THE EFFECT OF SYSTEMIC ADMINISTRATION OF CO-ENZYME Q10 ON ORTHODONTIC RELAPSE IN A RABBIT MODEL

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ABSTRACT

INTRODUCTION: Several pharmacological agents have been investigated for their ability to reduce orthodontic relapse.

OBJECTIVE: The current research was performed to test the short term influence of systemic Co-enzyme Q10 administration on post-orthodontic relapse in rabbits.

MATERIALS AND METHODS : Thirty New Zealand rabbits were randomly divided into 2 groups (n=15) : Experimental receiving Co-enzyme Q10 and control receiving control vehicle. Orthodontic tooth movement was performed using NiTi coil spring for 21 days for both groups, then this coil spring was detached, and teeth were allowed to relapse for another 21 days. Amounts and percentages of relapse were assessed on three-dimensional models of the experimental and control groups at two time points (T2: 1 week of relapse) and (T3: three weeks of relapse). Animals were sacrificed after 3 weeks of relapse for histological examination using H&E stain. Also, histomorphometric analysis was performed. Statistical analysis was computed. Significance was judged at the 5% level.

RESULTS: The amount and percentage of relapse showed insignificant difference among experimental and control groups, although relapse in the experimental group was less. However, the histological analysis showed that Co-enzyme Q10 resulted in significant reduction in osteoclast count with the area of new bone formation being significantly increased. Signs of bone resorption were more evident in the control group.

CONCLUSION: From the present results, it could be concluded that Co-enzyme Q10 is capable of altering bone resorption pattern favorably in spite of its short term ineffectiveness in minimizing relapse.

KEYWORDS: Co-enzyme Q10, tooth movement, relapse, osteoclast.

RUNNING TITTLE : Co-enzyme Q10 and Orthodontic relapse.

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INTRODUCTION

Retaining teeth in the new satisfactory position after orthodontic correction is one of the most difficult tasks in orthodontics (1). Orthodontic relapse results from multiple factors including muscle disorders, persistent unfavourable habits, alterations in the shape of dental arch, undesirable remaining growth and the rebound of elastic fibers (2).

One of the methods of gaining orthodontic retention is bio-modulation. Endogenous or pharmacological agents serve to inhibit osteoclasts and activate osteoblasts, which would result in hindering bone resorption and promoting bone formation, respectively. These effects would control orthodontic tooth movement (OTM) and prevent relapse (3). Many bio-modulators and chemicals had been proposed to control relapse but they have some potential risks which requires caution during their use in controlling relapse (4,5). Co-enzyme Q10 (CoQ10) is a benzoquinone compound synthesized naturally by the human body and found in virtually every cell (6). This Coenzyme has two basic functions which account for its clinical usage. First, it is important for producing Adenosine Tri-Phosphate (ATP) as well as for cellular respiration. This occurs by its vital role in the electron transport chain within the mitochondrial membranes. Second, CoQ10 acts as an intercellular antioxidant in blood, cell membranes and lipoproteins (6).

Being an endogenous antioxidant (7), CoQ10 acts against free radicals and thus protects DNA and lipids from being damaged.

Patients with CoQ10 deficiency including either primary or secondary CoQ10 deficiencies can make use of CoQ10 supplementation. It is also useful in cases of mitochondrial disorders, diabetes mellitus, neurodegenerative diseases, cardiovascular diseases, cancer, male infertility and periodontal diseases (8). In the oral cavity, it has been known for more than 30 years (9) that oral supplementation with CoQ10 can be used for treating periodontal diseases and gingivitis. Yoneda et al (10) found the reduced form of CoQ10 to be effective against age related periodontal inflammatory reactions and had the ability to suppress osteoclast differentiation by inhibiting oxidative stress.

Regarding the effect of CoQ10 on bones, Varela Lopez et al (11) tested the action of giving a low CoQ10 dosage in n-6, n-3 polyunsaturated fatty acid or mono-unsaturated fatty acid based diets on the periodontium of young and old rats when supplemented as life long feeding. They concluded that CoQ10 supplementation could inhibit alveolar bone loss associated with age when n-6 polyunsaturated fatty acid was given to the rats. In an In-vitro study, Moon et al (12) found that CoQ10 suppressed osteoclastogenesis and increased osteoblast differentiation.

