ISSN: 3033-3555

Research Article

Journal of Stomatology & Dental Research

Post-Orthodontic Relapse Prevention through Caffeine Administration on Osteocytes

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Received: February 20, 2025; **Accepted:** March 03, 2025; **Published:** March 10, 2025

ABSTRACT

Background: Relapse during passive orthodontic treatment is a major issue, with 70–90% frequency.

Purpose: This study also aims to analyze the effect of caffeine on orthodontic relapse in rats.

Methods: This study utilized 18 male Wistar rats which were randomly divided into two groups: caffeine and the control group (CG). The rats were subjected to a 35 cN orthodontic force for a duration of 7 days, after which the rats were conditioned to be passive. During this phase, the caffeine group received daily administration of caffeine. Subsequently, the appliances were detached to facilitate relapse. The distance between the mesial tips was measured using a digital caliper at three consecutive time points: 0, 3, 5, and 7 days after debonding.

Results: The number of osteocytes was examined using hematoxylin–eosin staining. The data were subjected to statistical analysis using a t-test. The relapse distance of the Caffeine group was lower than that of the control groups on day 7. Histological examinations using hematoxylin–eosin (HE) staining showed a significant increase osteocytes during orthodontic relapse movement ($p < 0.05$).

Conclusion: This study found that caffein may reduce orthodontic relapse by increasing osteocytes number in rats.

Keywords: Caffeine, Orthodontic Relapse, Osteocyte

Introduction

One of aspect the hardest in plan maintenance orthodontics is maintain tooth in position end post maintenance orthodontics finished. In 1934, Oppenheim asserted that maintain results obtained after maintenance orthodontics is one of the matter the hardest from all aspect overall care [1]. Maintenance orthodontics need retention for stabilize results and maintain harmony teeth. Without retention, teeth tend return to position originally, a condition called relapse. Various methods and assess which method is best for every patient for minimize relapse Already widely done [2]. Coffee is one of the lots of drinks liked all circles age, no except patients who are orthodontic treatment [3]. Coffee contains compound bioactive with characteristic antioxidants and anti- inflammatory, including sour chlorogenic acid, magnesium, lignans, quinides, trigonelline, diterpenes and N-methylpyridine [4]. Coffee contains, among other things, a substance called caffeine (1,3,7 trimethylxanthine), acid chlorogenic and caffeic acids, as well as flavonoids which have effect antioxidants. Robusta coffee has activity high antioxidant compared to with Arabica coffee and others [5]. Meanwhile, several epidemiological studies have shown that caffeine accelerates calcium loss, potentially increasing the risk of bone loss and osteoporosis [6]. Researchers have also found that caffeine can stimulate bone resorption in two ways: by increasing osteoclast differentiation and maturation and by affecting the osteogenic differentiation and bone-forming ability

Citation: Muhamat Muhtar S Abdurrohman, Fadhila Fahiratunisa'aini, Christina Mahardika, Niluh Ringga Woroprobosari. Post-Orthodontic Relapse Prevention through Caffeine Administration on Osteocytes. J Stoma Dent Res. 2025. 3(1): 1-4. DOI: doi.org/10.61440/JSDR.2025.v3.19

of bone marrow-derived mesenchymal stromal cells [7]. The activity of osteoclasts and osteoblasts is not regulated, bone metabolism will be negatively affected [4]. Animal studies have shown inconsistent results, with some studies reporting that high-dose caffeine consumption (diet with 0.2% caffeine or 100 mg/kg) inhibits bone growth, reducing bone mineral density [8].

Caffeine can also reduce the differentiation of mesenchymal stem cells (MSCs) into osteoblasts by reducing the binding of alpha-1 core binding factor (Cbfa1). Caffeine exposure in the right dose can inhibit the formation of osteoblast cells and cause a decrease in bone mineral density (BMD). Decreased BMD can trigger accelerated bone remodeling and shorten the duration of orthodontic treatment [9]. Based on other researchers, it has been shown that moderate caffeine intake (around 400 mg in humans) can maintain bone homeostasis by affecting the balance of osteoclast and osteoblast numbers. However, long-term high-dose caffeine consumption (around 800 mg in humans) can have adverse effects on the skeletal system [7]. The amount research that examines the impact of caffeine on orthodontic treatment, but the research has mostly reviewed its effects on accelerating tooth movement and there has been little research on its effects on relapse, making it interesting to conduct research.

