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Original Article

Dentistry Section

Comparison of Rate of Tooth Movement, Root Resorption and Pulp Vitality during En masse Anterior Retraction with Micro-osteoperforation and Low Level Laser Therapy: A Randomised Clinical Trial

ALLEN JOSEPH[1], GS PRASHANTHA[2], SHARANYA SABRISH[3], ROSHAN SAGARKAR[4], SILJU MATHEW[5]

ABSTRACT

Introduction: Micro-osteoperforation (MOP) and Low Level Laser Therapy (LLLT) are rapidly gaining popularity in clinical practice due to their proven success in accelerating tooth movement and acceptable patient compliance. However, literature shows an inconsistent and variable evidence of their iatrogenic effects on the root and pulp due to biological variations of the samples chosen by the previous studies.

Aim: To evaluate and compare the rate of tooth movement, changes in amount of external root resorption and pulp vitality in teeth during en masse anterior retraction associated with MOP and LLLT using split mouth technique.

Materials and Methods: This was a double blinded, single centre split mouth randomised clinical trial conducted at Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India from March 2019 to October 2019. Total of 11 patients with bimaxillary dentoalveolar protrusion which required all four first premolar extractions were included in the study. Nickel Titanium (NiTi) closed coil springs were used for en masse retraction in upper and lower arches with force of 150 g per side. Root resorption of all anterior teeth was evaluated using Cone Beam Computed Tomography systems (CBCT) and pulp vitality was checked using cold test after four months. The data was entered in Microsoft excel and the Statistical Package for Social Sciences software (SPSS) version 18.5 (SPSS Inc, Chicago) software was used for data entry and statistical analysis. A p-value of less than 0.05 was considered as statistically significant.

Results: Total of 11 patients in which 9 were females and 2 males aged between 18-30 years with mean age 19±4.21 year, participated in this trial. LLLT (4 mm) and MOP (4.05 mm) showed similar performance in acceleration of tooth compared to each other. The overall root resorption was more in the experimental groups (LLLT- 2.60 mm, MOP- 2.84 mm) compared to the allotted controls. However, the canine showed less root resorption in both the experimental groups compared to the control. The overall root resorption was similar in both the experimental groups. The canine in LLLT group (0.30 mm) showed less root resorption compared to canine in MOP group (0.59 mm). There was no change in the pulp vitality status in both the experimental groups and the control groups.

Conclusion: The overall root resorption in a given quadrant increases with increased rate of tooth movement. The tooth which was subjected to acceleratory orthodontic technique showed less root resorption compared to control. The tooth subjected to LLLT showed less root resorption as compared to the tooth subjected to MOP.

Keywords: Dentistry, External root resorption, Orthodontics, Orthodontic space closure

INTRODUCTION

One of the greatest concerns among patients undergoing orthodontic treatment is the increased treatment time. Typical orthodontic treatment time ranges between 18-24 and 19-28 months for non extraction and extraction therapies, respectively [1]. Accelerating the rate of tooth movement is beneficial since the long treatment duration has been associated with an increased risk of gingival inflammation, decalcification, dental caries, root resorption and also reduced patient co-operation [2]. Micro-osteoperforation (MOP) is a commonly used acceleratory orthodontic technique which needs minimal surgical intervention and works on the principle of Regional Acceleratory Phenomenon (RAP) [3]. Non invasive methods of acceleratory orthodontics achieve similar results as surgical methods but are better accepted by patients [4]. LLLT is one such method and its effects are limited only to the target tissue. This method accelerates the orthodontic tooth movement by increasing the basal metabolic rate of cells responsible for bone remodelling which in turn results rapid bone deposition and resorption [4].

