The Effect of Soft laser Application on Orthodontic Movement (In vitro study)

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Abstract: The present study was designed to evaluate the effect of low level laser therapy on alveolar bone remodeling and rate of tooth movement secondary to application of orthodontic forces. 42 male Guinea pigs were used in this study. The animals were divided into two groups (each group contains 21 animals), group (1) received soft laser therapy at the treatment site and group (2) as a control group. The orthodontic device was cemented to the lower central incisors to be activated once only. Daily measurements were taken directly from the oral cavity to record the rate of tooth movement of the experimental groups. Seven animals of each group were sacrificed at 3 days, 2 weeks and one month. Radiographic assessment was carried out at these intervals using Radio-Visio-Graphy (RVG), with its personal computer (PC) based version, to monitor the changes in the bone density mesial to each lower central incisor. The lower jaws were histologically treated to obtain mesiodistal sections of the lower incisors with their supporting structures and stained by H & E. Conclusion: Soft laser can enhance the rate of orthodontic tooth movement due to stimulation of bone remodeling.

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Key words: Orthodontic treatment, laser therapy

1.Introduction:

Orthodontic treatment is based upon the principle that if prolonged pressure is applied to a tooth, tooth movement will occur as the bone around the tooth remodels. The typical 2 to 3 years treatment period is burdensome for patients, so it is very important to accelerate alveolar bone remodeling during treatment to abbreviate the time required, Kawasaki and Shimizu (2000); Proffit(2007)

A long period of retention is necessary to prevent early relapse. Although the reason for the early relapse is not fully clear, bone regeneration after orthodontic treatment may affect the post treatment relapse. It would be potentially beneficial therefore to accelerate bone formation to prevent relapse and abbreviate the retention period, Saito and Shimizu(1997).

Orthodontic treatment involves the use and control of forces acting on the teeth and associated structures. An optimal orthodontic force intends to induce a maximal cellular response and to establish stability of the tissue. An unfavorable force does not result in a precise biologic response and may initiate adverse tissue reactions, Graber and Vanarsdall (2000).

A considerable number of studies based on human being illustrate the quantitative changes occurring during orthodontic treatment, but the main evidence for the qualitative histological responses to orthodontic treatment comes from experimental studies on animals , Graber and Vanarsdall (2000).

Lasers can be divided into two groups, the so-called hard lasers, which are used for surgical application as cutting and vaporization of hard and soft tissues (e.g. CO_2, Nd: YAG lasers), Sinha and Gallagher(2003); Esen etal.,(2004). Moreover, the so-called soft lasers, which are used for biostimulation, analgesic effects and promoting wound healing (e.g. He-Ne and Diode laser , Qadri et al.,(2005)

The use of Ga-As diode laser as a soft laser has grown increasingly during the last 10 years. This kind of laser is known to have a high depth of penetration in comparison with other types and thus offers the clinician a penetrative tool of great efficiency, Nissan et al., (2006)..

The effect of low energy laser on the alveolar bone after tooth extraction showed increase in the deposition of bone. Radiological analysis after tooth extraction demonstrates that low intensity laser can activate repair of damaged bone tissue in patients, Nagazawa et al.,(1991). In addition, low power laser irradiation significantly increased the number of viable osteocytes in the irradiated bone by a positive effect on bone matrix production to produce highly reactive and vital implant bone tissue, Dortbudak et al.,(2002). Moreover, it is effective on the bone healing process in artificially created osseous cavities by affecting calcium transport during new bone formation, Nissan et al.,(2006)..

Sun et al.(2001), reported that the irradiation of low energy laser promotes tooth movement and remodeling of alveolar bone in rabbits. In addition, Miloro et al.,(2007)reported that low level laser therapy (LLLT) accelerates the process of bone regeneration during the consolidation phase after distraction osteogenesis. The adjunctive use of LLLT may allow a shortened period of consolidation and therefore permit earlier device removal, with the avoidance of morbidity associated with prolonged device retention.

Therefore, if laser irradiation can cause the acceleration of bone remodeling, it may also have great potential benefit in abbreviating the orthodontic treatment period .

This study was conducted in an attempt to evaluate the effect of low level laser therapy (LLLT) on alveolar bone remodeling and rate of tooth movement secondary to application of orthodontic force.

2.Material & Methods:

2.1.Materials:

2.1.1.Subjects:

Forty two male Guinea pigs were used in this experiment. They were collected at one week age and were allowed to grow at the same conditions of good ventilation, adequate stable diet, temperature and humidity. The average age of the animals was five weeks and their average body weight was 260 grams ± 20 grams at the beginning of the experiment.

The animals were grouped randomly, seven in a cage, so that at the time of irradiation, the animals of each group could be selected from different cages to eliminate the effect of cage environmental variants. They were supplied with a daily maintenance diet which was almost stable in both quality and quantity to keep their body growth and functions almost constant throughout the experiment.

The animals were divided into two groups (each group contains 21 animals). One group (group 1) received soft laser irradiation at the treatment sites and the other group (group 2) was non-irradiated as a control group.

