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CBCT ASSESSMENT OF MANDIBULAR INCISOR ORTHODONTICALLY INDUCED ROOT RESORPTION DURING ACCELERATED TOOTH MOVEMENT VIA LOW LEVEL LASER THERAPY

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Objective: *To evaluate mandibular incisor orthodontically induced root resorption OIRR during accelerated tooth movement via low level laser therapy utilizing CBCT.* ***Materials:*** *26 female subjects with an age range between 18-25 years (average 21.5years) with mandibular anterior irregularity index ranged from 4 to 10mm were divided into two equal groups, 13 per group; group A (laser) and group B (control). CBCT images were acquired for each patient, at (T0) before treatment commencement and (T1) after complete alignment as indicated by Little's irregularity index less than 1. Each subject received the following archwire sequence Cu-NiTi (0.014, 0.016, 0.016x0.022 inch) and 0.019x0.025 inch St.St. Laser applications for the laser group were at 3, 7, 14 days and 1, 1.5, 2, and 2.5 months. The control group as a placebo received light application at the same timings. Mann-Whitney U test was used to compare between the two groups. Intra and inter-observer reliability were assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC). The significance level was set at P ≤ 0.05.* ***Results:*** *As regards the mandibular right and left central and right lateral incisors there was no significant difference between amount of OIRR in the laser group and the control group. Whereas, mandibular left lateral incisor in the laser group showed statistically significantly (p < 0.05) higher mean amount of OIRR than control group.* ***Conclusion:*** *There was no clinically significant difference regarding orthodontically induced root resorption between the laser group and the placebo-control group during alignment phase.*

Introduction

Orthodontically induced root resorption (OIRR) is one of the most prevailing adverse effects of orthodontic treatment resulting in the permanent loss of apical root structure. Root resorption contemplates a critical adjunct effect of orthodontic treatment, which might begin at any stage of treatment. Root resorption is normally initiated within the second and fifth weeks of orthodontic treatment, but it is recognized on radiographs after 3 to 4 months.[1] Nonetheless, OIRR greater than 3mm is experienced within approximately 4% of orthodontic patients while sever OIRR greater than 5mm occurs within 5% of orthodontic patients.[2]

OIRR is a complicated biological process and its etiology is multifactorial,[3,4,5,6] plausible orthodontic risk factors are; treatment duration, forces magnitude, two-phase versus single phase treatment, extraction treatment, maxillary expansion, bracket prescription, and the severity of overjet and overbite.[5] Although multiple studies have evaluated the connection between these factors and the incidence of root resorption, small consensus exists. Variation in methodology and small sample sizes might account for this divergence. Therefore, the interpretation of results is subject to criticism.

An escalating number of adults are seeking orthodontic treatment but their most important concern is the treatment duration and the type of orthodontic appliance utilized in the treatment.[7] The average orthodontic treatment is between 2–3 years.[7] Prolonged orthodontic treatment affects the patients' cooperation, predisposes to white spot lesions, greater caries incidence, gingival inflammation and recession, and increases risk and severity of OIRR.[8,9,10]

Hence, various methods have been pursued in an attempt to reduce treatment duration. Corticotomy[11], piezocision[12], mechanical vibration, pulsed electromagnetic fields, photobiomodulation and low level laser

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therapy[13] in addition to pharmacological agents such as prostaglandins and vitamin D have been introduced as possible methods to accelerate orthodontic tooth movement. Although many were effective, their utilization might not be clinically feasible due to their side effects and invasive nature.[14]

Low level laser therapy (LLLT) has become favored due to their simplicity, noninvasive with its effects limited to the target tissue, and clinical acceptability. Low level laser therapy applications cause no fear, no pain of injections, and no discomfort to the patient. Low level laser therapy widespread in dentistry is due to its biostimulating effects on metabolic activity and cascade signaling osteoblast proliferation, in addition to prompting epithelization, vascularization, collagen synthesis, enhanced tissue regeneration, and wound healing .[15,16] Thus, LLLT might be beneficial for treating inflammatory processes like OIRR.

There is lack of consensus regarding the influence of LLLT on OIRR. The effect of LLLT on OIRR was assessed in only two human studies with no adverse outcomes.[17,18] However, a key limitation of these studies was the utilization of two-dimensional periapical radiographs to quantify root resorption.[18,19] A more precise method for assessing root resorption is via CBCT as it allows three-dimensional identification of resorption. Thus the current study aimed to evaluate mandibular incisor OIRR during accelerated tooth movement via low level laser therapy with the prescribed parameters utilizing CBCT.

Materials and Methods

Study Design

This study is a two-arm, parallel group, randomized clinical trial with the allocation ratio of 1:1. The ethics committee at the Faculty of Dentistry Ain-Shams University approved the study protocol. (approval No. RECM071403).