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From the results of the previous studies, CoQ10 could inhibit RANKL-induced osteoclast differentiation and enhance osteoblast differentiation for bone formation.

The current study investigated the effect of CoQ10 on the post-orthodontic treatment relapse in experimental rabbit models. It was hypothesized that CoQ10 may have osteoclastic and osteoblastic activities on alveolar bone which might minimize tooth movement after active orthodontic treatment and reduce post-orthodontic relapse.

The Null hypothesis of this study assumed that CoQ10 supplement has neither impact on relapse following orthodontic tooth movement nor alveolar bone remodeling accompanying orthodontic relapse.

MATERIALS AND METHODS

The experiment was carried out matching the ARRIVE guidelines (13) for animal studies as well as national guidelines for care and use of laboratory animals. An approval was obtained from the Research Ethics Committee, Faculty of Dentistry, Alexandria University, in Egypt. (IRB 00010556-IORG 0008839).

The minimal sample size was calculated based on a previous study in New Zealand white rabbits (14). This research aimed to study the effect of systemically administrated Bisphosphonates Pamidronate, on OTM along with osteoclastic count. To detect the difference in molar tooth movement as a primary outcome of 1.268 (large sized standardized effect size), the level of significance 95% (α=0.05) and a power of 90%, 15 rabbits per group (number of groups=2), total sample size=30 rabbits were needed as the minimum sample size (15).The sample size was estimated using G-Power version 3.1.9.2. (16).

Thirty healthy male New Zealand albino rabbits *(Oryctolagus cuniculus)*, aged 16 weeks and in the weight range of 2.5 to 3.5 kg were used for the experiment. Intact mandibular incisors and premolars, with closed contact between first and second mandibular premolars were main inclusion criteria. Rabbits were housed in the Medical Research Institute of Alexandria University, Egypt. Throughout the whole study period, the animals were examined daily for evaluation of general health status, weight changes, appliance failure, gingival or soft tissue inflammation. They were maintained at room temperature and humidity. Rabbits were fed with water and standard soft diet to reduce the incidence of appliance breakage. The experiment was conducted under general anesthesia using Ketamine [Egyptian Int. Pharmaceutical Industries CO. (E.I.P.I.Co)] 35 mg/kg and Xylazine [ADWIA Pharmaceuticals Co., CAIRO, EGYPT] 5mg/kg intramuscular injection.

In this prospective randomized controlled trial, rabbits were randomly allocated into 2 equal groups; experimental and control. For randomization, the computer was used to generate a list of random numbers. To counteract bias, this list was performed by an investigator who was blinded to the allocation of the study groups. Either the right or left side of the mandibular arch of each rabbit was randomly assigned to be subjected to experimental tooth movement, by flipping a coin. Tooth movement was done for 21 days using a 12 mm NiTi closed coil spring [ORMCO Co., USA] delivering 100 grams of force (Fig. 1A) measured using a force gauge [Correx Gauge, Haag-Streit, Koeniz

Switzerland]. A ligature wire with a gauge of 0.010 inch was wrapped around the first premolar to ligate the coil spring posteriorly. As means of anchorage, a piece of ligature wire was bonded connecting buccal surface of second premolar and first molar in order to prevent the effect of interseptal fibers (Fig. 1B). Another ligature wire with a gauge of 0.010 inch was wrapped around the incisor on the same side to attach the coil spring anteriorly. In order to avoid dislodgment of the appliance and lessen soft tissue irritation of any wire projections; 37 % phosphoric acid was used to etch enamel for 30 seconds around the coronal portions of the premolar and incisor, and a thin coat of flowable composite [Z350 XT Flow, 3M ESPE, Calif, USA] was applied to the etched surfaces and the overlying ligature wire and cured (14).

Throughout the period of tooth movement and relapse, Group A control; received daily oral gavage of placebo (5 ml olive oil) and Group B Experimental; received daily oral gavage of 25 mg/kg CoQ10 (17, 18) mixed with 5 ml of olive oil. CoQ10 powder was obtained from (MEPACO-MEDIFOOD [Arab Company for Pharmaceutical and Medicinal plants], Cairo, Egypt). The principal investigator blindly administrated the assigned solution to the rabbits.

