

Effects of Carbonated Soft Drink Consumption on Orthodontic Tooth Movements in Rats

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Abstract

Objective: The aim of this animal study was to evaluate the possible effects of Carbonated Soft Drink consumption on the rate of orthodontic tooth movement in rats.

Materials and Methods: Thirty-six adult male Sprague-Dawley rats were randomly divided into two experimental groups and one control group. In the experimental groups (A&B), the water in the dietary regimen was replaced with soft drinks (Fanta® in group A and Cola® in group B) two weeks before placement of orthodontic appliances. Then 5-mm nickel-titanium closed-coil springs were placed between the maxillary right first molars and first incisors under general anesthesia. This regimen continued for two weeks more and animals drank soft drink ad libitum. At the end of the experimental period, the rats were sacrificed, and interproximal tooth movements were measured.

Results: The mean amounts of tooth movement were 0.19mm in group A, 0.22mm in group B and 0.37mm in group C. Statistical analysis with analysis of variance (ANOVA) test showed significant differences between all groups. The least movement occurred in group A that had received Fanta® drink.

Conclusion: CSDs consumption decreases the rate of orthodontic tooth movement. The role of soft drinks in decreasing tooth movement might be related to its effects on bone metabolism.

Key Words: Carbonated Beverages; Soft Drinks; Tooth Movement; Rats

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INTRODUCTION

Consumption of carbonated soft drinks (CSD) and sweetened beverages has increased among various age groups in many communities [1]. Many cross-sectional studies in the USA have

shown that the increasing consumption of these drinks has led to obesity in children and adults [2]. Frequent use of cola and sweetened beverages is statistically correlated with an increased risk of type II diabetes in liable

people [3]. Hypocalcemia is also another controversial side effect of these drinks on the general health of individuals [4].

Some studies also reported that regular consumption of these drinks that contain high sugar is correlated with higher risk of cardiovascular diseases in females [5]. Furthermore, cola consumption is a risk factor for metabolic diseases in middle-aged adults [6]. Nutritional and health related effects of soft drink consumption has been proved in researches [7].

Long-term consumption of caffeinated and uncaffeinated soft drinks seems to have bone catabolic effects in human beings with negative effects on the total protein intake [8]. Heavy cola intake in human and animal models induces some metabolic effects such as hypocalcemia, secondary hyperparathyroidism, and a reduced 1 α , 25-dihydroxyvitamin-D level [9]. It has also been reported that cola beverage consumption delays alveolar bone healing in rat models [10].

Approximately 15% of orthodontic patients are adults and the rest are teenagers and children [11]. Regarding high consumption of cola among lower age groups, it seems that CSD consumption could be a problem in orthodontic patients. The complications of CSD consumption in the oral cavity of orthodontic patients includes reduction in the shear bond strength of orthodontic brackets [12], decreased enamel microhardness [13], even in short-term consumption, and calcium release from the enamel surface specially in patients with salivary gland dysfunction or decreased salivary flow [14], and an increased risk of dental caries [15].

Based on the proved effects of CSD on bone metabolism, and since orthodontic tooth movement can be considered as a kind of bone remodeling process, it seems that these drinks may affect orthodontic tooth movement [16]. Therefore, this animal study was conducted to find the possible effect of CSD consumption on orthodontic tooth movement.

MATERIALS AND METHODS

The proposal of this study was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran. Thirty six male mature Sprague-Dawley rats weighing 260 \pm 20 g were selected from the animal keeping center of the school of medicine of Yazd University of Medical Sciences, Yazd, Iran. The rats were kept in plastic cages in standard conditions (12h light and 12h darkness at 22 \pm 2 $^{\circ}$ C temperature and 55% moisture). The rats were fed with the commercial standard rat chow (nutricubos) containing calcium (0.8%-1.2%), phosphorus (0.7%-0.9%) along with 3060- kg unit of vitamin D and a sufficient supply of water ad libitum. Experiments were performed according to the guidelines of the US National Institutes of Health (NIH Publication No 85-23, revised 1985)..

The rats were randomly divided into 3 equal groups; two experimental groups (groups A&B) and one control group (group C). Two weeks before placement of the orthodontic appliances, the diets of group A and group B were changed in the following way: in group A, water was replaced with Fanta[®] (one of the accepted soft drinks in the country) and in group B, water was replaced by Coca Cola[®] (another most frequently consumed cola soft drink in Iran), and the drinks of all groups were changed daily and animals drank ad libitum. The rats were anesthetized with interperitoneal injection of a mixture of xylazin HCL 0.9 mg/kg, and ketamine 70 mg/kg in the left groin. Following installing appliances a similar orthodontic force was applied to all three groups.