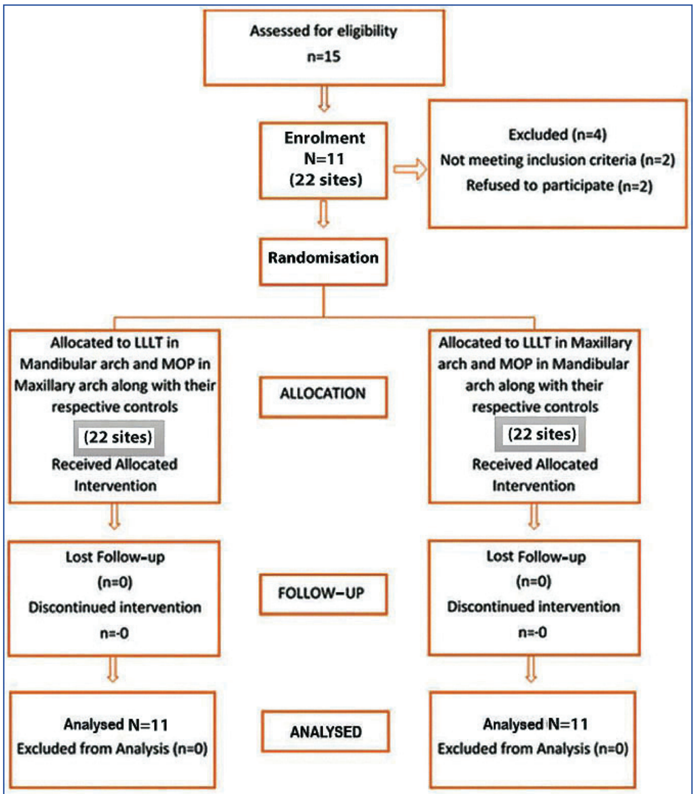
Studies have shown that the rate of space closure and risk of root resorption have a genetic predilection [5]. Inter-individual variability has been studied and it was proposed that individuals who are extremely susceptible to External Root Resorption (ERR) may show root resorption even without an apparent cause [6]. An ethnic dichotomy has been reported between Asian and Caucasian patients where the former exhibited significantly less ERR [7]. Familial clustering of ERR has also been reported however, the pattern of inheritance could not be identified [8]. There have been very limited studies conducted which take into account the genetic and biological variation between the experimental and control group. Michelogiannakis D et al., 2019 in their systematic review on iatrogenic effects of LLLT when used for accelerating tooth movement, concluded that results are diversified and debatable [9]. These studies in literature have compared the acceleratory effect on tooth movement and the associated iatrogenic effects of LLLT and MOP separately in comparison to conventional space closure mechanics [3,4,9].

There was no study which compared the rate of tooth movement and severity of the iatrogenic effect i.e external root resorption with LLLT and MOP in the same individual. This was conducted using split mouth design and the rationale of using this method was to eliminate the biologic variation which determines different individual's susceptibility to root resorption, and this has not attempted in the literature to the best of our knowledge. Also though it was planned to assess en masse retraction, the intervention was only performed in canine area since our aim was only to compare the two interventions in the least invasive way possible. Thus, the objectives of this study are to compare the rate of tooth movement during en masse anterior retraction with LLLT and MOP and to evaluate and compare the amount of external root resorption and pulp vitality status in LLLT and MOP using split mouth technique.

MATERIALS AND METHODS

This was an interventional, single centre, double blinded study and the study design was a randomised clinical trial with a split mouth technique, conducted from March 2019 to October 2019 at Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India, with the Institutional Ethical Committee approval (E-2019/PG/001). Both the experimental groups and their respective control groups were established in the same patient, thereby eliminating biological variation. The study design is shown in [Table/Fig-1].

Sample size calculation: To obtain a power of 90% and to detect a difference in mean value using an 'F' test with 0.05 significance level ($p \leq 0.05$), a sample number of minimum 11 patients were estimated using Process Automation Software System (PASS) with Student's t-test.



[Table/Fig-1]: CONSORT flow chart showing patient flow during the trial.

Inclusion criteria: Patients with bimaxillary dentoalveolar protrusion in which four first premolar extractions as a part of orthodontic treatment is indicated. Patients with good level of oral hygiene with no periodontal disease or a radiographic evidence of bone loss and who were agreed to sign the informed consent to participate in the study were included. Male and female patients in the age range of 18-30 years were considered for the study.