Research Methods

Study this quasi experimental with design study post-test only control group design has get permission from commission FKG UNISSULA ethics with No.578/B.1-KEPK/SA-FKG/VI/2024. Caffeine (purity 50% and 100%) was obtained from the distributor of Nusantara coffee.

In this study, 36 10-week-old male Sprague–Dawley (weighing 250–300 g) were randomly divided into two groups and then divided into four subgroups based on observation time (days) namely 0 (3 hours), 3, 7 and 14 after orthodontic appliance installation. Ketamine (35 mg/kg BW) and xylazine (5 mg/kgBW) anesthesia were given before orthodontic appliance installation. The bracket used was Edgewise which has no memory. The force was applied using a 0.12x0.30 NiTi open coil spring (diameter = 2 mm; wire arm length = 2.1 mm) and a 0.16x0.22 rectangular stainless steel main wire (DiynaFlex, Missouri, USA) with cinch back at both ends of the wire. The orthodontic force used was 3.5 oz which was measured using an orthodontic force meter and obtained a central interincisor distance of 4 mm. Shortly after orthodontic appliance placement, caffeine was administered to rats in the treatment group orally once a day using an oral tube at 9 am.

Samples were taken on the day to 0, 3, 7, and 14 after release device orthodontics (phase post stabilization). Taking sample day 0 done quick after release device orthodontics group days 0, 3, 7 and 14. Retrieval sample done in the morning day 08.00-10.00 WIB. Anesthesia animal use chloroform, after respiratory arrest, mandibular jaw in relapse area taken (decapitation) with cut use saw small with cutting from direction sagittal. Jaw lower Then entered to in tube contains 10% formalin for fixation network and labeled on the media location, then checked in the Histology Laboratory of the Faculty of Medicine, Sultan Agung Islamic University. Two-way ANOVA test for now difference between group. Further testing Post Hoc Tukey for now different groups.

Results

Research result osteocytes in a way histological use coloring Hematoxylin-Eosin (HE) and microscopy with 400x magnification. HE staining selected Because give good contrast, so that the cell nucleus looks blue old or purple, and cytoplasm seen red young, like seen in Figure 1.

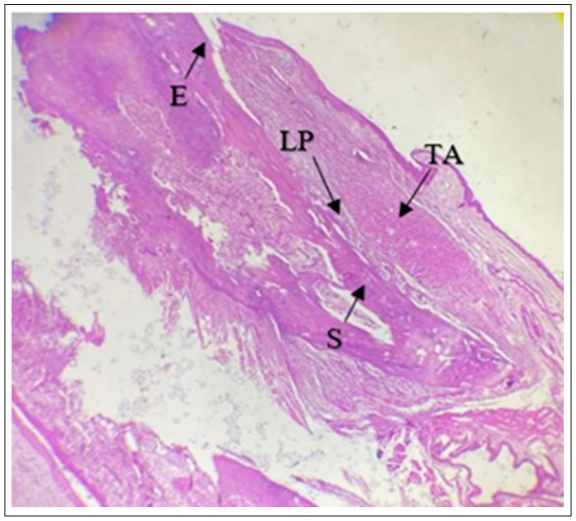

Figure 1: Histology relapse area 10x magnification with HE staining using microscope light. (TA) alveolar bone, (LP) periodontal ligament, (S) cementum, (E) enamel

In the group control, no There is improvement amount osteocytes day 0 to day 14. In contrast, in the group that received caffeine 50 mg/kg and 100 mg/kg showed improvement amount osteocytes on days 7 and 14, although No There is increase on day 0 and 3. Histological picture osteocytes from each group can see in Figure 2.

