Review Article

# Role of Vibrations in Orthodontics: A Review

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**ABSTRACT**

Long treatment time has been a deterrent for the patients for pursuing orthodontic treatment. Orthodontist from time immemorial have been trying different methods for reducing the treatment time. It has been documented in literature that vibration therapy helps in bone remodelling and muscle regeneration as demonstrated in cases of osteoporosis, muscle loss and joint pain. Using the similar approach orthodontist from different era have tried to accelerate the tooth movement using different methods. This article summarises the efforts of different clinicians and their approaches to achieve reduced orthodontic treatment time as well as reducing the discomfort, pain and root resorption using pulsations and vibrations

## INTRODUCTION

The scientists across the world have documented positive results using the vibrational therapy in patients with osteoporosis, muscle loss and joint pain. Eight years ago, NASA scientists reported that muscles atrophies relatively quickly and bones lose mass on prolonged exposures to weightlessness. Therefore, they suggested their astronauts to stand on a lightly vibrating plate for 10 to 20 minutes each day while in orbit so as to prevent bone loss.

### VIBRATIONS & TOOTH MOVEMENT

Traditional orthodontic treatment requires an average of 24 months, so the possibility of shortening this will be welcomed by both patients and clinicians. Pharmacological approaches have been employed (injection of prostaglandins and peptide hormones around the teeth) but they have all come along with different sets of problems, such as pain, severe root resorption and drug-induced side effects.[1,2] Vibration therapy has been used in health care since the 1800s. Advanced molecular biology techniques have shown the researchers new avenue towards finding answers to the questions asked for the last few decades.[3] The rate of tooth movement has been enhanced by pharmaco-therapeutic or electrophysiological means. The applied electrical fields can alter the normal electrical states of bone and cartilage, induce increased rates of cellular division and metabolism, and thus promote increased healing of bony and cartilaginous defects.[4,5] The application of an electric current may alter the electrolytic environment allowing changes in the type and rate of ions (K+, Ca++ etc) that move across the cell membranes & acts as a mediator for cellular changes. Micro-pulsed electrical stimulation could reach bone osteoblasts non-invasively and can result in an increase in the cAMP and cGMP. These cyclic nucleotides are a type of second messenger, which play a role in the efficient remodelling of alveolar bone and tooth movement.[3]

The first known attempt to apply pulsating forces to the dentition in an orthodontic application with humans was likely conducted by Everett Shapiro et al.[2] Davidovitch et al suggested orthodontic tooth movement may be accelerated by the use of locally applied electric currents.[6] The rate of movement as well as the total movement was found to be greater with the pulsed tooth than in the control tooth with the rate of movement being two-fold higher at times.[2,7,8] In a monkey model, tooth movement rates up to 40% faster were demonstrated in response to vibration as early as 1986 by Shimizu et al.[9,10] More recently, H. Utomo (Airlangga University) has suggested via literature search that patients who regularly chews gum (a crude form of vibratory force application) exhibit accelerated rates of tooth movement. It is believed that orthodontic tooth movement is accompanied by "site-specific" alveolar bone remodelling & is essential for tooth movement.[11] It is characterized by tandem periods of osteoclastic recruitment, bone resorption, reversal and bone formation.[12,13] This process involves the periodontal ligament and is dependent on the magnitude and consistency of the force being applied. In the area of periodontal ligament compression, osteoclasts proliferate and initial resorption of superficial bone occurs.[13-15] In the region of periodontal ligament tension, the periodontal fibres unwind, fibroblasts appear and osteoblasts form a non-mineralized collagenous matrix called osteoid. The osteoid is later mineralized, trapping some osteocytes in lacunae within the bone.[16] A study by Davidovitch et al results suggests that electric stimulation enhances cellular enzymatic phosphorylation activities in periodontal tissues and may be a potent tool in accelerating alveolar bone turnover.[17] According to Jafar Kolahi, direct electric current is a potent biologic mean to accelerate periodontal tissue turnover and orthodontic tooth movement.[18] In 1978 Meikle et al developed organ culture systems in which mechanical force could be applied to rabbit cranial sutures under controlled conditions.[19] This simple experimental model mimics the forces to which the periodontal ligament and other sutural articulations of the craniofacial skeleton are exposed during orthodontic treatment. Kopher and Mao assessed peak cyclic forces of 5N magnitude at 1 Hz in rabbits while Peptan and Mao assessed cyclic forces of 1N at 8 Hz in rabbits and Vij and Mao assessed cyclic forces of 300 mN at 4 Hz in rats. In aggregate, the data from these three studies indicate that cyclic forces between 1 Hz and 8 Hz with forces ranging from 0.3N to 5N, increase bone remodelling.[20,21] Jeremy Mao is the inventor of the concept behind vibrating force to enhance and accelerate tooth movement. A number of different devices have been marketed which use various means of vibrating the teeth.