Exclusion criteria: Patients with systemic diseases/craniofacial syndromes, which would influence the rate tooth movement, root resorption and pulp vitality, history of previous extraction of any permanent teeth as this will lead to bone resorption at the site in the long run, thereby effecting tooth movement, patients who were alcoholics and/or smokers, and patients receiving any medical treatment that could interfere with bone metabolism, such as NSAIDS or doxycycline were excluded. Alcohol-induced oxidative stress results in increased osteoclastogenesis and nicotine can increase bone resorption mediated through Cyclooxygenase (COX) enzyme. Both will effectively increase the rate of orthodontic tooth movement in a dose-dependent manner [10].

Diagnosis and treatment planning were based on clinical examination and other standard records which included photographs, study models, panoramic radiographs and cephalograms. Based on the above criteria, 11 patients, aged 18-30 years (mean 19±4.21 years) were selected. [Table/Fig-1] demonstrates the study design. Signed informed consent was attained from the patients.

Study Procedure

The routine orthodontic diagnostic records were collected and analysed. The first molars were banded and anchorage was reinforced using transpalatal/lingual arch. All first premolars were extracted at the beginning of the treatment to allow relief of crowding in some patients. Preadjusted edgewise appliance with McLaughlin, Bennet and Trevisi (MBT) prescription with 0.022-inch slot was bonded. En masse retraction was initiated after 21 days of engaging working 0.019×0.025-inch stainless steel archwires.

The intervention (MOP or LLLT) was carried out using a split-mouth design, which was assigned by the recruiter to prevent inter-individual biologic variation as shown in the [Table/Fig-2]. The recruiter explained to the patients in detail about the procedure and the purpose of the study. The recruiter then assigned the patient's quadrants into control or experimental sides randomly by picking sealed envelopes which were assigned based on the allotment concealment sequence (from 1-11) for either the LLLT/MOP or controls as explained in [Table/Fig-2]. This way each subject would have two experimental and two control quadrants. The evaluators were blinded about experimental and control sides.

Patients number	1st Quadrant	2nd Quadrant	3rd Quadrant	4th Quadrant
Subject 1	LLLT	Control	MOP	Control
Subject 2	Control	MOP	Control	LLLT
Subject 3	MOP	Control	LLLT	Control
Subject 7	LLLT	Control	Control	MOP
Subject 4	MOP	Control	LLLT	Control
Subject 5	Control	LLLT	MOP	Control
Subject 6	LLLT	Control	MOP	Control
Subject 8	Control	LLLT	Control	MOP
Subject 9	Control	MOP	LLLT	Control
Subject 10	Control	LLLT	Control	MOP
Subject 11	MOP	Control	Control	LLLT
TOTAL	LLLT= 3	LLLT= 3	LLLT= 3	LLLT= 2
	MOP=3	MOP=2	MOP=3	MOP=3
	Control=5	Control=6	Control=5	Control=6

[Table/Fig-2]: Randomisation sequence.

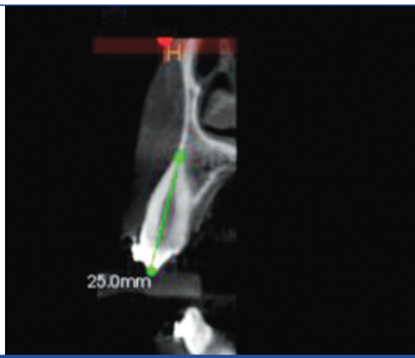
Following procedure were used for Laser side: A diode laser emitting infrared radiation at 975 nm and functioning in a continuous wave mode was used [Table/Fig-3]. The canine teeth were anaesthetised with local infiltration on both buccal and palatal side using lignocaine and 2% adrenaline injection. Protective glasses were worn by the operator, patient and the person controlling the stop watch. Administration of 4J/cm^2 with 0.16 J of energy per point was the energy density used. Extension of the laser spot was between 3-4 mm. The laser tip was held perpendicular and in contact with the mucosa during all the irradiations [Table/Fig-3]. A total of six irradiations were carried out each time, three from the buccal side and three from the palatal side. This was to cover the periodontal fibre network and the alveolar process surrounding the canine teeth. This was carried out in a sweeping fashion. The irradiation time for the cervical and middle third of the tooth was 10 seconds, and for the apical third of the tooth it was 8 seconds. Therefore, a total of 56 seconds of irradiation was done at each appointment. This was assessed using a stop clock. The laser irradiation was applied on days 0, 7 and 14 in the first month and thereafter, every 15 days for next three months on the experimental side. No intervention was carried out on the control side.