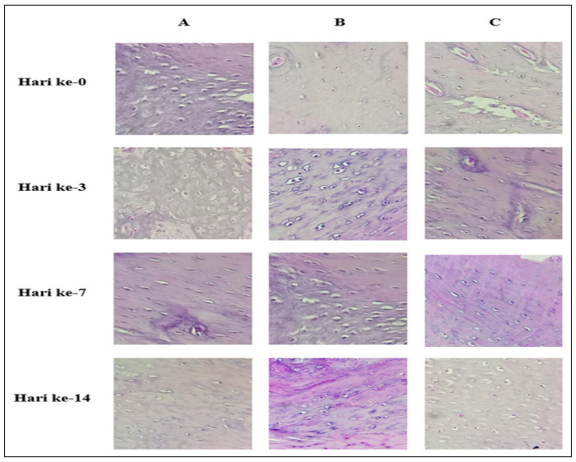

Figure 2: Histological picture cell osteocytes with HE staining at 400x magnification using microscope light on days 0, 3, 7, and 14. (A) group control negative aquadest (B) treatment giving caffeine 50 mg/kg (C) treatment giving caffeine 100 mg/kg.

Observation and calculation osteocytes of five fields view stock histological and analyzed using descriptive tests for determine mean and standard deviation each group treatment. The results showed that amount osteocytes lowest found in the group control negative aquadest on day 0, the amount highest found in the group treatment caffeine 100 mg/kg on day 14, as shown in Figure 3.

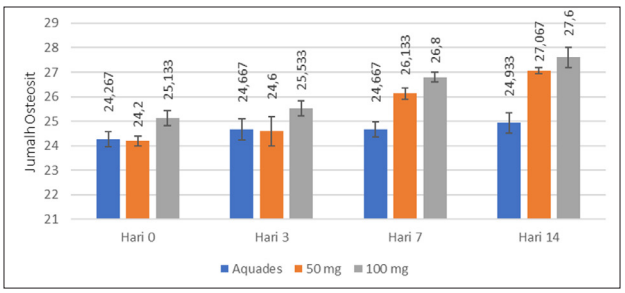

Figure 3: Graph Development Average Amount Osteocytes

Two-way ANOVA test p value =0.000 (p<0.05), exists difference significant between dose caffeine and phase post-stabilization orthodontics to amount osteocytes. Tukey's post hoc test p value <0.05, there is difference significant between time in day and group day 0 and 3 (p=0.086). Group control aquadest and group giving caffeine 50 mg/kg and 100 mg/kg (p=0.000), were present difference significant. In the group control negative distilled water, no There is improvement amount osteocytes. In contrast, in the group giving caffeine 50 mg/kg and 100 mg/kg, occurred improvement amount osteocytes on days 7 and 14.

Discussion

Component main coffee, caffeine own Lots benefit in metabolism and bone remodeling. Research previously show that intake caffeine can influence metabolism bones, with effects that depend on several factors, such as dosage, method granting, and conditions test animals [10]. Study other show results that giving caffeine effective increase expression osteocalcin in the area pressure and tensile areas [11]. Osteocalcin This secreted by osteoblasts. The amount osteocalcin in the area pulls bigger than area pressure. Osteocalcin This play a role in regulation metabolism bone with interact with cells bone others and factors growth. Osteoclastin also helps in maintenance balance between formation bone new (osteogenesis) and resorption the bone that occurs in a way experience in the bone remodeling process [12].

Osteocytes own a very important role in the bone remodeling process, namely in arrange balance between formation bone new and resorption old bone. Osteocytes functioning for to regulate two types of activities cell bone main, namely osteoblasts and osteoclasts. Osteocytes produce various factor molecular such as RANKL and OPG, both of which own function specific in arrangement activity osteoblasts and osteoclasts. RANKL is responsible answer for stimulate formation and activity osteoclasts, which play a role in the process of resorption or destruction bone on the other hand, OPG works as inhibitor activity osteoclast with binds to RANKL, preventing it from interact with receptors on osteoclasts. Interactions dynamic between RANKL and OPG is very important in arrange balance resorption bones, ensure that the bone remodeling process in progress in a way controlled and balanced. Relapse occurs on day 1 to 24th day after release orthodontic appliance [13].