Sample size, settings, eligibility criteria

The sample size calculation was performed with G*Power version 3.1.3 software (Franz Faul; Universität Kiel, Kiel, Germany). The power analysis yielded a total sample size of 26 participants when using a two-sample t-test at a conventional alpha-level (p = 0.05) and desired power of 80%, thus yielding 13 patients per group.

The 26 subjects were females the age range between 18-25 years (average 21.5years). The subjects were selected from the outpatient clinic of the Orthodontic Department at the Faculty of Dentistry, Ain-Shams University. The eligibility inclusion criteria were; full permanent dentition, mandibular anterior irregularity index ranged from 4 to 10mm, non-extraction treatment plan, no previous orthodontic treatment and systemically free. Whereas the exclusion criteria involved; Any medical problems that require periodic drug prescription that affects tooth movement, periodontal diseases, and pregnancies.

Before treatment was commenced a detailed written consent was signed by all the subjects of both groups after full explanation of the procedure and the aim of the study. Subjects were then randomly assigned to either the experimental (Laser) group or the control group using simple randomization. Even numbers were assigned for the laser group whereas odd numbers were assigned for the control group, the investigator was not involved in subject allocation.

CBCT images were acquired for each patient, the first image (T0) was taken before treatment commencement (before alignment) . The second image (T1) was taken within one week after Little’s irregularity index was equal to or less than 1 (Complete alignment). CBCT scans were obtained (PLANMECA, Promax 3D Proface, Finland). The CBCT scanning was performed with the patient biting on a tongue depressor with his tongue rolled back to keep the maxillary and mandibular teeth separated. CBCT scans were restricted to the mandibular arch, with a field of view (8x8 cm) per image. The CBCT scanner parameters were set to 90 kV at 12 mA and a voxel size of 200 microns.

Intervention

The mandibular arch was bonded with 0.022-inch pre-adjusted edgewise Mini-diamond brackets with Roth prescription (Ormco, Europe). In both groups the initial wire was 0.014inch Cu-NiTi (Ormco, Europe) which was inserted immediately after bonding of the brackets. The principal of changing the initial wire was to achieve 50 % relief of the initial crowding in both groups. The second wire placed was 0.016inch Cu-NiTi and was changed to 0.016x0.022inch NiTi when 80% of the initial crowding was relieved in either group. Finally when alignment was complete (100% relief of initial crowding) a 0.017x0.025inch Stainless Steel wire was inserted.

Laser Therapy

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. These parameters yielded an application dose of 72 J for each session. In order to encompass the area between the lower right and left canines in a single laser application the bleaching hand piece was implemented as it covered a rectangular spot size of 35 mm x 8 mm (area of 2.8 cm^2). The application of the laser beam through a wider tip yielded a total energy density of 25.7 J/cm^2 per application. Laser protocol application timetable is displayed in table1: Both the operator and the patient wore protective glasses which were in accordance with the European norm EN 207 and had an optical density of ≥ 5 at the wavelength of emission from the diode. The control group received light from a light cure, using the same timetable for laser group, as a placebo to ensure blinding. Subjects in both groups were recalled for follow up on days 3,7and 14 then at 1 month followed by every two weeks till completion of alignment. Laser or light from a light cure was applied and alginate impressions were obtained for the lower arch of each subject at each visit.

Table 1. Laser protocol timetable

L0: At the day of initial arch wire placement
L1: After 3 days from initial arch wire placement
L2: After 7 days from initial arch wire placement
L3: After 14 days from initial arch wire placement
L4: After 1 month from initial arch wire placement
Then every 2 weeks until complete alignment

Measurements and evaluation

Cone beam computed tomography images were obtained from Planmeca promax 3D proface CBCT unit. The DICOM files were processed into volumetric images using Planmeca Romexis viewer. Reconstructions were made so that the axial slices became perpendicular to the long axis of the tooth/root. On the multi-planner screen, each point was identified in the axial, sagittal, and coronal sections in the following manner; the coronal and sagittal cursors were adjusted to intersect at the middle of the pulp cavity of the tooth measured on the axial view. The sagittal curser was adjusted to pass through the long axis of the tooth on the coronal view and the coronal curser was adjusted to pass through the long axis of the tooth on the sagittal view. This provided optimum visualization of the tooth/root in axial, coronal and sagittal planes and the three-dimensional (3D) coordinates of each point were obtained. On the sagittal view the linear distance between the incisal edge (Ie) and root apex (Ra) of each mandibular incisor was measured and saved. (Figure 1)

Root shortening was defined as any reduction in length of any of the four mandibular incisors measured from the tip of the incisal edge (Ie) to the apex of the root (Ra). The pre- and post-alignment tooth lengths were recorded and the amount of apical root resorption was determined by subtracting the post-alignment from the pre-alignment length.