Impressions were taken to the animals at three time points : day 21; T1 (at the appliance removal), day 28; T2 (1 week of relapse) and day 42; T3 (3 weeks of relapse). An injection type of silicone impression material, manufactured by 3M Dental Products was used to register these impressions after being placed in customized acrylic trays. Then, improved die stone [Elite Rock Dental Stone; Zhermack, Badia Polesine, Italy] was used to pour these impressions.

Three dimensional models in .stl file format were produced using a specific scanner [InEos X5; Sirona Dental Systems, Bensheim, Germany]. A method previously described using Viewbox software (19, 20) was employed to orient the models. First, the the mandibular occlusal plane was determined following the mandibular molars and second premolars through their cusp tips. Then, two perpendicular planes were constructed from the mandibular occlusal plane, one passing by the most distal point of the first premolar, and the other passing by the most mesial point of the second premolar. The distance between the 2 constructed planes was measured and regarded as the amount of tooth movement (Fig. 2a, 2b). These measurements were performed at each time point, to determine tooth movement and relapse after 1 and three weeks.

For intra-rater reliability, one investigator repeated tooth movement measurements, at 2 weeks interval. An intraclass coefficient was calculated to correlate between both readings. This would help to counteract any intra-examiner errors.

After 3 weeks of relapse, 8 animals were randomly chosen from each group to be euthanized following the American Veterinary Medical Association guidelines. Decapitation was performed after administration of 100 mg/kg intraperitoneal sodium pentobarbital.

The mandibles were dissected to obtain the half that was used in the experiment. The samples were fixed in 10% neutral-buffered formalin solution for 3 days, then decalcified using 10% EDTA for 4 weeks. Dehydration was done in ascending concentration of ethyl alcohol (50%, 70%, 90% and absolute

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alcohol). Then they were cleared in xylene, in-filtered in paraffin wax and embedded in blocks of paraffin wax and parasagittal serial sections of 6-mm thickness were obtained. The sections were stained with hematoxylin and eosin (21).

A light microscope [Primo Star; Carl Zeiss, Oberkochen, Germany] was used for histological examination of the longitudinal midsections found between both first and second bicuspids. Images of representative areas were taken by means of a 5-megapixel digital camera attached to the microscope and described histologically in a blinded manner without knowing the origin of each section. These images were also used for histomorphometric analysis.

Image J software [Image J software for Windows, version 1.50i; National Institutes of Health, Bethesda, Md] was used for image scale calibration. A square grid overlay was superimposed over the histologic sections. The length of each side of the square was 1 mm. The 2 opposite sides of the square were perpendicular to the root surface of the first premolar. To quantify the effect of CoQ10 on the periodontium, some parameters were measured. This included osteoclast (22), osteoblast (23) and capillaries count, areas of new bone formation (24) and active bone-resorptive lacunae (25). Intra-rater reliability was checked by repeating the measurements of the histomorphometric parameters by the same investigator at 2 weeks interval and intraclass correlation coefficients were calculated.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Kolmogorov- Smirnov test was used to verify the normality of distribution of variables. Student t-test was used to compare two groups for normally distributed quantitative variables. Intra class Correlation Coefficient was used for the agreement between R1 and R2. Significance of the obtained results was judged at the 5% level.

Figure 1: (A) A NiTi closed coil spring delivering 100 grams of force placed in one side of both experimental and control rabbits. (B) A piece of ligature wire was bonded connecting buccal surface of second premolar and first molar for anchorage.
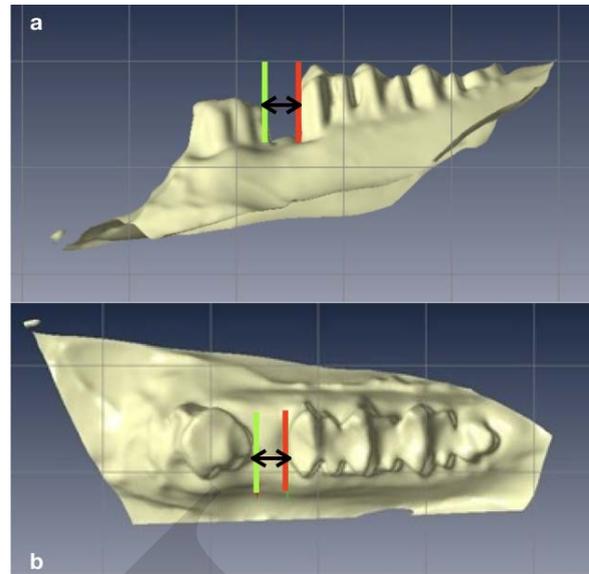

