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Three-Dimensional evaluation of low level laser therapy on orthodontically induced root resorption: a prospective randomized split mouth trial

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Abstract

Orthodontically induced inflammatory root resorption is the most unpredictable side effects of orthodontic treatment.

The objective: of this prospective randomized split mouth trial was to investigate the effect of low level laser therapy on orthodontically induced root resorption using cone beam computed tomography.

Methods: The sample consisted of 10 patients (18-24 years old) with the therapeutic need to extract the maxillary first premolars and subsequent canine retraction. All patients maxillary quadrants were randomly allocated to either the experimental side (receive a low level diode laser with a wavelength of 910 nm) or the control side (receive a placebo laser). The low level laser was applied days 0, 1, 2, and 3 of canine retraction and then weekly during the 3 month of the study period. Bilaterally, canine retraction was performed with closed-coil nickel-titanium springs that applied 150g of force on each side. The root length of the maxillary canine and maxillary first molar on both sides were compared and length reduction was measured from the pre- and post-treatment cone beam computed tomography scans to quantify OIRR.

Results: There was a statistically significant decrease in mean root length post-treatment for both experimental and control sides. However, the mean amounts of root resorption at the experimental and control sides was not statistically significant.

Conclusions: The incidence of orthodontically induced inflammatory root resorption on the Low level laser therapy side was lower than in the control group, yet, statistically insignificant.

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Introduction

Orthodontically induced inflammatory root resorption (OIIRR) is the most unpredictable side effects of orthodontic treatment1. OIRR is due to the biologic changes in the root cementum during orthodontic treatment coming from the orthodontic forces acting on the apical root third1. Maintaing root length is an important condition for successful orthodontic movement and treatment stability2.

Treatment prolongation has been connected to increased associated risks as well as severity of OIRR3 ; hence, different modalities was introduced in an attempt to reduce treatment duration. Surgical intervention to achieve faster orthodontic tooth movement (OTM) were utilized45, however, there are many side effects for such approach including discomfort, post operative pain, swelling and loss of periodontal support6.

The search for a non invasive technique to accelerate orthodontic tooth movement was directed to the use of low level laser therapy (LLLT). LLLT is one of the non-invasive techniques used to accelerate orthodontic tooth movement. Also, the effect of LLLT is confined to the target tissue area7. Laser energy absorption by the targeted tissue leads to increase in cellular metabolism, and anti-inflammatory changes8. Low level laser therapy initiates tissue regeneration. This occur by the increase of cellular differentiation and cellular proliferation. It also speeds up the elimination of tissue debris as well as the induction of angiogenesis9. Therefore, Low level laser therapy may be of a possible benefit for treating inflammatory activity such as inflammatory root resorption.

The impact of LLLT on orthodontically induced root resorption was previously reported with mixed outcomes10. However, a fundamental limitation of these reports was the integration of two-dimensional (2D) periapical radiographs to asses root resorption11. Periapical radiographic technique have been always the clinical standard for measuring tooth length and estimating root resorption12. These periapical radiographs are prone to orientation error, procedural, and projection errors. A more precise and accurate technique to asses root resorption is to utilize three-dimensional (3D) cone beam computed tomography (CBCT)11.

Therefore, the aim of this prospective randomized split mouth trial was to investigate the effect of low level laser therapy on orthodontically induced root resorption using cone beam computed tomography

Methods

Experimental Design

This was a prospective randomized split mouth controlled trial. Each member had one quadrant randomly assigned to receive Low level laser therapy (experimental side) and the contralateral quadrant was assigned to the placebo-laser (control side). Randomization was done using computer software.

Sample

The sample in this study consisted of 10 participants selected from the out patient clinic of the Orthodontics Department, Faculty of Dentistry, Ain Shams University. The sample size was determined by G* power program.

The inclusion criteria were: All subjects had complete permanent dentition. Their age range was between 18 to 24 years. They had Angle Class II divsion 1 malocclusion with excessive overjet (>5mm). This entailed bilateral therapeutic extraction of the maxillary right and left first premolar and retraction of the maxillary right and left canine. The exclusion criteria were: presence of dental anomalies, systemic diseases, periodontal diseases, previous orthodontic treatment, history of dental trauma, endodontic treatment, and radiographic signs of external apical root resorption (EARR).

All subjects signed an informed consent after receiving detailed information about the planned orthodontic treatment. The ethics committee of the Faculty of Dentistry Ain Shams University approved experimental protocol of this study. No changes to the methods occurred after the trial commencement.