Following procedure were used for MOP side: Mini-implants were used to perform micro-osteoperforation as seen in [Table/Fig-4]. The region was anaesthetised locally with lignocaine and adrenaline combination. A 2 mm by 6 mm mini-implant was used. A rubber stop was used to mark the desired depth before insertion. Three small perforations were performed in the extraction space of first premolar at equal distances from the canine and the second premolar. Each perforation was 1.5 mm wide and 2-3 mm deep [3]. To keep the invasiveness minimal no MOP was done mesial to canine. Also, no intervention was carried out on the control side. NiTi coil springs were engaged for retraction with a force of 150 g per side on both the control and experimental sides. These coil springs were changed after two months.

[Table/Fig-3]: Diode laser with continuous wave mode was used in sweeping manner on the laser side of the experiment.
[Table/Fig-4]: Mini-implants were used to perform the micro-osteoperforation with a rubber stop for depth control. (Images from left to right)

Parameters Assessed

1. **Root resorption-** Root resorption was measured using arch temporal bone cross section of CBCT (CS 3D Imaging v3.5.7 Carestream Health Inc.). CBCT images were obtained with the head in "Natural Head" position. The tooth length was measured using mid-sagittal section from the mid-incisal point of the crown to the root apex along the long axis as shown in [Table/Fig-5]. The reference line was oriented as per the angulation of the tooth and poly line was used in case of curved roots. Apical root resorption was measured as the difference between the length of the root at T1 and the length of the root at T2 in millimeters. Although very minimal craters were observed along the root surface area, they were difficult to measure due to beam hardening and cupping artefacts. In order to ensure reproducibility, 8 randomly selected CBCT images were remeasured after 2 weeks to determine the intra operator error and confirm the reproducibility of measurements at 95% confidence intervals.
2. **Pulp sensitivity-** Conventional pulp sensitivity test using Endo-frost (Coltene) to assess the pulp vitality was performed in this study. Cotton was used to apply Endo-Frost on the tooth of interest. The sensitivity exhibited by the tooth determined the vitality status of the pulp. It was done in the beginning of the study to establish the baseline and at the end of the study to evaluate the change in the vitality status of the pulp. Conventional pulp sensitivity test provides information only about the presence or absence of nerve receptors in the pulp and not about the pulpal blood supply. Although newer methods involving the use of laser Doppler flowmetry and pulse oximetry are far more accurate in assessing pulpal circulation even in presence of brackets, we could not make use of these methods because of non availability.



[Table/Fig-5]: Assessment of root resorption using CBCT.

3. **Tooth movement-** Dontrix gauge was used to measure the force applied and digital Vernier calliper was used to measure the distance of tooth movement. The measurements were made from the canine cusp tip to the mesio- buccal cusp tip of first permanent molar. The measurements for tooth movement were tabulated on day 0 and at the end of 4 months. The measurements were carried out after the alignment phase on stiff full size arch wires hence we did not anticipate any significant rotations to affect the measurements.

None of the subjects demonstrated any long-term complications such as pain, infection, etc. and the follow-up was done for a period of 6 months after the interventions.

STATISTICAL ANALYSIS

The data was entered in Excel format and the Statistical Package for Social Sciences software (SPSS) version 18.5 was used. The results of the experiment were averaged (mean±SD) for continuous data and number and percentage was used for dichotomous data. The Student's t-test was used to determine whether there was a statistical difference between groups in the parameters measured. Student's t-test is as follows:

$$t=\frac{\bar{x}_1-\bar{x}_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \sim\sim\sim t_{n_1+n_2-2} \quad \text{Where } s^2=\frac{(n_1-1)s_1{}^2+(n_2-1)s_2{}^2}{(n_1+n_2-2)}$$

In the above test a p-value of less than 0.05 was considered as statistically significant.