Orthodontic treatment and Orthodontic Tooth Movement (OTM) measurements

The orthodontic force application system consisted of a 5mm NiTi closed coil spring ((Hitek, 3M Unitek, Monrovia, Calif) which was placed between the first molar and the right incisor using a ligature wire (0.25mm

stainless steel, Dentaurem, Ispringen, Germany). To increase retention in the incisor area, a cervical groove was created in the cervical portion of the incisor with a round 0.8-mm diamond bur and each tooth was etched with 37% phosphoric acid for 40 s, and then rinsed with sterilized water. Next, the ligature wire was placed on the fissure and bonded with composite resin (Super Bond; Sun Medical, Shiga, Japan). The NiTi closed coil spring exerts a 60 g force in the activation ranges between 2 and 7 mm.

OTM measurements

In this study inclusion criteria were existence of tight interproximal contact between the right first and second maxillary molars. Fourteen days after placement of the appliances, the rats were anesthetized with ether and sacrificed. After separation of the maxilla, the amount of orthodontic tooth movement between the maxillary first and second molar was measured using interproximal filler gauge.

This gauge has several sheets with different thicknesses. The thickest sheet is 0.63 mm and the thinnest one is 0.02 mm. Measurements were performed before removal of the orthodontic appliance to prevent possible errors that result from relapse.

All the measurements were done by the same person and then repeated by another person for accuracy.

Statistical analysis

The mean value was used for the final assessment.

According to the Kolmogorov-Smirnov test, data distribution was normal and ANOVA and LSD test were used to compare means between groups.

RESULTS

At the end of the 14-day period of orthodontic force application, the amount of orthodontic tooth movement was measured in all groups. Mean, standard deviations, maximum, and minimum amounts of orthodontic tooth movement in all three groups are presented in Table 1. One-way ANOVA showed significant difference in the amount of tooth movement between all groups ($P=0.009$). The LSD test showed that the amount of tooth movement in groups A and B that received soft drinks were significantly lower than the control group (C) ($P<0.05$). Additionally, it has been shown that the amount of tooth movement in group A (mean, 0.19mm) was lower than group B (mean, 0.22mm), but the difference was not statistically significant ($P=0.613$).

DISCUSSION

Orthodontic tooth movement is a complicated process based on the bone remodeling process [16]. Many human and animal studies have evaluated the effects of drug therapy and hormonal changes on tooth movement [17], but we did not find any study that had evaluated the effects of CSD consumption as an reputed diet regime on orthodontic tooth movement. Since most of the orthodontic patients are children and teenagers, the issue of CSD consumption is considered a potential problem among orthodontic patients [11].

Table 1. Mean, Standard Deviation, Maximum and Minimum Tooth Movement

| Group | Mean Movement (mm) | SD | Max Mov.(mm) | Min Mov.(mm) |
|----------------|--------------------|------|--------------|--------------|
| A (Fanta®) | 0.19 | 0.09 | 0.3 | 0.03 |
| B (Coca Cola®) | 0.22 | 0.14 | 0.4 | 0.08 |
| C (Control) | 0.37 | 0.12 | 0.5 | 0.20 |



Fig 1. Coposition of carbonated soft drinks

Coca Cola®: water, carbon dioxide, sugar, caramel, phosphoric acid, flavorings, caffeine (<100 mg/l).

Fanta®: water, carbon dioxide, sugar, citric acid, acacia gum, potassium sorbate, sodium nitrate, flavorings, gum sitrate

CSDs contain various ingredients including water, sugar, citric acid, phosphoric acid, and other additives (Figure 1).

Coca Cola®: water, carbon dioxide, sugar, caramel, phosphoric acid, flavorings, caffeine (<100 mg/l).

Coca Cola® drinks contain 17 mg/100ml of phosphate in the form of phosphoric acid, 10 mg/100ml caffeine and 10/69 mg/100ml sucrose as the main ingredients [18].

Theoretically, diets with a high amount of phosphate and low amount of calcium lead to a decreased serum level of calcium and a provoking complex for PTH, leading to decalcification of the bones and reestablishment of calcium homeostasis in the body. Yet, it has been suggested that the amount of phosphoric acid present in the Cola drink® is not sufficient for this scenario[19].

High phosphorus intake was shown to cause bone loss in animals [20]. In another study, cola intake caused significant hypercalciuria and hyperphosphaturia; in immature and adult rats, the older animals also developed hyperparathyroidism [21].