Error of measurement

The error of measurement in this study was assessed through evaluating the intra-operator and inter-operator reliability. For intra-reliability, root lengths pre and post-traetment was measured, by the same operator, for 10 randomly chosen subjects. A trained orthodontist, of similar training to the operator conducting measurements in this study, measured root length on the same CBCT scans to assess the inter-operator error.

Statistical Analysis

Numerical data were explored for normality by checking the data distribution and implementing Kolmogorov-Smirnov and Shapiro-Wilk tests. All data showed non-normal (non-parametric) distribution. Mann-Whitney U test was used to compare between the two groups. Intra and inter-observer reliability were assessed using Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC). The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS Statistics Version 20(SPSS Inc., Chicago, Ill) for Windows.

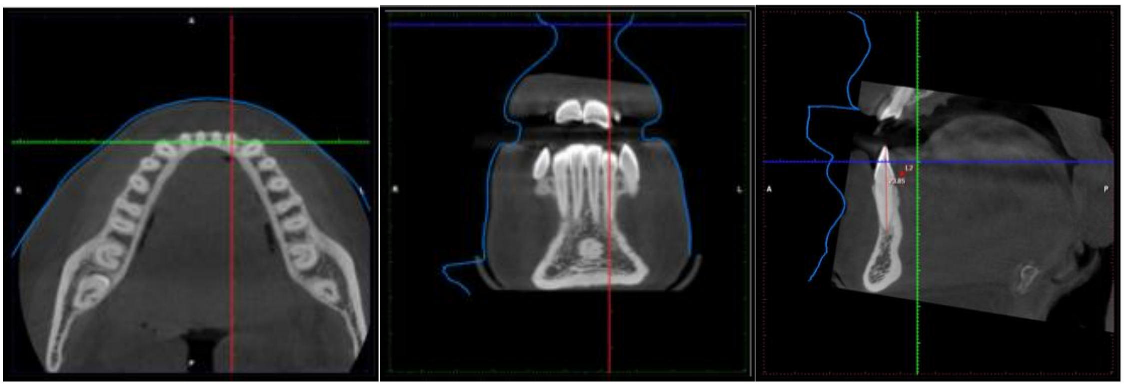

Figure 1(a, b, and c) a and b Orienting the cursers on the axial and coronal views to pass through the center of the root, c Measuring incisor length from incisal edge to root apex on the sagittal view

Results

Amount of root resorption was calculated as follows:

Pre-operative tooth length – Post-operative tooth length

Where the tooth length was determined by measuring the distance between the incisal edge (Ie) and root apex (Ra) of each tooth. As regards the mandibular right central and lateral incisors there was no statistically significant difference between amount of orthodontically induced root resorption in the laser group and the control group (placebo). The mandibular left central incisor displayed no statistically significant difference in the degree of orthodontically induced root resorption between both groups. Whereas, for mandibular left lateral incisor the laser group showed statistically significantly ($p < 0.05$) higher mean amount of orthodontically induced root resorption than control group (placebo) Table 2. Assessment of orthodontically induced root resorption represented a very good intra-observer reliability with Cronbach's alpha values ranging from 0.879 to 0.942. There was very good inter-observer reliability with Cronbach's alpha values ranging from 0.840 to 0.936 Table 3.

Table (2): Mean, standard deviation (SD) values and results of Mann-Whitney U test for the comparison between amounts of orthodontically induced root resorption in (mm) for the laser group and the control group.

Tooth	Laser		Control		P-value
	Mean	SD	Mean	SD	
R2	0.14	0.21	0.08	0.19	0.455
R1	0.10	0.24	0.11	0.18	1.000
L1	0.13	0.32	0.06	0.17	0.259
L2	0.18	0.15	0.03	0.19	0.041*

*: Significant at $P \leq 0.05$

Table (3): Results of Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC) for intra- and inter-observer reliability regarding root resorption

Time	Tooth	Intra-observer agreement		Inter-observer agreement	
		Cronbach's alpha	ICC	Cronbach's alpha	ICC
Pre-operative	R2	0.879	0.845	0.857	0.823
	R1	0.915	0.903	0.911	0.893
	L1	0.902	0.888	0.879	0.840
	L2	0.926	0.893	0.900	0.864
Post-operative	R2	0.882	0.834	0.840	0.819
	R1	0.890	0.874	0.855	0.831
	L1	0.934	0.911	0.928	0.917
	L2	0.942	0.910	0.936	0.908

Discussion

Especially with the escalating number of adults undergoing orthodontic treatment numerous methods are being implemented effectively to accelerate orthodontic tooth movement and reduce treatment duration some are invasive (e.g. corticotomy, peizocision, and corticision), while others are noninvasive (e.g. low level laser therapy, mechanical vibration, low intensity ultrasound, and electric pulses). However, an adverse outcome to orthodontic treatment reported in the literature is orthodontically induced root resorption. A significant reduction in root length might lead to an unfavorable crown/root ratio which in turn increases tooth mobility and compromises periodontal health. Numerous experimental studies[16,17] have tested various procedures to inhibit orthodontically induced root resorption (OIRR) among which is low level laser therapy