Figure 2 : 3D scan of the rabbit model showing the measurement of the distance between first premolar (green line) and second premolar (red line) to estimate the relapse amount and percentage. (a) lateral view. (b) occlusal view.

RESULTS

Mean values and standard deviations for amounts of first premolar movement and relapse at T1, T2 and T3 were calculated for both experimental and control groups (Table 1). Amounts as well as percentages of relapse were compared between both groups and found not to be statistically significant after 1 week [T1-T2] where the amount and percentage of relapse for control group were 0.86 ± 0.30 mm and 43.94 ± 14.94 % and for the experimental group were 0.72 ± 0.10 mm and 38.27 ± 7.53 %, nor after 3 weeks [T1-T3] where the amount and percentage of relapse for control group were 1.24 ± 0.39 mm and 59.11 ± 9.17 % and for the experimental group were 1.06 ± 0.29 mm and 54.71 ± 10.14 %.

Between both readings of teeth movement, the correlation coefficient was 0.958, indicating excellent level of agreement for these measurements.

Regarding the histological examination along the distal surface of mandibular first premolar, in control group, most examined slides showed disoriented periodontal fibers with numerous fibroblasts and dilated blood vessels, large Howship's lacunae containing osteoclasts and osteoblasts which deposited thin layer of woven bone and thin osteoid tissue (Fig. 3A). Some slides of the control group showed persistent bone segments which succeeded to escape the resorption caused by the compression force of relapse and were traced behind the resorption bays of osteoclasts and outlined interiorly by straight resting lines (Fig. 3A). On the other hand, the majority of the sections obtained from the experimental group contained many longitudinally oriented and deeply stained reversal lines, together with the bone being mature (the woven bone resorbed and replaced by lamellate bone) more than that on the same surface of the control group (Fig. 3B, 4B). Osteoclasts were still seen in the experimental sections, but were smaller, less frequently encountered and less active than those observed in the control (Fig. 4A, 4B). In the control group, some areas showed regular distribution of the periodontal fibers and others

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revealed irregular arrangement (Fig. 3A, 4A) while the experimental rabbits' sections showed a more regular arrangement pattern of the principal fibers and fibroblasts with minimum hyalinization areas (Fig. 4B). At discrete areas, extravasation of blood vessels were observed in both groups (Fig. 3, 4).

Regarding the histomorphometric parameters along the distal surface of mandibular first premolar, the area of new bone formation in the experimental group, was significantly more than the control group (P < 0.001) and the osteoclast count in the same group was significantly less (P = 0.001) (Table 2). There were no statistically significant differences between both groups regarding osteoblast count, area showing resorptive lacunae and capillaries count (Table 2). The calculated intraclass correlation coefficients for the repeated measurements of histomorphometric parameters were 0.811 for number of osteoclasts, 0.997 for areas of bone-resorptive lacunae, 0.759 for number of osteoblasts, 0.982 for area of new bone formation and 0.878 for capillaries count. Most of these results indicated high reliability for these measurements.

DISCUSSION

Rabbits have been selected as experimental models for evaluating the effect of CoQ10 on post-orthodontic relapse because rabbits have been widely used as models to study osteoporosis and bone growth into implants and bone implant interfaces (26). In addition, there were some similarities between rabbits and human regarding the bone mineral density and fracture toughness of mid-diaphyseal bone (26). Rabbits were also used due to their ease of handling and maintenance (26). In comparison to rats, the installation of intra-oral orthodontic appliance in rabbits is relatively easier and faster. Being less aggressive in nature with less health problems as compared with other breeds, New Zealand white strains of rabbits were selected for this study (26).