Records

Subjects that satisfied the previous criteria were required to complete a full set of orthodontic diagnostic records. All records were taken for each subject at two intervals; pretreatment at T1 and at T2 after 3 month of maxillary canine retraction.

These records included; a diagnostic sheet, an orthodontic study cast, extra & intra oral photographs, and radiographic examination using cone beam computed tomography.

All patients were subjected to a pre-operative CBCT examination at T1, image acquisition was performed using i-CAT next generation (Imaging Sciences International, Hatfield, PA, USA) at the Oral Radiology Department, Faculty of dentistry, Ain shams university. The field of view (FOV) used was 4cm covering the maxilla and mandible (120kV, 5mA, 7second), voxel size (0.125mm). Images were saved as DICOM (digital imaging and communication in medicine) files. DICOM files were then exported to a third-party software; RealGUIDETM 5.0 (3DIEMME, Cantù (CO), Italy) for generation of reconstructed panoramic images and lateral (ray sum) images. These images were used for analysis of skeletal and dental inclusion criteria. Also, post-operative CBCT was performed for each subject after the treatment completed at T2 using the same exposure parameters. All images were viewed in a dimmed-light room on a 17inch laptop LED screen (Dell Inc, Berkshire, UK).

Orthodontic set-up

The orthodontic treatment was done with a full fixed edgewise appliance which included molar bands and brackets with Roth prescription, 0.022 x 0.030inch slot (Ormco Corporation, Orange, California, USA). A transpalatal arch was placed for anchorage reinforcement.

After alignment and leveling, canine retraction on 0.016 x 0.022inch stainless steel (St.St.) archwire was intiated. The first molars and second premolars were tied together with St.St. 0.010inch ligatures. Retraction of the canines was done via nickel titanium closed coil spring (Sentalloy, Tomy, Tokyo, Japan) attached to the molar hook at one end and to the canine hook on the other end. A force level of 150g was used on both quadrants. The predetermined length of the coil spring was selected according to the distance between the canine and the molar anchorage.

Laser application

The laser medium used was Indium Gallium Arsenide (InGaAs), which is considered a semi-conductor diode laser. The Laser machine (Epic x; Biolase Inc, Cromwell, Irvine, CA, USA) had a wavelength of 940±10nm. Parameters for low-level laser acceleration of tooth movement were adjusted as follows: Laser beam was in a continuous mode, power was 2.5 watt, and the session duration was 30 seconds. In order to cover the area between the canine and first molar in a single laser application, the laser light was applied to the gums along the buccal and the palatal surface using the bleaching hand piece. The handpiece had a rectangular size of 35mmx8mm and covered an area of 2.8cm2 as shown in (figure 1). The application of the laser beam through a wider tip yielded a total energy density of 25.7 J/cm2 per application. LLLT was done to the maxillary canine and maxillary first molar area both buccally and palatally according to the following protocol: days 0, 1, 2, 3 and 7 of maxillary canine retraction and then weekly during the 3 month of the study length. There were a total of 17 laser exposures both buccally and palatally.

Study analysis

DICOM files of both pre- and post-operative acquisitions were analyzed by two radiologists with a clinical experience of 18 years. Observers agreed on a specific protocol for viewing and reconstructing the images; the coronal, sagittal, and axial planes were adjusted to intersect on the root canal of the root of the tooth to be measured. This procedure was performed for maxillary first molars and canines, for both pre- and post-operative DICOM files. The tooth length was determined as the measurement between crown tip and root tip. The root length was measured in millimeters from the most apical point of the root to the cusp tip of the maxillary canine. The same was done for each of the 3 roots (Mesiobuccal, Distobuccal, and the Palatal) of the maxillary first molar along the long axis in the sagittal view (Figure 2). The difference in the tooth length measured from the pre- and post-treatment scans was used to quantify OIRR. Results of pre- and postoperative teeth lengths were recorded and tabulated for statistical analysis.