(LLLT). LLLT is an inexpensive and harmless method with its effects limited at the target tissue.
However, various explanations are present regarding the effect of LLLT on OIRR. The reduction in OIRR on the laser side might be due to the preventative effect of LLLT or due to its reparative potential. One suggested mechanism might be that LLLT accelerates the overall cellular response at the target tissues involved in the inflammatory process of orthodontic tooth movement via increasing osteoblastic and osteoclastic activity in the short term but diminishing the overall amount of osteoclasts in the long term to reduce root resorption.[20,21] Histologically, LLLT has been revealed to induce osteoblast proliferation, whilst decreasing osteoclasts.[20,21] Another hypothesis might include the reparative effect of LLLT on root resorption. Studies have displayed that LLLT promotes cementoblast and fibroblast proliferation and boosts the reparative process,[22] through new capillary formation, secondary cementum production,[23] and decreasing of osteoclastic activity secondary to RANKL/OPG ratio reduction.[22]

The diagnosis of OIRR in most cases is performed radiographically, since it is clinically asymptomatic for the most part and increased tooth mobility is apparent in severe cases.[24] Usually, two-dimensional radiographic (2D) methods as periapical or panoramic radiographs are obtained before, during, and after orthodontic treatment to record OIRR.[25] Studies using 2D imaging techniques revealed OIRR to be less than 0.60 mm at the end of treatment.[26] However, OIRR affects all aspect of the root surface in 3D therefore, 2D radiographs might mask the true degree of OIRR. Additionally, the true extent of OIRR may be misestimated due to the problematic repeatability of 2D radiographs and magnification errors.[27]

Cone beam computed tomography (CBCT) was presented as a three-dimensional diagnostic method capable of imaging dental and maxillofacial structures with reduced radiation dose. The diagnostic value of CBCT in the diagnosis of OIRR is due to its ability to obtain distortion- free and reproducible images for the roots with high sensitivity and specificity.[28] Additionally, three-dimensional reconstruction of 2D CBCT slices permits precise quantification of both linear OIRR measurements and compensates for changes in root angulation and position during orthodontic treatment.[29]

To date it is still controversial clinically which parameters in LLLT would lead to simultaneous orthodontic tooth acceleration and inhibit OIRR. Thus in this clinical investigation our aim was to evaluate the changes in mandibular incisor root lengths on CBCT as an indication for OIRR during orthodontic tooth acceleration via low level laser therapy.

In this study in order to decrease the radiation exposure, and following the recommendations of American Academy of Oral and Maxillofacial Radiology, CBCT scans were restricted to the mandibular arch, also the CBCT machine used had a small field of view (8x8 cm) per image. According to Loubele et al.[30] the radiation exposure of standard resolution CBCT scan ranged between 13 to 82 μSv. The American nuclear society stated that the allowed maximum radiation dose yearly was 50 mSv/year (50000μSv/year) above the background radiation, which was 6.2 mSv/year (6200 μSv/year). In our study, the principle of as low as reasonably achieved (ALARA) was followed so we limited the CBCT imaging to the mandibular arch.

In the current study external root resorption and root shortening was assessed for two reasons; the first was to investigate the effect of the laser beam itself and its biostimulatory effect on the roots of the lower incisors. The second reason was to investigate the effect of acceleration of tooth movement on the roots of lower incisors by comparing between the amounts of orthodontically induced root resorption in the laser accelerated group and the control group.

Our results revealed no statistically significant difference between the amount of orthodontically induced root resorption in the two groups with regards to the lower right incisors and the lower left central incisor this corroborates with the results of Doreen et al.,[31] . While for the lower left lateral incisor laser group showed statistically significantly higher mean amount of root resorption than control group. The unexplained minor amount of root resorption found on the lower left lateral incisor was considered to be clinically insignificant. Our findings were concurrent to those of the study by Vasconcelos et al.[32] who used an energy density of 25 J/cm2, in their study to asses the effect of laser on root resorption ,which is similar to the energy density used in our study. They found that these parameters did not induce any root surface alterations and did not seem to be clinically recommended to avoid or reduce inflammatory root resorption.

Conclusions

The duration of the study was 3 months; hence, results and conclusion should be interpreted with caution.

- LLLT has a clinically insignificant effect on orthodontically induced root resorption during the initial stages of orthodontic force application.
- There was insignificant difference in amount of OIRR between the laser group compared to the placebo-control group, indicating no possibility of prevention or induction of root repair in patients susceptible to root resorption with laser application.
- However, further research is required with patients undergoing a full course of orthodontic treatment and LLLT application.

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