CoQ10 is characterized by its supplementation safety. Hidaka et al (27) concluded that the endogenous natural formation of CoQ10 is not affected by external intake. Also, when supplementation ends, CoQ10 does not accumulate into plasma or tissues. An acceptable daily intake of 12 mg/kg/day of CoQ10 was evaluated from a 52-week chronic toxicity study in rats as there weren't any side effects when a dose of 1200 mg/kg per day was given. In humans, clinical trials suggested that doses up to 3000 mg/day of CoQ10 did not cause serious adverse effects except for nausea and other minor adverse gastrointestinal effects. CoQ10 was found to be effective against osteoporosis (28, 29). Zhang et al (28) showed CoQ10 to be effective in attenuating spinal cord injury induced osteoporosis. In another study (29), CoQ10 alleviated ovariectomy induced osteoporosis in female Sprague-Dawley rats. These studies and others made us think of the effect of CoQ10 on alveolar bone remodelling and therefore, its usage in orthodontics to reduce bone resorption and induce bone formation following orthodontic treatment.

To our knowledge, the present study was the first to use CoQ10 as a bio-modulator in orthodontics for enhancing retention following active orthodontic treatment in rabbit models. The period of force application for tooth movement was 21 days which agreed with other studies evaluating OTM in rabbits (30, 31). A 100 cN force was employed to move

teeth. This was similar to the amount of force used for generating tooth movement of mandibular premolar in rabbits (31).

CoQ10 was administrated at the start of the experiment with OTM as it was found that by two weeks, plasma ubiquinol concentration reached steady-state (32). Therefore, this would guarantee that maximum plasma CoQ10 concentration was obtained at the time the relapse commenced.

The bioavailability of the drug is an important factor affecting its clinical effectiveness. The formulation of the drug is a crucial issue affecting the bioavailability. This study used CoQ10 in crystalline powder form. The crystalline powder CoQ10 is characterized by its poor solubility and high molecular weight, which resulted in its low and variable bioavailability in humans (33). A very basic improvement to powdered CoQ10 formulations is to disperse, suspend, or emulsify the CoQ10 in oil suitable for soft gels, as CoQ10 absorption is known to improve in the presence of fat (34). Oil-dispersed products had been shown to have improved bioavailability over crystalline CoQ10 (33). Therefore, CoQ10 was mixed with olive oil in the current study to improve its absorption, bioavailability and thus clinical benefit. The reduced form of CoQ10 (ubiquinol) had shown a higher bioavailability than the oxidized form of CoQ10 as ubiquinone (35, 36). In a recent trial with human subjects, the superior bioavailability profile of ubiquinol was clearly demonstrated when it was tested alone (32). In the conducted study, CoQ10 was used as ubiquinol.

The histomorphometric findings showed a significant reduction in the number of osteoclasts along the bone on the distal side (relapse side) of the first premolar of experimental group compared to the control group, which is in accordance with Yoneda et al (10) who revealed the ability of topically applied reduced CoQ10 in decreasing osteoclastic count when applied to Male Fischer 344 rats at 6 months of age. Also, Moon et al (12) found that CoQ10 suppressed osteoclastogenesis in an in-vitro cellular level study. Similarly, Gad et al (37) found significant reduction in the osteoclast count along the relapse pressure side in the experimental group of rabbits after omega-3 systemic administration. A significant decline in the number of osteoclast was also found when PRP was tested to evaluate its effect on orthodontic relapse (38). Locally administrated simvastatin (20) resulted in similar lowering of osteoclastic count as the current study.

The area of newly formed bone was significantly greater in the CoQ10 group than the control group which agreed with the results of Moon et al (12) who concluded that CoQ10 enhanced osteoblastogenesis new formation on the cellular level.

The histological picture along the distal surface of mandibular first premolar gave evidence of the presence of osteoclasts in the new woven bone of the experimental sections which indicated the replacement of woven bone with the lamellar one (remodeling). On the other hand, in control group, the presence of osteoid bone lining the old mature alveolar bone indicated the delayed formation of woven bone (modeling) and subsequent absence of remodeling of alveolar bone mechanism. These events proved the osteoinductive ability of CoQ10.