The orthodontic appliances were constructed so that each appliance was formed of two main parts two bands & wire in the form of a vertical loop with a helical. An eyelet was welded on the middle part of the labial aspect of each band. These eyelets were the attachment components of the appliances, El-Dakroury(1998).

2.1.2.Drugs:

Intramuscular injection of a mixture of Xylazine (10 mg/kg b.wt.) and Ketamine (87 mg/kg b.wt.) was used for anesthesia, Kandil(1995).

2.2.Methods:

2.2.1. Experimental design

After anaesthetization, glass ionomer cement was used for cementation of the orthodontic appliance on the lower incisors of the animal (Fig.1). The orthodontic device was activated once only at the beginning of the experiment with no further activation during the treatment period, which lasted for thirty days.

Fig. (1): The orthodontic appliance in place

The first group was received laser irradiation by the **Gallium- Arsenide laser system (Ora-laser-*ORALIA* Dental Products Ltd., Weiherstraße 20, D-78465 Konstanz-Dettingen / Germany).**

It is a semi-conductor low level laser therapy(LLLT), with a wavelength 904 nm (Infrared); it was pre-adjusted to deliver a laser beam with an output power of 30 mW, and a frequency of 9999 Hz for 3 minutes daily for two weeks starting from the day of activation of the orthodontic appliance.

The surface area of the probe covers the whole target area of the lower incisors (from the tip of the interdental papilla to the depth of the gingival sulcus, and one millimetre distal to the roots of both lower incisors). The applicator probe was moving in a continuous slow circular motion to assure full exposure of the target surface to the beam.

Seven animals from each group were sacrificed at three days, two weeks and one month intervals from the date of beginning of orthodontic appliance activation. Each animal was anesthetized by intramuscular injection of a mixture of Xylazine (12 mg/kg body weight) and Ketamine (80 mg/kg body weight). While the animal was under deep anesthesia, a lethal dose of ketamine chlorhydrate was used , Kandil(1995)**.**

2.2.2. Assessment of the Rate of Tooth Movement:

During the experimental period, the amount of tooth movement was measured directly from the oral cavity of the animals using a Vernier caliper. The measurement were taken daily throughout the study period. During the measurement the end of the caliper were in contact with the opposing upper mesial points of the bands around the lower incisors.

2.2.3. Assessment of the Bone Density:

Radiographic assessment was done, after scarification, using Radio Visio Graphy (RVG) (Dür Vistaray system, manufactured by Dür Dental Gm pH and Co. Germany) with its personal computer (PC) base version. The x-ray generator was Orix-65 dental unit (65 kv, 8 mA) (Orix- 65 mobile x-ray machine, with digital x-ray control palm time 100, manufactured by ARDET srl, Italy) with a computer controlled timer, electric digital control device, and centesimal time regulation ranged from 0.01 to 2.99 seconds. In this study the time of exposure was 0.05 second.

The mandible of the animal was put in contact with the sensor and the inferior border of the mandible is parallel to the sensor. The distance between the end of the long cone (16 inch) and the sensor was fixed to 5 cm and the cone was kept perpendicular to the sensor all the time. The read out starts automatically, the image was displayed gradually on the computer screen, when the read out was completed; the newly read image was stored.

2.2.4. ***Measurement of bone density***

The computer program, with an appropriate software (Dür DBS Win image processing software, manufactured by DUr Dental Gm pH and Co. Germany) for image processing and manipulation, was used to evaluate the bone density at the mesial sides of both right and left lower central incisors. Two successive straight lines were drawn 0.5 mm apart and parallel to the mesial surface of each root, then the density were measured at three different and fixed points on each line (at 3,6 and12mm) then the means were calculated and statistically analyzed, Salah et al.,(2000)**.**

By assigning the value (0) to black and (256 to white, the mean gray value in each region of interest was calculated. Areas of bone loss represented as (darker areas), while areas of bone gain represented as (lighter areas), Yokota et al.,(1994) . These data were used for comparing the bone density between irradiated and non-irradiated groups.

Obtained data were presented as mean±SD and ranges. Results were analyzed using paired Wilcoxon test (Z-test). Statistical analysis was conducted using the SPSS (Version 10, 2002) for Windows statistical package. P value <0.05 was considered statistically significant.

2.2.5. Histopathological Assessment:

The mandible was removed and the soft tissue covering it was removed. Each specimen was fixed in 10% neutral buffered formalin for not more than 48 hours. After fixation, assessment of bone density was done, and then the specimens were decalcified in 20% ethylenediamine-tetra-acetic acid (EDTA) for 6-8 weeks. Natural EDTA decalcifying solution consisted of EDTA (di-sodium salt) 250 g. dissolved in distilled water 1750 cm^3. The solution was adjusted to pH 7 by the addition of about 26 g. sodium hydroxide. A volume of 150 times that of the tissue was renewed every 5-7 days during the decalcification process.