Figure 1. Laser application during canine retraction

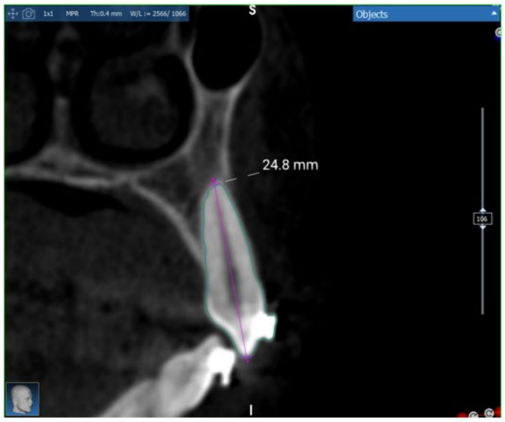

Figure 2. Root length measurement on CBCT for maxillary canine

Statistical Analysis

All numerical data in this study was tested for normal distribution. This was done using Kolmogorov Smirnov and Shapiro Wilk normality tests. Root length data showed normal parametric distribution while root resorption data showed non normal non-parametric distribution. Data were presented as mean and standard deviation (SD) values. For parametric data; repeated measures ANOVA tests were used to compare between root lengths pre- and post-treatment. Bonferroni's post-hoc test was used for pair-wise comparisons when ANOVA test is significant. For non-parametric data; Wilcoxon signed-rank test was used for comparison between amounts of root resorption at the left and right sides. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Method Error

Root resorption analysis on CBCT was done by each examiner and were rechecked by the same examiner after a 10day interval. Any difference in measurement of OIRR between these two intervals were compared using a paired Wilcoxon test.

Results

Maxillary canines and first molars in both the experimental and control sides showed a statistically significant decrease in mean root length post-treatment (OIRR) (table 1).

Table (1):The mean, standard deviation (SD) values and results of repeated measures ANOVA test for comparison between root lengths pre-and post-treatment

Side	Tooth	Pre-treatment (n = 10)		Post-treatment (n = 10)		Amount of resorption		P-value	Effect size (Partial eta squared)
		Mean	SD	Mean	SD	Mean	SD		
Exp side	U3	25.55	1.75	24.31	1.4	1.25	0.98	0.005	0.646
	U6 MB	17.87	1.11	17.51	0.97	0.36	0.36	0.014	0.554
	U6 DB	17.51	0.81	17.14	0.93	0.37	0.27	0.003	0.682
	U6 P	19.09	1.17	18.6	0.94	0.49	0.39	0.005	0.643
Control side	U3	25.6	1.64	24.33	1.22	1.27	0.77	0.001	0.752
	U6 MB	18.13	1.47	17.76	1.53	0.39	0.22	0.001	0.769
	U6 DB	17.6	1.32	17.09	1.21	0.51	0.42	0.007	0.621
	U6 P	19.66	1.44	18.93	1.25	0.73	0.44	0.001	0.761
Overall	U3	25.58	1.66	24.32	1.25	1.26	0.79	0.001	0.742
	U6 MB	18	1.23	17.62	1.14	0.38	0.2	0.001	0.79
	U6 DB	17.56	1.01	17.12	1.03	0.44	0.22	<0.00	0.818
	U6 P	19.38	1.25	18.77	1.03	0.61	0.38	0.001	0.742

**: Significant at $P \leq 0.05$*

The amount of OIRR in the root of the maxillary canine in the experimental and control sides was1.25mm and 1.27mm respectively. The amount of OIRR in the mesiobuccal root of the maxillary first molar in in the experimental and control sides was 0.36mm and 0.39mm respectively. Whereas the amount of OIRR in the distobuccal root of the maxillary first molar in the experimental and control sides was 0.37mm and 0.51mm respectively and the amount of OIRR in the palatal root of the maxillary first molar in the experimental and control sides was 0.49mm and 0.73mm respectively.

On the other hand, the comparison between the mean amount of orthodontically induced root resorption for both the maxillary canine root and maxillary first molar roots showed no statistically significant difference between the amounts of root resorption on the experimental and control sides (table 2), (Figure 3).

Table (2). The mean, standard deviation (SD) values and results of Wilcoxon signed-rank test for comparison between root resorption (mm) at the experimental and control sides

Tooth	Experimental side (n = 10)		control side (n = 10)		*P*-value	Effect size *(d)*
	Mean	SD	Mean	SD		
U3	1.25	0.98	1.27	0.77	0.859	0.119
U6 MB	0.38	0.36	0.39	0.22	0.726	0.235
U6 DB	0.37	0.27	0.51	0.42	0.192	0.965
U6 P	0.49	0.39	0.73	0.44	0.051	1.718

*: *Significant at P ≤ 0.05*

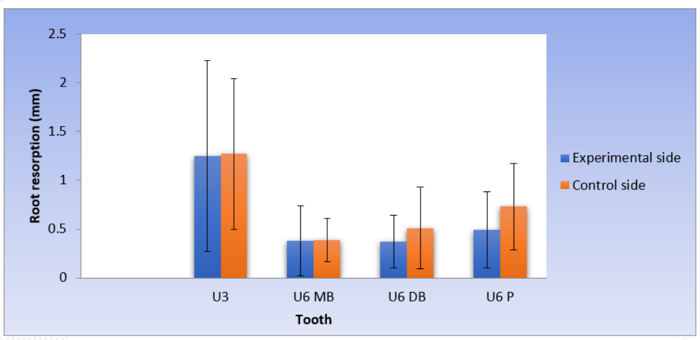

Figure 3.: Bar chart representing mean and standard deviation values for amounts of root resorption (mm) at the experimental and control sides.