RESULTS

The distribution of the subjects with respect to age and sex distribution is shown in [Table/Fig-6]. Among 11, 9 (81.81%) were females and the rest were males 2 (18.18%). The comparison of the rate of space closure for LLLT and MOP and their controls is shown in [Table/Fig-7]. There was a statistically significant difference seen with respect to LLLT group and its control and the p-value was 0.047. In the laser group, the tooth movement was 1.27 times faster. Comparison of total root resorption between LLLT and MOP group shows no significant differences [Table/Fig-8]. Comparison of total root resorption between LLLT and its control is shown in [Table/Fig-9]. Comparison of total root resorption between MOP and its control group shows no significant differences [Table/Fig-10]. From the tables it is clear that with increase in rate of tooth movement the amount of root resorption also increases, however this finding was not statistically significant. The MOP group showed 0.24 mm more root resorption in comparison with the laser group, but the findings were not statistically significant. The lateral incisor showed maximum root resorption compared to other teeth in all the groups (more resorption in the MOP group, followed by LLLT group and then the control group).

Age (in years)	Male n (%)	Female n (%)
19	1 (9.09)	2 (18.18)
20	0	2 (18.18)
21	1 (9.09)	1 (9.09)
23	0	3 (9.09)
30	0	1 (27.27)
Total	2 (18.18)	9 (81.81)

[Table/Fig-6]: Age and Gender distribution of sample size.

Comparison	N	Mean	SD	Min.	Max.	t-value	p-value
LLLT	11	4.00	0.819	2.4	5.0	0.007	0.933
MOP	11	4.05	1.428	2.8	7.3		
LLLT	11	4.00	0.819	2.4	5.0	4.756	0.047*
Control	11	3.13	0.785	2.2	4.0		
MOP	11	4.05	1.428	2.8	7.3	3.415	0.086
Control	11	2.81	1.244	1.1	5.3		

[Table/Fig-7]: Comparison of space closure in 4 months between LLLT and MOP, LLLT and its control and between MOP and its control.
LLLT: Low level laser therapy; MOP: Micro-osteoperforation)
p-value- *Probability value denoting significance. The student 't' test was used for statistical analysis. "p" value of less than 0.05 was considered as statistically significant

Type of teeth	Comparison	N	Mean	SD	Min.	Max.	t-value	p-value
Central incisor	LLLT	11	0.80	0.628	0.00	2.20	0.265	0.615
	MOP	11	0.66	0.421	0.00	1.10		
Lateral incisor	LLLT	11	0.93	1.044	0.00	3.10	0.042	0.841
	MOP	11	1.02	0.907	0.00	2.50		
Canine	LLLT	11	0.30	0.251	0.00	0.50	2.807	0.116
	MOP	11	0.59	0.416	0.00	1.10		
Second premolar	LLLT	11	0.57	0.690	0.00	1.70	0.001	0.971
	MOP	11	0.56	0.644	0.00	1.30		
Total	LLLT	11	2.60	1.619	0.00	4.50	0.106	0.749
	MOP	11	2.84	1.274	1.10	4.20		

[Table/Fig-8]: Comparison of total root resorption between LLLT and MOP group.
LLLT: Low level laser therapy; MOP: Micro-osteoperforation

Type of teeth	Comparison	N	Mean	SD	Min.	Max.	't' value	p-value
Central incisor	LLLT	11	0.80	0.628	0.00	2.20	0.895	0.360
	Control	11	0.49	0.692	0.00	2.00		
Lateral incisor	LLLT	11	0.93	1.044	0.00	3.10	2.015	0.178
	Control	11	0.34	0.529	0.00	1.40		
Canine	LLLT	11	0.30	0.251	0.00	0.50	1.950	0.184
	Control	11	0.90	1.189	0.00	2.40		
Premolar	LLLT	11	0.57	0.690	0.00	1.70	3.057	0.102
	Control	11	0.13	0.231	0.00	0.50		
Total	LLLT	11	2.60	1.619	0.00	4.50	0.963	0.343
	Control	11	1.85	1.433	0.00	4.70		

[Table/Fig-9]: Comparison of total root resorption between LLLT and its control.
LLLT: Low level laser therapy

Also, there was no change in the pulp vitality status at the end of the study period.