The specimens were prepared for haematoxylin and eosin (H&E), histochemical examination to evaluate the process of bone remodeling and the cellular activities in bone and PDL at the cervical one half of the root

<u>3.Results:</u>

3.1.Clinical Findings:

The animals lost some of their body weight during the first two weeks then weight regain started during the third week and continued up to the end of the study period.

Clinically during the first 3 days of the study, the gingiva in all cases was of normal color and texture except for slight gingival inflammation in few animals in both groups. No bleeding tendency or gingival enlargement was noted in any of the study cases. During the period from 4th to 14th days, the gingiva was normal irradiated group. On the other hand, four animals in group V showed slight gingival inflammation. During the period from 15^{th} to the 30^{th} days, the gingiva was normal with no evidence of gingival bleeding, enlargement or inflammation in the irradiated group. While slight gingival inflammation was still detected in three animals in the non-irradiated group.

The rate of tooth movement was measured daily for the studied groups. The highest measurements throughout the study period were recorded in irradiated group than non- irradiated group. Group (1) reached the maximum distance between the two incisors (10 mm) (as the device became inactive after reaching its maximum opening) on the 24th day, while the group (2) on the 29th day.

The mean distances during the first three days were (3.5 ± 1 mm for group (1), and 3±0.5 mm for group. During the period of 4th – 14th, the mean distances were (5.86 ± 0.84 for group (1) and 4.86 ± 0.83. For the period (15th – 30th days), the mean distance was (9.25 ± 0.84 for group (1) and 7.84±1.2mm for group.

Statistically, there was a non-significant difference (P>0.05) between both groups during the three days period {table 1, Fig.2}. While during both 4-14 days and 15-30 days periods there was a significant difference (P< 0.05) between the irradiated group and the non –irradiated one{Table 2&3, Figs. 3&4}.

Table (1): Statistical analysis of mean distance (mm) estimated at 3 days in both groups.

	mean±SD (mm)	Statistical analysis	
		Z	p
Group (1)	3.5±1	1.342	P_1>0.05
Group (2)	3±0.5		

Fig (2): Mean ± (SD) of estimated distance in the studied groups during the 3 days period

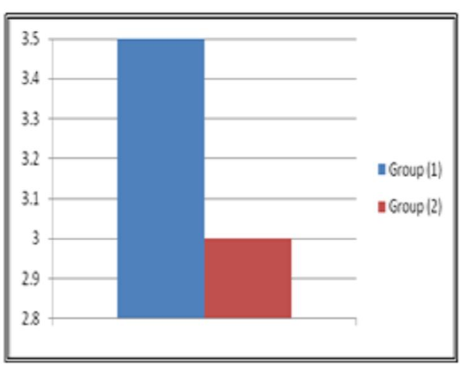


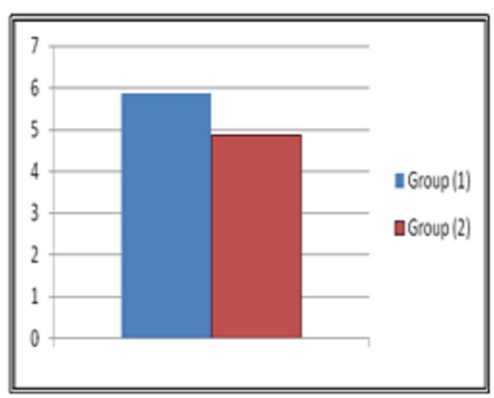
Table (2): Statistical analysis of mean distance (mm) estimated in the period of 4th -14th day in both groups.

	mean±SD (mm)	Statistical analysis	
		Z	p
Group (1)	5.86±0.84	3.207	P_1<0.05
Group (2)	4.86±0.83		

Table (3): Statistical analysis of mean distance (mm) estimated in the period of 15th -30th day in both groups.

	mean±SD (mm)	Statistical analysis	
		Z	p
Group (1)	9.25±0.84	3.462	P_1<0.05
Group (2)	7.84±1.2		

Fig (3): Mean ± (SD) of estimated distance in the studied groups during the period 4-14 days



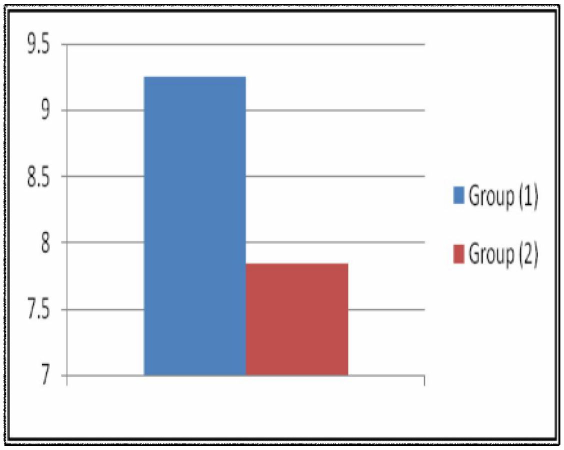


Fig (4): Mean ± (SD) of estimated distance in the studied groups during the period 15-30 days

3.2. Assessment of bone Density:

The mean bone density was compared between the right and left incisors of both groups. For group (1), it was 100.5±3.21 pixel/mm^2 and 95.6±6.13 pixel/mm^2 respectively Fig. (5). for group (2), it was 90.5±2.75 pixel/mm^2 and 90.4±4.4 pixel/mm^2 respectively Fig. (6). Statistically, there was a non-significant difference (P> 0.05) of the bone density evaluated for either the right or left incisors between the both studied groups {Table 4, Fig. 7}.