Two recent studies have proved negative effects of these phosphate containing drinks on the bone metabolism. In this regard, we can expect negative effects of these drinks on orthodontic tooth movements as a bone remodeling phenomena. It has been noted that high amounts of sugar (also needed to sweeten the carbonated soft drinks) can negatively affect the mineral balance of the bone [22]. Paldanius [23] reported that high loads of glucose significantly decrease S-OC (serum osteocalcin), its carboxylated type, and bone resorption markers as β CTX-I, TRACP 5b and bone formation markers as PINP in normoglycemic individuals with a normal response to insulin during OGTT. This approves the negative effect of high loads of sugar on bone metabolism. The oral intake of high amounts of sugar leads to a rapid, statistically significant decrease of bone formation and resorption markers, osteocalcin and its carboxylated type [23]. This shows the strong effects of glucose on bone turnover. The controlling effect of glucose on bone turnover was proved in the study by Clowes and co-workers [24].

The type of sugar also appears to be an important factor by influencing the amount of beverage consumed. Tsanzi et al. illustrated that glucose promotes beverage consumption and this in turn affects mineral homeostasis by altering mineral intake and excretion [25]. Both types of CSDs studied in this research have high amounts of sugar as sweeteners (12.9 gr/100ml for Fanta® and 10.6gr/100ml for Coca Cola®); therefore, we can expect that this added sugar may affect bone and mineral conditions negatively. So both types of these drinks, due to high levels of sugar can adversely affect orthodontic tooth movement.

Caffeine as an additive in some types of drinks, specially Cola types, may also lead to exertion of calcium in the urine, a condition known as calciuria [26]. Wink et al. showed that growing rats that received caffeine had significant histological differences such as fewer osteocytes per area of femoral cross section, impaired structural remodeling of the tibial metaphysis, osteoblasts and osteocytes with disrupted swollen mitochondria compared to the control group [27]. However, the ultimate effects of caffeine on the bone and the calcium economy in human beings depends on other factors, mainly calcium intake from the diet, and net effects are controversial [26, 28]. It is noticeable that Fanta® drink has no caffeine and this consideration does not apply to it. The present study used closed coil spring to apply orthodontic forces. This method is better than the elastic module for closing the spaces [29]. Also, this study used Coca Cola® and Fanta® that are two common drinks in Iran. Findings of the present study revealed that consumption of carbonated soft drinks as Coca Cola® and Fanta® reduced the rate of orthodontic tooth movement in rats. Various observational studies have demonstrated that consumption of CSDs are associated with a decrease in bone mass or an increase in the risk of bone fracture in children, teenagers [30] and higher ages [31], which is more considerable with Cola consumption compared to other drinks. It is

claimed that increased phosphorus intake or acid load due to consuming these drinks or the caffeine in caffeine-containing drinks are contributing factors to this correlation. Though no studies have proved the net correlation between phosphorus intake, caffeine and these effects [32-34] there is still concern about the acid load [35].

The acid loads may also affect the bone content and metabolism. Acidemia increases bone degeneration and calcium release [36], and it decreases the activity of 1α hydroxylase, and the production of $1\alpha, 25$ dehydroxy vitamin D [37]. It has been noted that high consumption of Cola causes acidosis in immature rats [21]. Both these drinks contain acidic components (carbon dioxide, phosphoric acid in Coca Cola® and citric acid in Fanta®) that may alter bone metabolism toward this condition. This may influence the bone remodeling process and subsequently orthodontic tooth movements.

Many studies [4, 9, 38, 39] proved that carbonated soft drinks affect the bone metabolism negatively. Furthermore, replacement of enriched nutrients such as milk with drinks in diet leads to decreased bone density due to decreased calcium intake [40]. Wyshak [31] demonstrated that a positive correlation exists between bone fracture and CSD consumption. In this study, we found that Fanta® drink compromises tooth movement more than Coca Cola®. This effect may be related to the higher sugar content of Fanta® (rather than Coca Cola®), or the effect of the other ingredients (such as citric acid). In addition, due to the complex composition of these drinks, referring this result to a single cause may not be possible. In this regard, we propose other studies on the effects of various components of these drinks on orthodontic tooth movements.