DISCUSSION

The efficiency of LLLT and MOP in increasing the rate of tooth movement is now widely accepted, but their iatrogenic effects on the periodontium were not well-documented which could be attributed to the face that such procedures are done mostly on patients who can have either a high or low risk of root resorption [11]. In this study, a spilt-mouth randomised clinical trial was designed to evaluate the extent and severity of root resorption and effect on the pulp vitality.

Type of teeth	Comparison	N	Mean	SD	Min.	Max.	't' value	p-value
Central incisor	MOP	11	0.66	0.421	0.00	1.10	0.363	0.556
	Control	11	0.53	0.489	0.00	1.30		
Later incisor	MOP	11	1.02	0.907	0.00	2.50	0.397	0.539
	Control	11	0.76	0.752	0.00	2.30		
Canine	MOP	11	0.59	0.416	0.00	1.10	0.002	0.963
	Control	11	0.57	0.611	0.00	1.40		
Premolar	MOP	11	0.56	0.644	0.00	1.30	0.016	0.902
	Control	11	0.61	0.923	0.00	2.80		
Total	MOP	11	2.84	1.274	1.10	4.20	0.229	0.639
	Control	11	2.47	1.721	0.10	5.20		

[Table/Fig-10]: Comparison of total root resorption between MOP and its control.
MOP: Micro-osteoperforation

Laser and MOP were done randomly in both upper and lower arches to remove any bias. Equal samples had laser in upper and lower arches and similar for MOP. The patient selection was restricted to a sample with the age range of 18-30 years since it has been found that the younger patients (<15 years) demonstrated faster tooth movement than the older ones [12].

The levels of sex hormones in women are another confounding variable that can affect the rate of bone and cementum remodelling and tooth movement throughout the estrous cycle. This could also have potential implications on the extent of root resorption [13,14]. Unfortunately, this variable could not be addressed because of the limited number of subjects willing to participate in this study.

The use of periapical radiographs to assess the root resorption as done in the earlier studies would yield less than accurate results [15]. Therefore, recent studies used three-dimensional methods like scanning electron microscope and histological root samples [16]. However, these assessments were done in-vitro by extracting the tooth of interest. Moreover, these teeth were extracted within 14-28 days of the commencement of the study, which is too early to induce any measurable change in the root where conventional orthodontics was performed [17]. Hence, in this study full mouth CBCT was used to assess the root resorption in all the teeth of the experimental and control groups. Also, in the above mentioned studies, the teeth of interest were buccally tipped and then extracted. In contrast in the present study, the first premolars were extracted and the anteriors were retracted bodily into the extraction space which is representative of actual clinical scenarios.

A majority of the studies done so far have employed a laser with a lower wavelength spectrum in the 780-980 nm range, among which 810 nm was most commonly used [15,17,18]. Yassaei S et al., in 2016 were the first to explore the effect of 980 nm laser on orthodontic tooth movement [19]. Using the same parameter, a previous unpublished study carried out by the authors, showed that use of LLLT with 975 nm laser caused 52% faster tooth movement compared to conventional orthodontics. Hence, in this study also 975 nm wave length was used.

The mode of delivery of the laser device is also a factor in the effect of the laser. While Bradley et al., in 2000 and Takeda et al., in 1988 have supported the use of continuous mode, Kim et al., in 2009 and Ng D et al., in 2017 have preferred the pulsed mode. Ng D et al., claimed that the root resorption was 5% less with the pulsed mode and Yoshida T et al., claimed that laser units functioning in continuous mode show more biostimulatory response [17,20]. Therefore, in this study the irradiations were performed with a continuous mode. Ozawa Y et al., and Saito S and Shimizu N, recommended more frequent application of laser in the beginning phase as cells are more readily influenced by LLLT in the initial stages of biological response [21,22]. Also, Khadra M et al., and Ng D et al., suggested that multiple doses are better than single dose [17,23]. Hence, the regime of laser irradiation in this study was on days 0, 7 and 14 in the first month and thereafter, every 15 days for next 3 months.