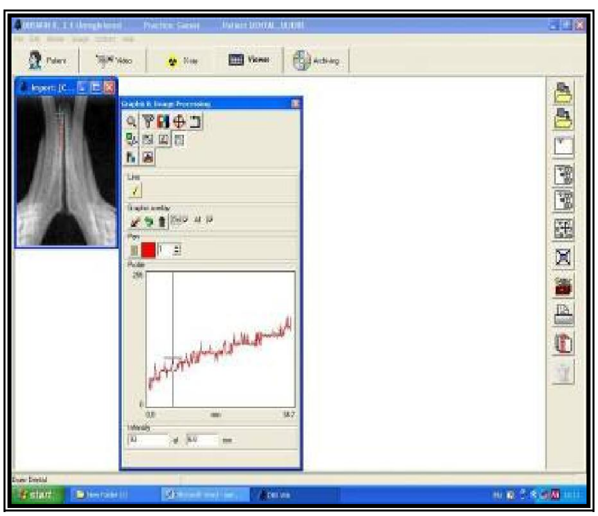


Fig. (5): RVG bone density measurements in group (1)

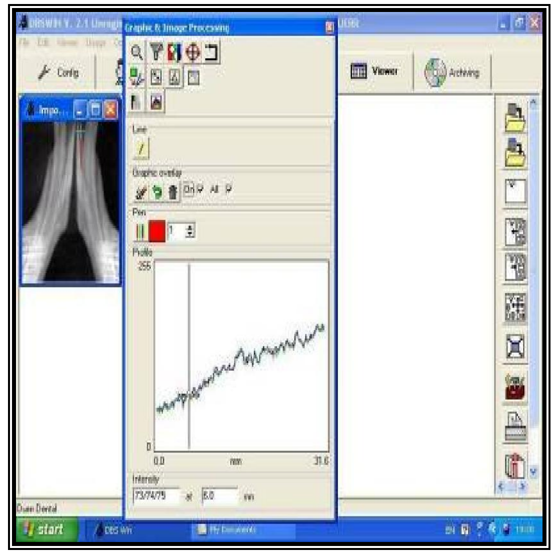


Fig. (6): RVG bone density measurements in group (2)

Table (4): Statistical analysis of the mean bone density (pixel/mm^2) between right and left incisors of each group.

	Rt incisor	Lt incisor	Statistical analysis	
	mean±SD (pixel/mm^2)	mean±SD (pixel/mm^2)	Z	p
Group (1)	100.5±3.21	95.6±6.13	0.099	>0.05
Group (2)	90.5±2.75	90.4±4.4	0.007	>0.05

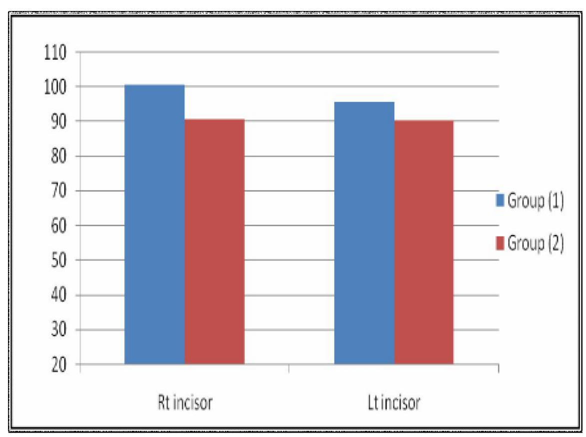


Fig (7): Mean ± (SD) of estimated bone density of both right and left incisors in the studied groups at the end of the study period.

The sum of the measurements of the bone density of both right and left incisors of each animal was used to calculate the mean bone density for each group. In group (1) the bone density was 99.6 ± 3.4; range: 95-104 pixel/mm^2. While, in group (2) it was 90.3 ± 2.72; range: 84 – 94 pixel/mm2; (Fig. 49). Statistically, there was a significant difference of bone density between both groups (P<0.05). {Table 5, Fig. 8}.