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The present events of increasing vascularity, alveolar bone remodelling, enhancing osteogenesis and osteoblastic activity, decreasing osteoclastic activity and down-regulating bone resorption were matching to the histological findings resulted in studies testing other agents for minimizing orthodontic relapse in experimental rabbits (20, 37, 38, 39).

In both groups, the experimental and control, the moved teeth showed post-orthodontic relapse toward their original positions after removal of the orthodontic appliance. The relapse amounts and percentages in the experimental group were less than that of the control group after 1 and 3 weeks of relapse, however, this difference was not statistically significant. The systematic administration of omega-3 polyunsaturated fatty acids in rabbits (37), was tested to reveal its effect on relapse of tooth movement. Similar results were obtained regarding the amounts and percentages of relapse after 1 and 3 weeks of relapse which is similar to the current results, except for the relapse percentage after 3 weeks which was significantly less in the experimental group than control group. Alswafeeri et al (20) in their split mouth design, carried out to evaluate the effect of local administration of simvastatin on post treatment relapse in rabbits. They found that there was insignificant difference in the relapse amount and percentage between the 2 mandibular quadrants.

On the other hand, the local injection of PRP in rabbits throughout a split mouth design (38) found a significant decrease in the amount and percent of relapse in the PRP injected teeth when compared to the control group at both 1 week and 4 weeks relapse intervals. Similarly, the local injection of carbonated hydroxyapatite-incorporated advanced platelet-rich fibrin (CHA-aPRF) resulted in significant reduction in the relapse rate and distance when compared to the control group at days 14 and 21 of relapse (39).

One can argue that since there were significant differences in the osteoclast count and area of newly formed bone between both groups, post-orthodontic relapse would be significantly lower in the CoQ10 group. Unfortunately, this did not take place which could be justified by the fact that no specific single causative factor could be blamed alone for orthodontic relapse. The importance of remodeling of the PDL and surrounding alveolar bone in the relapse process could not be ignored. In addition, as soon as the orthodontic appliance was removed and the force had stopped, transeptal elastic fibers released a stored energy and resulted in significant post-orthodontic relapse in both groups (40). It can be proposed that a longer period of tooth movement or of relapse could have yielded significant difference in relapse, which is yet to be researched.

The dose of CoQ10 given to the experimental group rabbits was 25 mg/kg/day. This dosage was equivalent to some animal studies using CoQ10 in rabbits (17, 18). However, these studies were not testing the effect of CoQ10 on orthodontic tooth movement. Therefore, another dose of CoQ10 would have elicited different results which needs further future studies.
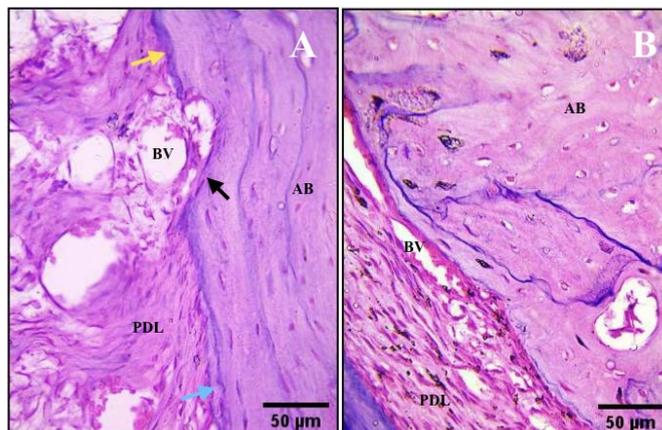