Periodontal ligament and surrounding gingiva tooth will experience stretching when tool orthodontics used for move teeth. Movement process This trigger activity cells osteoblasts and osteoclasts, osteoblasts to form bone new and osteoclasts bone destruction [14]. Contraction gingival fibers will happen after maintenance orthodontics that can causing relapse especially If amount active osteoblasts lower compared to with amount osteoclasts that break down bones. The growth pattern is still in progress after maintenance orthodontics can also become reason relapse occurs due to improvement activity osteoclast in change supporting bones teeth. Teeth that have been moved will surrounded by new osteoid formed which is produced by osteoblasts. This is can result in relapse if amount osteoblasts No Enough For stabilize position new teeth. Condition medium bone experience calcification this, if No balanced with activity adequate osteoblasts No will give sufficient stabilization For teeth, so that increase possibility relapse occurs due to domination osteoclast in the bone remodeling process [15].

Osteocytes in the area pull with more amount tall found in mice with treatment giving caffeine with dose of 100mg/kg compared with dose of 50 mg/kg. This is can concluded that in the area pull the happen improvement activity metabolism more bones tall compared to the group control aquadest. This is Still needing inspection more carry on about activity metabolism bone is a positive thing or going to changes that can be made lower density bone. Osteocytes Alone Already often known as regulating cells homeostasis from bone. Osteocytes arrange signal from the bone remodeling process, both going to phase regeneration and also degeneration phase [13].

Research conducted by Miao et al., which traced effect from giving caffeine to osteoclastogenesis and osteoblastogenesis. Animal experiments giving dose moderate (55.44 mg/kg) protection to erosion bone consequence ovariectomy with hinder osteoclastogenesis and promote osteogenesis, whereas at doses high (110.88 mg/kg) increasingly to worsen erosion bones and reduce strength bone with inhibits osteogenesis and promotes osteoclastogenesis.

In vitro, caffeine dose moderate (12.5 μg /mL) inhibits track RANKL -induced signals (MAPKs and NF- κB) with obstruct RANK interaction with c-Fos. In addition, it hinder MAPK, NF-κB, and AKT pathways that stimulate Runx2 expression, so that promotes osteogenesis. In contrast, caffeine dose high (50 μg / mL) increases track RANKL (MAPKs and NF- κB) signaling with facilitate interaction between RANK and c-Fos. It also activates phosphorylation IκB α, P65, and JNK, which decrease Runx2 expression and with thus suppress osteogenesis [7].

Amount osteocytes in study This is also influenced by factors time. Time factor can influence osteocytes in study about influence giving caffeine to amount cell osteocytes in the area of post- alveolar bone relapse stabilization orthodontics Because happen improvement activity osteoblasts. Osteoblasts are cells the bones responsible answer on formation matrix bone. Activity increased osteoblasts can produce improvement production matrix bones, which in turn can trigger proliferation and differentiation of osteocytes [16].

Osteocytes is cells bone mature involved in the process of bone remodeling, incl bone resorption and apposition [17]. This process need time for happens and changes in amount osteocytes can observed as response to external stimuli like giving caffeine. Osteocytes can react to caffeine with change activity they, proliferation, or metabolism bones, but response This Possible need time certain For observed or assessed [18].

On day 0 and 3 no there is difference amount osteocytes that may cause by the range short time. Osteocytes plays a role in bone remodeling some activities [19]. In the study histological show that stage first bone remodeling that is resorption happen in 3-5 days followed with recovery in 5-7 days. In line with results study This moment resorption process occurs that is, day 3rd no There is addition amount osteocyte cells [20]. This is followed by the stage end apposition bone between 7 and 14 days. Apposition the bone that occurs during movement tooth orthodontics is a biological process that involves response inflammation acute. Stage end This happen addition or formation bone new (osteogenesis) around moving teeth [21]. This is in accordance with our findings were found improvement amount cell osteocytes on the 7th and 14th day, which can indicate the ongoing osteogenesis process happened. Recommendation clinic in study This that caffeine capable affect post relapse maintenance orthodontics.

Thank-You Note

We say accept love to Department Orthodontics Faculty Dentistry of Sultan Agung Islamic University and LPPM Sultan Agung Islamic University Semarang on behalf of support in study This.

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