Table (5): Mean bone density (Pixel/mm2) estimated in both groups

	mean±SD (pixel/mm^2)	Statistical analysis	
		Z	p
Group (1)	99.6±3.04	3.059	$P_1<0.05$
Group (2)	90.3±2.72		

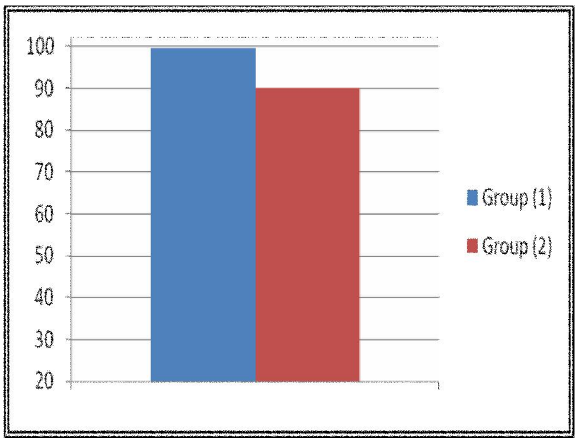


Fig. (8): Mean (±SD) of estimated bone density in the studied groups

3.3. ***Histological evaluation by using H&E stain:***

The histological changes after orthodontic movement were mainly based upon changes shown in the non-irradiated group (2). The results were mainly detected in periodontal ligament (PDL) as regard its cellularity, continuity, vascularity and architecture. Alveolar bone changes were also observed as regard its bone cells, bone resorption and new bone formation. As a general, the tipping movement resulted in pressure and tension sites.

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***3.3.1.* <u>Three days later:</u>**

For pressure sites:

In the non-irradiated group, the PDL showed hyalinization zone of collagen bundles adjacent to both tooth, and bone surfaces, with multiple edematous spaces and vacuolation. Degenerative changes were also observed. Narrow interstitial spaces with compressed blood vessels were prominent and located near the wall of alveolar bone. A few numbers of osteoclasts in their Howship's lacunae was evident. The bone surface was irregular and scalloped with few number of resorption foci. Fig. (9) While *the irradiated group* showed similar results to the non-irradiated one. The bone surfaces revealed increased number of osteoclasts. Multiple interstitial spaces encircling numerous compressed vessels were demonstrated Fig. (10).

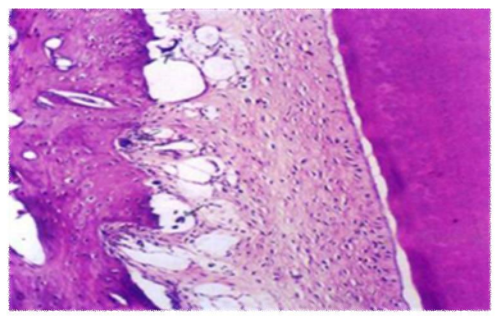

Fig. (9): Photomicrograph of the pressure site in group (2) at 3 days showing few numbers of osteoclasts. Note the multiple edematous spaces (H&E x 100).

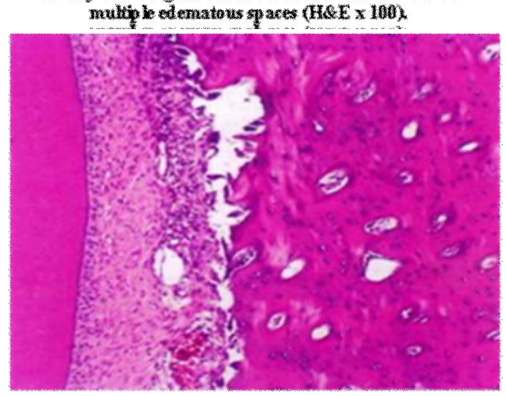

Fig. (10): Photomicrograph of the pressure site in group (1) at 3 days showing excessive osteoclasts activity (H&E. x 100).

3.3. 2.For tension Sites:

Non-irradiated group revealed over-stretching of PDL with prominent wavy course. The fibers became dense and elongated with irregular arrangement. Vasodilatation of thin walled vessels was obvious and located at the center of PDL. Normal bone architecture was noted Fig. (11). While *the irradiated group,* showed more pronounced over stretching of PDL than found in group V. In addition, evidence of laid down osteoid tissue was detected in the irradiated groups. Numerous proliferations of mononuclear cells (osteoblasts & fibroblasts) were detected near to root and bone surfaces Fig. (12**)**.

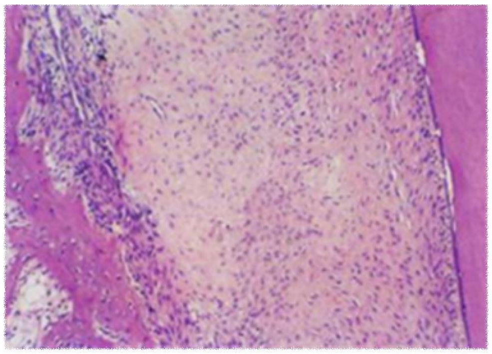

Fig. (11): Photomicrograph of the tension side in group(2) at three days showing widening of the PDL with focal degeneration (H. & E. x 100).

