0.75 ± 0.18		0.75 ± 0.22	0.71 ± 0.19	
Canines	0.75 ± 0.28	0.71 ± 0.20		0.70 ± 0.19	0.68 ± 0.15	

NS: not significant $P > 0.05$.

OIIRR. Less than 1% of the roots in both groups showed moderate resorption (*table III*). The lateral incisors showed highest OIIRR followed by central incisors and canines in both groups (*table IV*).

Alveolar bone thickness, vertical bone height

There were significant differences between pre-retraction (T1) and post-treatment (T2) overall means for alveolar bone thickness and height (*tables V and VI*). All upper and lower anterior teeth showed statistically significant differences between buccal and lingual bone thickness. Higher bone thickness reduction occurred on the lingual side in both groups. However, no significant differences were noted between MOP and control groups (*table V*). Significant loss of vertical bone height was noted on the lingual aspect of all anterior teeth, with higher loss in the mandible. But similar findings were noted between the MOP and control groups with the difference in values being statistically non-significant (*table VI*).

TABLE V
Intergroup comparison of bone thickness overall means of maxillary and mandibular anteriors for T1 and T2 measurements

	Group	Side	Overall mean ± SD	*P*-value[a]	*P*-value[b]
Maxillary T1-T2	MOP	Buccal	+0.8 ± 1.43	0.013 (S)	0.179 (NS)
		Palatal	−3.01 ± 1.58		
	Control	Buccal	+0.72 ± 1.46	0.016 (S)	
		Palatal	−3.20 ± 1.03		
Mandibular T1-T2	MOP	Buccal	+0.9 ± 1.21	0.001 (S)	0.257 (NS)
		Lingual	−3.65 ± 1.26		
	Control	Buccal	+0.8 ± 1.7	0.001 (S)	
		Lingual	−3.75 ± 1.05		

T1-T2 duration: MOP group – 5.34 ± 1.10 months; control group – 6.01 ± 1.55 months; (+): increase in bone thickness; (−): decrease in bone thickness; NS: not significant $P > 0.05$; S: significant $P < 0.05$.
[a]Unpaired *t*-test between two sides in same group was performed.
[b]Unpaired *t*-test for both arches between MOP and control groups.

TABLE VI
Intergroup comparison of vertical bone height overall means of maxillary and mandibular anteriors for T1 and T2 measurements

	Group	Side	Overall Mean ± SD	*P*-value[a]	*P*-value[b]
Maxillary T1-T2	MOP	Labial	0.74 ± 1.43	0.0215 (S)	0.125 (NS)
		Palatal	2.01 ± 1.58		
	Control	Labial	0.78 ± 1.40	0.0291 (S)	
		Palatal	2.20 ± 1.03		
Mandibular T1-T2	MOP	Labial	0.81 ± 1.35	0.0284 (S)	0.239 (NS)
		Lingual	2.11 ± 1.16		
	Control	Labial	0.79 ± 1.06	0.0210 (S)	
		Lingual	2.31 ± 0.95		

T1-T2 duration: MOP group – 5.34 ± 1.10 months; Control group: 6.01 ± 1.55 months; NS: not significant $P > 0.05$; S: significant $P < 0.05$.
[a]Unpaired *t*-test between two sides in same group was performed.
[b]Unpaired *t*-test for both arches between MOP and control groups.

Discussion

The current study compared OIIRR and alveolar bone changes between an MOP and control group. Inclusion criteria and methodology were stipulated to reduce bias due to confounding factors: age, genetic susceptibility, individual variation, systemic factors, timing of extraction, periodontal type, occlusal forces observed with various malocclusions, and growth patterns. Our clinical study was the first to quantitatively evaluate the MOPs effect on OIIRR and alveolar bone using CBCT during miniscrew supported en-masse retraction of the maxillary and mandibular anterior teeth.

The surgical technique like MOPs cause controlled microtrauma to alveolar hard and soft tissues which, in turn, accelerates orthodontic tooth movement due to the so-called regional acceleratory phenomenon (RAP) [20]. The RAP effect seen in bone following injury is due to a significant increase in osteoclast and macrophage activities leading to cortical bone porosity and turnover [7,20]. A single application of MOPs has been shown to increase mass retraction rates, at least during the initial 4–6 weeks after surgery [4]. There is a concomitant increase in the levels of inflammatory markers such as cytokines, which are essential for orthodontic tooth movement, following MOP [7]. Considering the similarities in origin, morphology, and activation and the functional resemblance between osteoclasts and odontoclasts, the accelerated presence or activation of osteoclasts following surgical trauma such as, MOPs, may lead to an excess odontoclastic activity and root resorption [21]. These cytokines, namely PGE2, IL-1α, Il-1β, IL-6, Il-17 and TNF-α, have also been associated with the root resorption process [8]. So, its pertinent to know whether there is an increased risk of OIIRR following surgical trauma like MOPs.

Jaiswal et al. observed a peak increase in IL-1β levels only up to 1 day after the first application of MOPs, after which IL-1β levels decreased to normal levels by day 30 [22]. In this trial, OIIRR was not measured. In a corticotomy study based on an animal model, Lin et al. observed in the high-force group an increase in IL-6, IL-17 levels leading to root resorption and alveolar bone destruction, while the corticotomy group showed accelerated tooth movement without OIIRR and bone loss. The authors attributed this to increased expression of T regulatory cells involved in remodelling, reduced bone density and resistance to tooth movement [23]. In another rat animal study, Erdenebat et al. reported that MOPs did not significantly add to root resorption by increase in the number of MOPs, rather may promote cementogenesis activity in resorption areas [24]. Thus, on the basis of the evidence currently available, it would appear that even when levels of the interleukins that cause OIIRR increase after MOPs, their levels are not sufficient to cause severe OIIRR and the interaction with cells involved in remodelling activities would minimise the extent of damage.