All the above-mentioned factors show the detrimental side effects of CSD consumption on general bone health. Regarding the fact that orthodontic tooth movement is a process related to bone metabolism, it is not a far-fetched

idea that any process affecting bone metabolism can affect the orthodontic tooth movement as well. It has been demonstrated that drinking CSDs with a low pH increases the risk of dental demineralization and dental caries [15]. The decrease of the shear bond strength of orthodontic brackets is also in doubt [12, 41]. The previous discussion covers just some parts of the detrimental complications of soft drink consumption on the general health of individuals and orthodontic patients. So, the findings of this study suggest that consumption of CSD must be reduced as much as possible during orthodontic treatment due to its effect on reducing the rate of orthodontic tooth movement.

CONCLUSION

CSDs consumption decreases the rate of orthodontic tooth movement. The role of soft drinks in decreasing tooth movement might be related to its effects on bone metabolism.

REFERENCES

- 1- Rampersaud GC, Bailey LB, Kauwell GP. National survey beverage consumption data for children and adolescents indicate the need to encourage a shift toward more nutritive beverages. *J Am Den Assoc.* 2003 Jan;103(1):97-100.
- 2- Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet.* 2001 Feb;357(9255):505-8.
- 3- Schulze MB, Manson JE, Ludwig DS, Colditz GA, Stampfer MJ, Willett WC, et al. Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA.* 2004 Aug;292(8):927-34.
- 4- McGartland C, Robson P, Murray L, Cran G, Savage M, Watkins D, et al. Carbonated soft drink consumption and bone mineral density in adolescence: the Northern Ireland Young Hearts project. *J Bone Miner Res.* 2003 Sep;18(9):1563-9.
- 5- Fung TT, Malik V, Rexrode KM, Manson JE, Willett WC, Hu FB. Sweetened beverage consumption and risk of coronary heart disease in women. *Am j clin nutr.* 2009 Apr;89(4):1037-42.
- 6- Dhingra R, Sullivan L, Jacques PF, Wang TJ, Fox CS, Meigs JB, et al. Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. *Circulation.* 2007 Jul;116(5):480-8.
- 7- Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health.* 2007 Apr;97(4):667-75.
- 8- Libuda L, Alexy U, Remer T, Stehle P, Schoenau E, Kersting M. Association between long-term consumption of soft drinks and variables of bone modeling and remodeling in a sample of healthy German children and adolescents. *Am J Clin Nutr.* 2008 Dec;88(6):1670-7.
- 9- Fernando G-R, Martha R-M, Evangelina R. Consumption of soft drinks with phosphoric acid as a risk factor for the development of hypocalcemia in postmenopausal women. *J Clin Epidemiol.* 1999 Oct;52(10):1007-10.
- 10- Teófilo JM, Leonel DV, Lamano T. Cola beverage consumption delays alveolar bone healing: a histometric study in rats. *Braz Oral Res.* 2010 Apr-Jun;24(2):177-81.
- 11- Buttke TM, Proffit WR. Referring adult patients for orthodontic treatment. *J Am Dental Assoc.* 1999 Jan;130(1):73-9.
- 12- Oncag G, Tuncer AV, Tosun YS. Acidic soft drinks effects on the shear bond strength of orthodontic brackets and a scanning electron microscopy evaluation of the enamel. *Angle Orthod.* 2005 Mar;75(2):247-53.
- 13- Van Eygen I, Vannet BV, Wehrbein H. Influence of a soft drink with low pH on enamel surfaces: an in vitro study. *AmJ Orthod Dentofacial Orthop.* 2005 Sep;128(3):372-7.