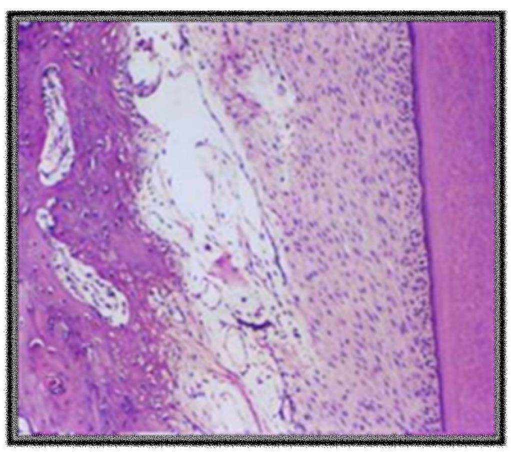

Fig. (12): Photomicrograph of the tension site of group(1) at three days showing over stretching of PDL with prominent degenerative changes (H. & E x 100).

3.3. 3. **Two weeks later:**

(For pressure sites):

Non-irradiated group, revealed a PDL hyalinization which was similar to the previous period. Increased osteoclasts number along the bone surface was detected. Areas of degeneration were persistent in the vicinity of resorbed bone Fig. (13). While the irradiated group showed narrowing of the PDL space and evidence of periodontal reorganization especially with group (IV) and to a lesser extent in remaining groups. Increased mononuclear cell proliferation was detected with persistence of degenerative remnants with a higher intensity in addition to increased osteoid tissue formation. With the appearance of few wide reversal lines than that found in non-irradiated group Fig. (14).

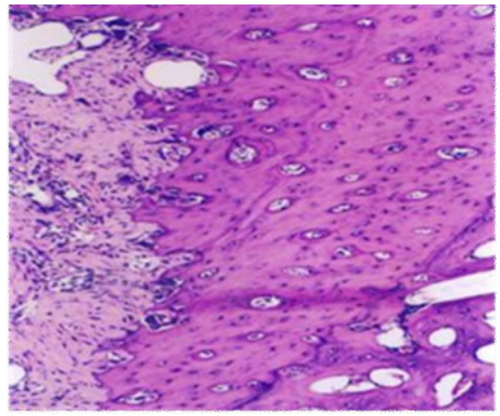

Fig. (13): Photomicrograph of the pressure site of the group(2) at two weeks showing increased osteoclast activity. Note the multiple interstitial spaces (H. & E. x 100).

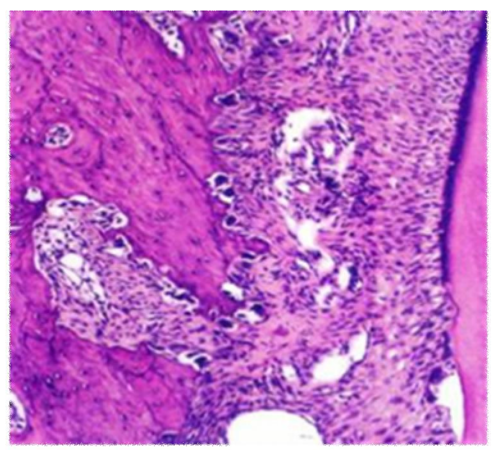

Fig. (14): Photomicrograph of the pressure site of group (I) at two weeks. Note the increased number of osteoclast (H. & E. x 100).

3.3.4.For tension sites:

The non-irradiated group revealed increased osteoid deposition than the previous interval with the appearance of few number of reversal lines. Numerous thin-walled dilated vessels were also prominent Fig. (15). While *the irradiated group* revealed similar results but with the appearance of numerous deep reversal lines. Vasodilatation was more prominent. The bone surface revealed a highly cellular surface with increased mononuclear cell proliferation opposite to the bone surface. It was also seen adjacent to the root surface in the form of cementoblastic proliferation Fig. (16).

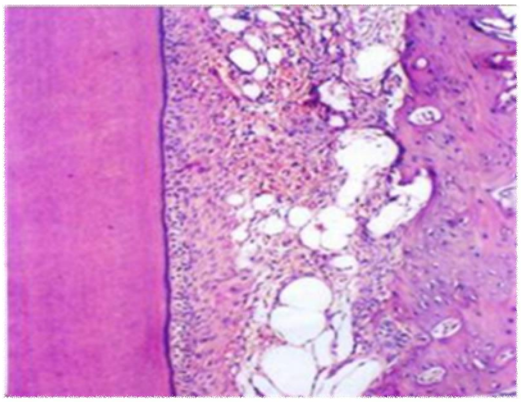

Fig. (15): Photomicrograph of the tension site of group (2) at two weeks showing evidence of osteoid deposition. Note the numerous thin walled vasculatures (H. & E. x 100).