In this study, it was found that in the laser group, the tooth movement was 1.27 times faster and there was 1.4 times more root resorption when compared with the control group. When individual teeth were evaluated for root resorption in LLLT group, the 2nd premolar showed maximum root resorption (4.3 times) when compared to the control group counterpart, followed by lateral incisor (2.7 times) and central incisors (1.6 times). The canine however, showed 3 times less root resorption compared to the control group counterpart which was similar to the study results by Ng D et al., [17]. This variation could be due to the selective exposure of canine in the laser group. Also, the energy density used in this study falls well within 0.5-4 J/cm^2 which is the most efficient in triggering tissue biological response [23-25]. Whether this lesser level of root resorption found in the canine is the result of the laser's preventive action against resorption or due to its reparative potential is debatable [17]. Teeth which were further from the site of laser exposure showed more root resorption.

The MOP group showed 1.44 times increase in the rate of tooth movement which is in similar to the findings of Alikhani M et al., [26]. It also demonstrated 1.14 times more root resorption as compared to the control side, but the measurements showed no statistical significance. Majority of the literature including meta-analyses showed either none or clinically insignificant root resorption with MOP [27-31]. Only Chan E et al., concluded that MOP leads to increased root resorption when used to accelerate tooth movement [32]. The maximum root resorption was exhibited by the lateral incisor (1.2 times) followed by central incisor and premolar. Canine showed least root resorption compared to control group however, the values were not statistically significant.

When comparing the overall amount of root resorption, the MOP group showed 0.24 mm more root resorption in comparison with the laser group, but the findings were not statistically significant. The lateral incisor showed maximum root resorption compared to other teeth in all the groups (more resorption MOP group> LLLT group>control group). According to Jacobson, Kjaer, Harris and Krishnan V the reason for the increased risk of root resorption can be attributed to the morphology of the lateral incisor roots which tend to be slenderer compared to other teeth and exhibit pipette / spindle /trigonal shaped roots which leads to stress accumulation at the root apex [6-8,33,34,35]. Another reason for lateral incisor's susceptibility to root resorption is the increased distance travelled during extraction space closure. Both the central and lateral incisor move a large distance during orthodontic treatment [6,32]. In this study, the second highest root resorption was shown by central incisor and premolar. The premolars susceptibility to root resorption can be attributed to its anatomical features like short root, less root surface area and apical movement [8,33,34]. The least amount of resorption was shown by the canine in all the groups; showing less root resorption in the laser group compared to MOP but the values were not statistically significant.

The leads to angiogenesis which in turn facilitates rapid expulsion of resorption causing agents [15,17]. LLLT also increases the rate of remodelling in which the anabolic activity is more than catabolic activity. These factors contribute in reducing root resorption. MOP relies on decortications of bone to reduce the resistance and facilitate faster root movement. Another reason is that reduced hyalinisation and undermining resorption could lead to lesser cementum loss and reduced root resorption. Kurol J et al., and Taithongchai R et al., concluded that approximately 90% of subjects undergoing orthodontic treatment have some extent of root resorption and among them 32% showed moderate resorption (>3 mm) and 8% severe resorption (>5 mm) [36,37]. There was no change in the pulp vitality status in both the experimental groups and the control group in the four months of study.

Limitation(s)

Although newer methods involving the use of laser doppler flowmetry and pulse oximetry are far more accurate in assessing pulpal circulation even in presence of brackets, authors did not make use of these methods because of non availability. The assessment of the volume and shape changes of the pulp chamber through CBCT is also an alternate method to assess vitality [38]. The sample size was restricted since an increased sample size would raise ethical concerns due to the use of CBCT to measure root resorption and the associated radiation exposure of the patients.

CONCLUSION(S)

The total root resorption of all the teeth increases with the increase in rate of tooth movement. The ability of LLLT and MOP to reduce root resorption is limited to the exposed tooth (Canine). The LLLT group showed less root resorption in comparison to the MOP group. The pulp vitality status is not affected by the increased rate of tooth movement.

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PARTICULARS OF CONTRIBUTORS:

1. Orthodontist, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.
2. Professor and Head, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.
3. Reader, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.
4. Reader, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.
5. Professor, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Sharanya Sabrish,
Reader, Department of Orthodontics, Faculty of Dental Sciences, MS Ramaiah University of Applied Sciences, Bangalore, Karnataka, India.
E-mail: drsharanyaortho@gmail.com

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