- 14- Fathilah A, Rahiml Z. The effect of beverages on the release of calcium from the enamel surface. *Ann Dent Univ Malaya*. 2008 Mar;15:1-4.
- 15- Shenkin JD, Heller KE, Warren JJ, Marshall TA. Soft drink consumption and caries risk in children and adolescents. *Gen Dent*. 2003 Jan-Feb;51(1):30-6.
- 16- Frost HM. A 2003 update of bone physiology and Wolff's Law for clinicians. *Angle Orthod*. 2004 Feb;74(1):3-15.
- 17- Bartzela T, Türp JC, Motschall E, Maltha JC. Medication effects on the rate of orthodontic tooth movement: a systematic literature review. *Am J Orthod Dentofacial Orthop*. 2009 Jan;135(1):16-26.
- 18- Scherz H, Senser F. Food composition and nutrition tables. Medpharm GmbH Scientific Publishers; 1994. Zurich
- 19- Fitzpatrick L, Heaney RP. Got soda? *J Bone Miner Res*. 2003 Sep;18(9):1570-2.
- 20- Calvo MS. Dietary phosphorus, calcium metabolism and bone. *J Nutr*. 1993 Sep;123(9):1627.
- 21- Amato D, Maravilla A, Montoya C, Gaja O, Revilla C, Guerra R, et al. Acute effects of soft drink intake on calcium and phosphate metabolism in immature and adult rats. *Revista de investigacion clinica; organo del Hospital de Enfermedades de la Nutricion*. 1998 May-Jun;50(3):185.
- 22- Milne DB, Nielsen FH. The interaction between dietary fructose and magnesium adversely affects macromineral homeostasis in men. *J Am Colleg Nutr*. 2000 Feb;19(1):31-7.
- 23- Paldanius P, Ivaska K, Hovi P, Andersson S, Väänänen H, Kajantie E, et al. The effect of oral glucose tolerance test on serum osteocalcin and bone turnover markers in young adults. *Calcif Tissue Int*. 2012 Feb;90(2):90-5.
- 24- Clowes JA, Allen HC, Prentis DM, Eastell R, Blumsohn A. Octreotide abolishes the acute decrease in bone turnover in response to oral glucose. *J Clin Endocrinol Metabol*. 2003 Oct;88(10):4867-73.
- 25- Tsanzi E, Light HR, Tou JC. The effect of feeding different sugar-sweetened beverages to growing female Sprague-Dawley rats on bone mass and strength. *Bone*. 2008 May;42(5):960-8.
- 26- Massey LK, Whiting SJ. Caffeine, urinary calcium, calcium metabolism and bone. *J Nutr*. 1993 Sep;123(9):1611-4.
- 27- Wink CS, Rossowska MJ, Nakamoto T. Effects of caffeine on bone cells and bone development in fast-growing rats. *Anat Rec*. 1996 Sep;246(1):30-8.
- 28- Heaney RP. Effects of caffeine on bone and the calcium economy. *Food Chem Toxicol*. 2002 Sep;40(9):1263-70.
- 29- Samuels RH, RudgeSJ, Mair LH. A clinical study of space closure with nickel-titanium closed coil springs and an elastic module. *Am J Orthod Dentofacial Orthop*. 1998 Jul;114(1):73-9.
- 30- Petridou E, Karpathios T, Dessypris N, Simou E, Trichopoulos D. The role of dairy products and non alcoholic beverages in bone fractures among schoolage children. *Scand J Soc Med*. 1997 Jun;25(2):119-25.
- 31- Wyshak G. Teenaged girls, carbonated beverage consumption, and bone fractures. *Arch Pediatr Adolesc Med*. 2000 Jun;154(6):610.
- 32- Barger-Lux MJ, Heaney RP. Caffeine and the calcium economy revisited. *Osteoporos Int*. 1995 Mar;5(2):97-102.
- 33- Wise KJ, Bergman EA, Sherrard DJ, Massey LK. Interactions between dietary calcium and caffeine consumption on calcium metabolism in hypertensive humans. *Am J Hypertens*. 1996 Mar;9(3):223-9.
- 34- Kynast-Gales S, Massey LK. Effect of caffeine on circadian excretion of urinary calcium and magnesium. *J Am College Nutr*. 1994 Oct;13(5):467-72.
- Barzel US. The skeleton as an ion exchange system: Implications for the role of acid-base imbalance in the genesis of osteoporosis. *J Bone Miner Res*. 1995 Oct;10(10):1431-6.

- 35- Lemann J Jr, Lennon EJ. Role of diet, gastrointestinal tract and bone in acid-base homeostasis. *Kidney Int.* 1972 May;1(5):275-9.
- 36- Lee SW, Russell J, Avioli LV. 25-hydroxycholecalciferol to 1, 25-dihydroxycholecalciferol: conversion impaired by systemic metabolic acidosis. *Science.* 1977 Mar;195(4282):994-6.
- 37- Heaney RP, Rafferty K. Carbonated beverages and urinary calcium excretion. *Am J Clin Nutr.* 2001 Sep;74(3):343-7.
- 38- García-Contreras F, Paniagua R, Avila-Díaz M, Cabrera-Muñoz L, Martínez-Muñiz I, Foyo-Niembro E, Amato D. Cola beverage consumption induces bone mineralization reduction in ovariectomized rats. *Arch Med Res.* 2000 Jul-Aug;31(4):360-5.
- 39- Hintz H. Calcium, cola, calamity. *Cornell Vet.* 1980 Jan;70(1):3-9.
- 40- Omid Khoda M, Heravi F, Shafae H, Mollahassani H. The effect of different soft drinks on the shear bond strength of orthodontic brackets. *J Dent. (Tehran).* 2012 Jun;9(2):145-9.

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