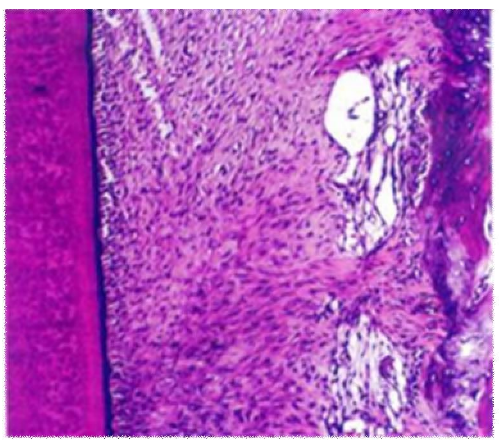

Fig. (16): Photomicrograph of the tension site of group (1) at two weeks showing evidence of PDL re-organization with prominent mononuclear cell proliferation (H. & E. x 100).

3.3.5.**<u>One month later:</u>**

For pressure sites:

The non-irradiated group showed a minor evidence of PDL reorganization with persistence of necrotic remnants. Osteoid tissue with numerous wide resting lines was detected. Mononuclear proliferation was highly manifested Fig. (17). Alveolar bone resorption was still active and the newly formed bone was few, with thin and immature trabeculae. While the irradiated groups showed more evidence of PDL reorganization, more new bone formation with thick and mature trabeculae and smooth regular bone surface Fig. (18).

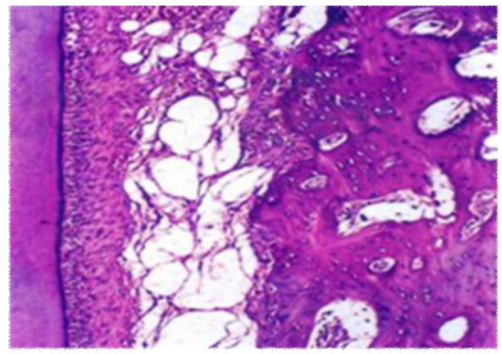

Fig. (17): Photomicrograph of the pressure site of the group(2) at one month showing a minor evidence of PDL reorganization. Note the persistence of multiple interstitial spaces and the new laid down osteoid (H. & E. x 100).

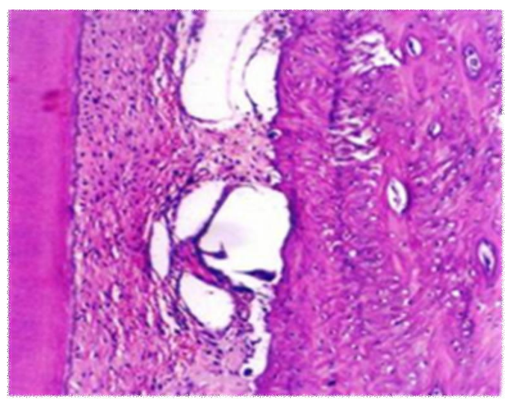

Fig. (18): Photomicrograph of the pressure site of group(1) at one month showing few numbers of osteoclasts (H. & E. x 100).

3.3.6.For the Tension Sites:

Non-irradiated group showed fibrous condensation with numerous dilated capillaries. Some areas of PDL were still stretched. Precementum was focally calcified and some uncalcified cementum still persists

Fig. (19). While *the irradiated group* showed highly detectable reorganization of PDL and to a lesser extent for the remaining groups. Besides Increased incidence of new bone tissue with multiple deep reversal lines, the newly formed bone had thick and mature trabeculae. Cementoblasts and precementum were increased. The bone surface showed highly cellular surface and osteoblastic proliferation Fig. (20).

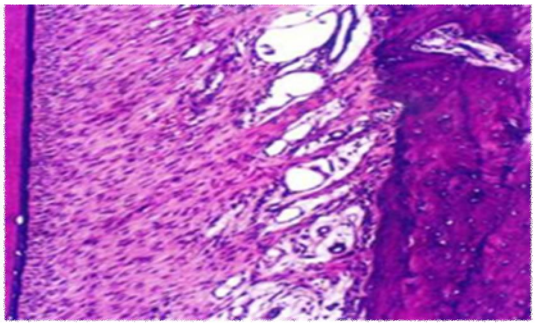

Fig. (19): Photomicrograph of the tension side of group (2) at one month showing evidence of PDL reattachment. Note, multiple dilated capillaries (H. & E. x 100).

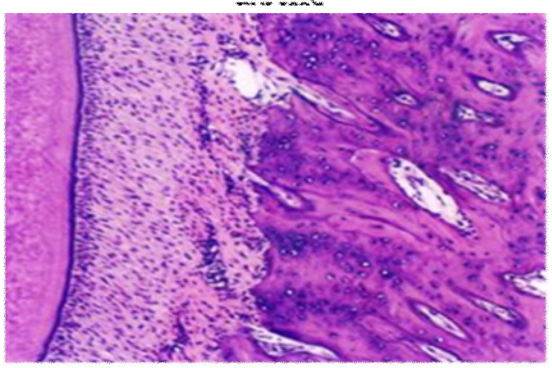

Fig. (20): Photomicrograph of the tension site of group (1) at one month showing increased cementoblastic layer, deep reversal lines and PDL reorganization (H. & E. x 100).