Figure 3 : Photo micrograph of the distal surface of the mandibular first premolar of control group (A) shows disoriented periodontal fibers with numerous fibroblasts and dilated blood vessels, a large Howship's lacuna containing osteoclasts and osteoblasts (black arrow), thin layer of woven bone (blue arrow) and thin osteoid tissue (yellow arrow). Photo micrograph of the distal surface of the mandibular first premolar of CoQ10 group (B) illustrates oriented periodontal fibers with numerous fibroblasts and dilated blood vessels, a relatively smooth alveolar bone surface with numerous palisaded osteoblasts. The dark blue reversal line delineated the new lamellate bone formation of the alveolar area along the distal surface of the mandibular first premolar. BV: blood vessels, PDL: periodontal ligament, AB: alveolar bone. (hematoxylin and eosin stain, magnification ×400).
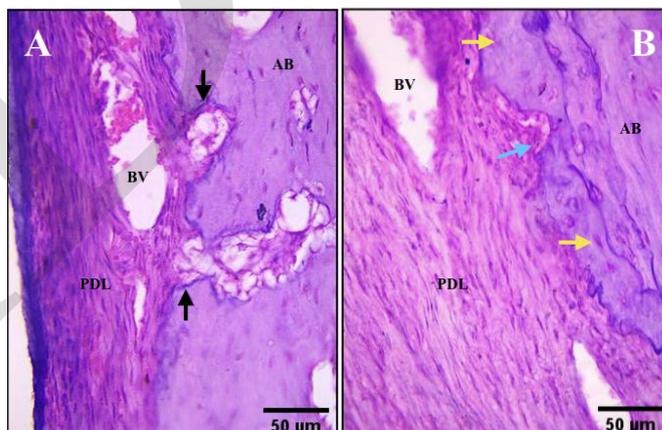

Figure 4 : Photo micrograph of the distal surface of the mandibular first premolar of control group (A) shows disoriented periodontal fibers with numerous fibroblasts and dilated blood vessels, two large Howship's lacunae containing numerous osteoclasts and thin blue layer of osteoid tissue (black arrows). Photo micrograph of the distal surface of the mandibular first premolar of CoQ10 group (B) illustrates orientated periodontal fibers (oblique fibers) with numerous fibroblasts and dilated blood vessels, thick irregular layer of woven bone (yellow arrows) containing large numerous osteocytes. Note the osteoclast in its lacuna (blue arrow). The dark blue reversal line delineated the new bone formation of the alveolar area along the distal surface of the mandibular first premolar. BV: blood vessels, PDL: periodontal ligament, AB: alveolar bone. (hematoxylin and eosin stain, magnification ×400).

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Table 1 : Amount of first premolar movement and relapse (T1: at appliance removal, T2: 1 week relapse and T3: 3 weeks relapse) in control group and CoQ10 group

	Amount of tooth movement (mm)	Amount of relapse (mm)		Percentage of relapse	
	T1	**T1-T2 1 week**	**T1-T3 3 weeks**	**1 week**	**3 weeks**
Control	2.08 ± 0.44	0.86 ± 0.30	1.24 ± 0.39	43.94 ± 14.94	59.11 ± 9.17
Experimental	1.96 ± 0.54	0.72 ± 0.10	1.06 ± 0.29	38.27 ± 7.53	54.71 ± 10.14
t	0.662	1.794	1.474	1.314	1.245
p	0.513	0.091	0.152	0.199	0.223

t: Student t-test
p: p value for comparing between the studied groups

Table 2 : Histomorphometric parameters in control group and CoQ10 group

	Osteoclasts count **	Osteoblasts count **	Area of new bone formation***	Area of bone resorptive lacunae ****	Capillaries count **
Control	3.0 ± 0.85	90.47 ± 3.74	28.55 ± 2.38	0.26 ± 0.07	11.60 ± 4.05
Experimental	1.93 ± 0.70	90.93 ± 2.89	32.37 ± 2.59	0.26 ± 0.05	12.13 ± 3.74
t	3.756*	0.382	4.209*	0.211	0.375
p	0.001*	0.705	<0.001*	0.834	0.711

t: Student t-test
p: p value for comparing between the studied groups
*: Statistically significant at p ≤ 0.05
** : number per square millimeter of bone surface.
***: % (percentage) of total bone.
****: mm2/ mm2 of bone surface