Discussion

Apical root resorption associated with orthodontic tooth movement is one of the undesirable and unpredictable orthodontic treatment side effect that is hard to anticipate and difficult to repair. In this randomized clinical trial we investigated the effect of LLLT on root resorption induced by orthodontic treatment using CBCT as a mean of root resorption analysis.

During orthodontic treatment, the only procedure to quantify apical root resorption is radiographic assessment13. Root resorption is a three dimensional phenomenon, and therefore it should be analyzed with precision in all dimensions.

Yet, most of the studies investigating the effect of LLLT on root resorption only used two dimensional periapical radiographs14. Periapical radiographs have been shown to underestimate the extent of apical root resorption15. Therefore, a three dimensional cone-beam computed tomograph is a more precise approach for the detection of inflammatory induced orthodontic root resorption than a two dimensional periapical radiograph13.

In this study, laser was used during orthodontic treatment with the aim of utilizing its bioinhibitory and/or biostimulatory effects on tissues to reduce the incidence of inflammatory root resorption16. Various laser parameters need to be considered, such as wavelength, spot area, number of applications and energy density when choosing the protocol of treatment using LLLT17. The wavelength of this study (940 nm) was previously used by Qamruddin et al18 to report the influence of LLLT on orthodontic tooth movement rate throughout canine distalization. Multiple applications of laser were applied in the present study with an average of 17 exposures on each experimental quadrant. It was reported that multiple applications of LLLT are superior to a single laser exposure19.

Our results indicate that the incidence of OIRR in the upper maxillary canine root and all three roots of the upper maxillary first molar (mesiobuccal, distobuccal, and palatal) during canine retraction on the experimental side was lower than in the control side, yet, statistically insignificant. These results are similar to those of Sousa et al10 and Cruz et al20 and in contrast to those of D. Ng et al14 who found that the with use of LLLT there was a statistically significant reduction in OIRR.

Also, our study suggests that the orthodontic load as well as treatment duration during maxillary canine retraction is a contributing factor causing OIRR, as maxillary canines and first molars in both the experimental and control sides showed a statistically significant decrease in the mean root length post-treatment. This agrees with the reports of Jiang et al21 who assessed the contributing factor to OIRR. In the current study, a force of 150g applied with a nickel titanium closed coil spring was used for the retraction of the maxillary canines into the premolar extraction spaces. This orthodontic force was selected based on the assumption that lighter forces are optimal for canine retraction and are more biologic as recommended by Boester and Johnston22 and Huffman and Way23. However, this retraction force of 150g level was sufficient enough to cause OIRR. The highest amount of OIRR occurred within the maxillary canine root.

This could be accredited to the type of tooth movement that occur during canine retraction. The maxillary canine root tips mesially during retraction. Many studies revealed that there is stress concentration at the root apex during tipping24. Also, as the maxillary canines are moved significant distances, they experience an increased exposure to the resorptive cycles and longer duration of treatment25. Numerous investigations have upheld this immediate relationship between the extent of orthodontic root resorption and the extent of tooth movement25,26.

The statistically insignificant lower incidence of OIRR in the upper maxillary canine root and all three roots of the upper maxillary first molar (mesiobuccal, distobuccal, and palatal) during canine retraction on the experimental side is suggestedto be due to the initiation of cellular reaction in the target tissues by LLLT27. These cells are responsible for the inflammatory activity during orthodontic movement. It is suggested that low level laser therapy increases both osteoblastic cellular activity and osteoclastic cellular activity in the short term. However, LLLT increases the overall amount of osteoclasts in the long term to minimize inflammatory root resorption27.

Limitations:

This randomized clinical trial was initiated using split mouth experimental design. The main reported limitation of split-mouth studies is the possible crossover effect. However, the laser targets a specific area, thus acting locally. Therefore, LLLT effect is site specific and the crossover effect would be minimal7.

Conclusion

Within the parameters used in this study, the incidence of orthodontically induced inflammatory root resorption on the Low level laser therapy side was lower than in the control side, yet, statistically insignificant.

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