4.Discussion:

Orthodontic tooth movement is dependent on the ability of periodontal cells to react to mechanical stimuli. The most prominent features are the remodeling of the periodontal ligament and the resorption and deposition of alveolar bone, Ren et al.,(2005).

The orthodontic force is the promoting factor of alveolar bone remodeling. The force should be as slight as possible to prevent collateral effects such as bone necrosis or root resorption. On the other hand, accelerating the teeth movement is desirable, because the treatment duration, frequently months or even years, is considered very long, Cruz et al.,(2004).

Literatures show some methods to stimulate bone remodeling such as**,** drug injections like Prostaglandin, Yamasaki(1983) and osteocalcin. Kobayashiet al.,(1998), electric stimulation, Spadaro(1997) and ultrasound application are other methods, Hadjiargyrou et al., (1998).These methods could be associated with discomfort and pain, Kawasaki and Shimizu(2000) or need sophisticated apparatus and demands applications for a long term to achieve its therapeutic effects, Roberts et al.,(2006).

Recently, low level laser therapy (LLLT), a non-invasive and simple method, was reported to be able to accelerate tooth movement in animals with formation of better quality bone, and augmented production of differentiated osteoclasts, Kawasaki and Shimizu (2000); Youssef et al.,(2008).

Laser energy, when deposited on tissues, causes reactions of a physiological nature. In the organism, the interaction of low level radiation constitutes the energetic incorporation contained in the laser light beam on the radiated tissues. The consequences of these interactions are: 1) primary effects, subdivided into biochemical, bioelectrical and bioenergetics; 2) secondary effects that stimulate the microcirculation and cellular tropism; 3) therapeutic effects, which are analgesic, anti-edematous and healing results, Moreira et al.,(2004); Silveira et al.,(2007).

The amount of the force applied during orthodontic treatment affects the repair capacity; Steigman et al.,(1993). The fixed orthodontic appliance used in this study was designed to produce a distal tipping movement of the incisors by applying the same amount of force with all animals. This is why a moderate force of 90 gm was used in this study to avoid the effect of heavy force on the repair capacity, El-Namarawey(1986).

The rates of tooth movement were high especially during the second (4^{th}–14^{th} days) and third (15th-30th) periods of the study in group (1) compared to group (2). This is in accordance with Cruz et al. [18] who concluded that LLLT does accelerate human teeth movement and could therefore considerably shorten the whole treatment duration. By the end of the study period, all animals in reached the maximum interdental distance. This was due to cessation of the orthodontic force secondary to loss of the springing action of the orthodontic device by reaching the maximum distance between the two ends of the loop arms. This occurred earlier in group (1) followed by group (2). A clinical observation of value is the fewer occurrences of the gingival inflammation and swelling in the irradiated group compared to the non-irradiated one. This was in accordance with Honmura et al.,(1996) who reported that low power infrared irradiation on affected parts has an anti-inflammatory effect on acute and chronic inflammations.

In the present study, radiographic analysis was carried out for evaluation of bone density using direct digital system that has many advantages, among which, ability of image adjustment and manipulation , possibility of Image storage and the stored images can be used almost instantaneously, Topback et al.,(1999). Bone density at the tension sites was evaluated in this study. Statistically, there was a significant difference of bone density between irradiated and non-irradiated groups.

These results could be explained on lights of the results of Saito and Shimi(1997) who reported that LLLT significantly stimulated the number of bone nodules in a laser dose dependent manner. Also, Nicolau et al.,(2003) concluded that LLLT increased the osteoblasts activity and mineralization apposition rate during healing of bone defects in rats. Moreover, Khadra et al.,(2004) reported that LLLT stimulated the deposition of calcium, phosphorus, and insoluble proteins in rat calvarial bone defects.

The mechanisms by which laser irradiation can stimulate bone formation are not well understood but may be multifactorial and include osteogenic cell proliferation and differentiation, mitochondrial respiration, and ATP synthesis, in addition to promotion of angiogenesis and healing acceleration, Maegawa et al.,(2000); Khadra(2005).

By the end of the study period (30 days), highly detectable reorganization of the PDL, besides increased incidence of new bone tissue with multiple deep reversal lines and mature trabeculae in addition to osteoblastic proliferation were noted. The cementoblasts and precementum were increased. These histological features were more prominent in the irradiated group than the non-irradiated one.

The histological (H&E) results of the present study were in harmony with the clinical results. They explained the higher rate of tooth movement in the irradiated group compared to the non-irradiated one according to the fact that the speed of tooth movement is greatly dependent on the speed of bone remodelling, Kawasaki and Shimizu(2000) ;Youssef et al.,(2008)

In the current work, there was an agreement between clinical, bone density and histological findings and the statistical analysis of this experimental study.

In conclusion, low-level (Ga-Al-As) diode laser irradiation stimulated tooth movement accompanied with an acceleration of collagen formation and alveolar bone remodeling, as indicated by increases in the number and activity of both osteoclasts and osteoblasts in PDL and mineralized bone formation.

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