Figure 1: (A) A NiTi closed coil spring delivering 100 grams of force placed in one side of both experimental and control rabbits. (B) A piece of ligature wire was bonded connecting buccal surface of second premolar and first molar for anchorage.
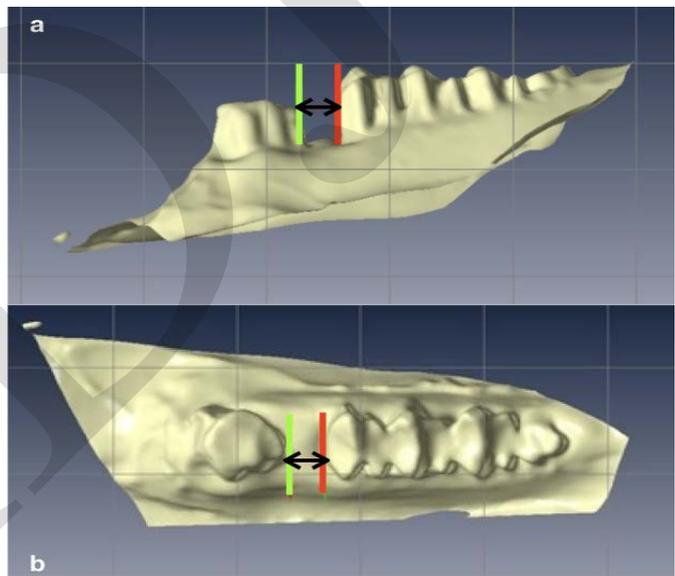

Figure 2 : 3D scan of the rabbit model showing the measurement of the distance between first premolar (green line) and second premolar (red line) to estimate the relapse amount and percentage. (a) lateral view. (b) occlusal view.
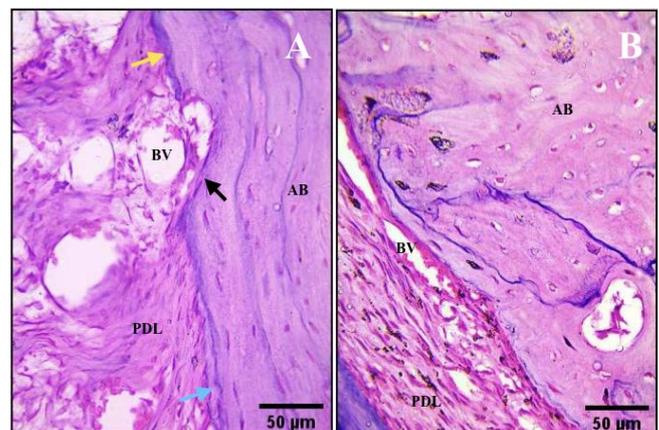

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Figure 3 : Photo micrograph of the distal surface of the mandibular first premolar of control group (A) shows disoriented periodontal fibers with numerous fibroblasts and dilated blood vessels, a large Howship's lacuna containing osteoclasts and osteoblasts (black arrow), thin layer of woven bone (blue arrow) and thin osteoid tissue (yellow arrow). Photo micrograph of the distal surface of the mandibular first premolar of CoQ10 group (B) illustrates oriented periodontal fibers with numerous fibroblasts and dilated blood vessels, a relatively smooth alveolar bone surface with numerous palisaded osteoblasts. The dark blue reversal line delineated the new lamellate bone formation of the alveolar area along the distal surface of the mandibular first premolar. BV: blood vessels, PDL: periodontal ligament, AB: alveolar bone. (hematoxylin and eosin stain, magnification ×400).
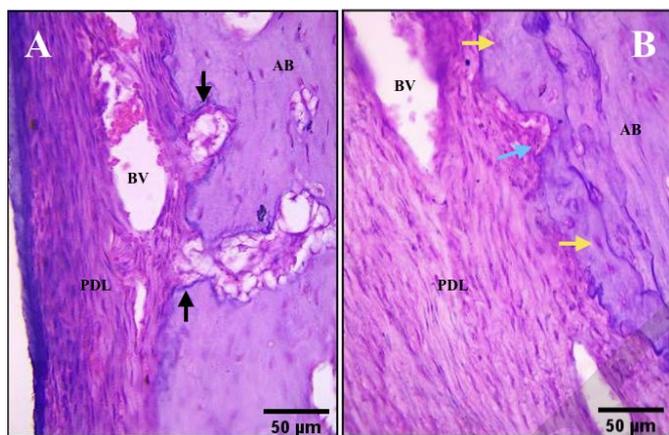

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CONCLUSION

Although the present results showed insignificant differences in relapse amounts and percentages between control and experimental groups, the histomorphometric study proved that CoQ10 is still a potent bio-modulator which can be used with different parameters in future researches to evaluate its effectiveness.

CONFLICT OF INTEREST
The authors declare that they have no conflicts of interest.

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