CBCT is an accurate and reliable OIIRR quantification method. It is more accurate for detecting root resorption than periapical radiography [25]. The CBCT imaging with a limited FOV (canine to canine region) and small voxel size (200 μm) used in our study facilitated better observer performance, OIIRR and alveolar bone-change detections, and lower radiation doses [26]. Additionally, detection of OIIRR by CBCT at each clinical appointment would be unethical on grounds of radiation doses.

In the present CBCT study, readings were taken at an interval of approximately 6 months, i.e., start and end of retraction period. OIIRR detected was small, with a mean reduction of 0.7 mm. A comparison between the MOP and control groups revealed no significant difference (*table II*). Our findings are similar to the CBCT-based studies by Elkalza et al. [13] who reported no major difference in mean OIIRR between the MOP (0.45 mm) and control groups (0.69 mm). Additionally, Alqadasi et al. reported similar results between their MOP and control groups (P = 0.934 and 0.842, respectively) [13]. Shahrin et al. noted no exacerbation of OIIRR on IOPAs in MOPs group placed inter-radicularly during maxillary anterior alignment phase. This may be due to low forces required for alignment compared to en-masse retraction [14]. On the other hand, Al-Attar et al. observed higher OIIRR on IOPA's with MOPS during mandibular anterior alignment phase [27]. The different result may be due to short observation period of 3 months compared to the 6-month period of Shahrin et al. [14], where remodelling activities may have lowered the OIIRR. Moreover, use of periapical radiographs and the trial being underpowered as mentioned by the authors, may have resulted in incorrect detection of OIIRR. Chan et al., in a micro-CT-based trial, reported that MOPs significantly increased the total volumetric root loss [28]. They showed an increased OIIRR of 0.17 mm^3, measured on extracted first maxillary premolars after a 28-day application of buccal tipping forces (150 g). The results of Chan et al. regarding the increase in OIIRR can be attributed to their methodology, whose routine clinical relevance is questionable; furthermore, the volumetric root loss of 0.17 mm^3 is also of no clinical relevance. However, their findings revealed no significant difference in overall root resorption in the apical region. Even in a piezocision-corticotomy trial on en-masse retraction, which involved higher surgical insult as compared to MOPs, the amount of OIIRR on CBCT examination was even lower than control group [29]. This could be due to increased surgical insult decreasing the bone volume and density, as observed by Chang et al. [30].

Studies have shown that during the PAR period following MOP, there is an increase in osteoclastic activity, which reduces the density of cortical bone, thus decreasing the mechanical strength for tooth movement [20,31]. Similar to previous studies, these RAP attributes may have led to a lower OIIRR in the present study [3,7,9–14].

Liou and Chang, in a study of OIIRR in mini-screw supported en-mass retraction, noted that prolonged retraction times may predispose teeth to higher OIIRR [32]. The class I bi-dentoalveolar protrusion cases in our study with similar baseline characteristics required less than 6 months of retraction time in both groups (MOP and control). Furthermore, a relatively shorter treatment duration might have reduced the risk of exacerbation of OIIRR.

Linear root-length measurements of anterior teeth may be affected in cases involving large apical curvatures or varying apical geometries [19]. To arrive at better results, we further investigated by objective measurement of the Levander and Malmgren index. Our results (*table III*) corroborate those of Aboalnaga et al. who showed no resorption in 67.6% of the teeth, slight resorption in 8.8%, minor resorption in 17.6% and severe resorption in 5.9% of their MOP group. In contrast, their control group showed no resorption in 73.5%, mild resorption in 5.9%, moderate resorption in 17.6% and severe resorption in 2.9% [11]. Amongst all the anterior teeth, the lateral incisors showed highest OIIRR followed by central incisors and canines in both groups (*table IV*). These findings are similar to those reported in recent CBCT-based en-masse retraction studies

[11,32]. These results could probably be due to the retraction force being directed closer to the lateral incisors, which would be slightly heavier than that on the central incisors. Another reason may be that the lateral incisors are inherently more prone to OIIRR due to their root shape and size [33]. Our findings (*table V*) highlight that alveolar bone thickness decreased significantly on lingual side and increased slightly on labial side. Similar observations have been noted by Ahn et al. [16]. This may be a result of controlled tipping and bodily anterior teeth movement through the alveolar bone with higher resorption on lingual side and mild bone apposition on tension labial side. With miniscrew anchorage, higher distal tooth movement is effectively achievable resulting in significant alveolar bone changes. The findings at T2 stage (*table VI*) reveal higher vertical bone height loss on lingual than on labial side. This might result from direction of tooth movement relative to the labiolingual axes of anterior teeth. Our findings corroborate the clinical trial of Hung et al. [34].

Harms

Mild pain and discomfort for 1 or 2 days following the MOPs procedure were common and were addressed with proper consultations and analgesics. Three miniscrews loosening were noted which were re-inserted at later appointments after adequate tissue healing. No periodontal tissue damage or root perforations were noted.

Limitations and generalizability

The MOPs effect on OIIRR and alveolar bone in other age groups, malocclusions and tooth movements such as intrusion and molar protraction need to be evaluated.

Conclusion

Within the settings of the current RCT, the MOPs procedure during the en-masse retraction phase did not increase the extent of OIIRR and alveolar bone changes when compared to control group.

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Contribution: Harshal Chandorikar: Conceptualization, Methodology; Formal analysis; Investigation; Data curation; Resources; Validation; Visualization; Roles/Writing - original draft. Wasundhara Bhad: Conceptualization, Project administration, Supervision, Writing - review & editing.

Disclosure of interest: The authors declare that they have no competing interest.

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