In early 2008, a confirmatory paper was published in the American Journal of Orthodontics and Dentofacial Orthopaedics out of Tohoku University, Sendai, and Japan using a rodent model. The results were clear. The treatment group received cyclic forces once per week for just eight minutes and showed significantly accelerated tooth movement when compared to the control group.[10] A physical force has five fundamental properties: magnitude, direction, point of application, duration, and frequency. As orthodontists, we have studied all of these characteristics extensively with the exception of frequency. A study by Darendeliler (2001), suggested that the PEMF-induced vibration may enhance the effect of mechanical and magnetic forces on tooth movement.[22]

**BONE BIOLOGY**

Some reports described asymmetric voltage waveforms from mechanically deformed live bone. These changes were presumed to occur in bone during physical activity as a result of mechanical forces. The polarity depends on the direction of bending. Areas under pressure will be in an electropositive state & are usually associated with osteoclastic activity and areas under tension will be in an electronegative state & are associated with osteoblastic activity. Hence the associated area of alveolar bone is associated with both increased osteoblastic activity and osteoclastic activity. The application of cyclic loading (controlled vibrations) will not only increase the rate of tooth movement but will also create a solid foundation of bone and adjacent tissues in the mouth.[23,24]

**HISTORY OF VIBRATIONAL FORCE TO ACCELERATE BONE REMODELLING**

Based on Wolff's Law of bone remodelling and literature from long bone biology it becomes evident that vibration could accelerate bone density formation. Bone remodelling can be significantly accelerated via the application of pulsating force of various frequency and magnitude combinations.[7,8] It is believed that cyclic forces increase the cellular signalling that regulates bone remodelling thus enhancing the rate of orthodontic tooth movement. Factors that increase the rate of bone remodelling have been shown to increase the rate of tooth movement. Bassett proposed that tissue integrity and function could be restored by applying electrical and/or mechanical energy to the area of injury.[25] Previous animal and clinical studies have shown that electrical & mechanical stimulation, in particular low intensity pulsed ultrasound, when applied to the non- healing fractures, improved the rate of bone healing via up-regulation of cartilage formation and maturation of endochondral bone formation.[16]

In a number of studies it has been shown that prostaglandins are involved in the bone removal component of orthodontic tooth movement. In addition, inhibitors to prostaglandin production (cyclo-oxygenase or COX inhibitors) are known to decrease the amount of orthodontic tooth movement. Parathyroid hormone (PTH) is a potent bone-remodelling factor. Continuous infusion of PTH has been shown to cause a two fold increase in the rate of orthodontic tooth movement in rats.[1,2]

## VIBRATION TO CONTROL PAIN

A device that vibrates at frequency (between 100 Hz and 250 Hz) and at a force (approximately 100g or 1N) has been commercially distributed and used in humans for reducing pain associated with orthodontic adjustments. Marie, et al reported on 48 patients who experienced significant reduction in pain; no adverse events were reported.[26]

## VIBRATION AND ROOT RESORPTION

Nishimura et al studied 60 Hz vibrations in a direct tooth movement model in rats. Rats received "standard orthodontics" through application of a spring that applied a force between the molars. Vibration to the molars at a 60 Hz frequency was added through a separate apparatus. The group that received vibration had a statistically significant increase in tooth movement when compared to the spring-force (static force) only group. Interestingly, the vibration group had a trend toward less root-resorption as compared to the static force-only group.[27]

## VIBRATIONAL EFFECT ON BONE ARCHITECTURE

Research has demonstrated that the use of cyclic forces increases the rate of bone remodelling compared to static forces.[13,28,29] In a pilot study in one human subject, a pulsating force device was investigated and was found to enhance and speed tooth movement, although it was never introduced commercially; both the rate of movement and the total amount of movement were enhanced. Cyclic forces have been found to accelerate the rate of

bone remodelling to levels far greater than static forces or intermittent forces.[30-33] While similar in their non-constant nature, cyclic forces– sometimes referred to as pulsatile forces, are different than intermittent forces that are applied for some duration of time, removed, and then reapplied.[34] A static force occurs once and affects cells once; an intermittent force is still a static force, the only difference is that it is introduced episodically. In contrast, cyclic forces are oscillatory in nature and change magnitude rapidly and repeatedly, affecting the cells with each oscillation of force magnitude.[34,35] The frequency of cyclic forces is never zero. Force frequency is a concept of critical importance, but has rarely been considered in the field of orthodontics and Dentofacial Orthopedics until recent years. Cyclic forces cause deformation by changing a structure's length multiple times, whereas intermittent and static forces can only do so once per application. At force frequencies that are greater than zero, cells are impacted multiple times. Frequencies of interest for orthodontic application range from several hertz (Hz.) up to 100 Hz. or more. Cyclic forces impact tissue structures and cells multiple times, and this seemingly subtle difference has been shown to lead to dramatic differences in biological response in both orofacial and long bones.[35,36] Multiple cycles of change in force magnitude or cyclic forces are significant because cells respond more readily to rapid oscillation in force magnitude than to constant force.[36]

A force propagating through a biological tissue, such as alveolar bone and the periodontal ligament, is transduced as a tissue-borne and cell-borne mechanical stress that in turn induces interstitial flow.[37] Although fluid flow is a current focus of the mechanotransduction pathways, its anabolic and catabolic effects rely upon deformation of extracellular matrix molecules, transmembrane channels, the cytoskeleton and intranuclear structures.[36-38] Cells are known to respond more readily to rapid oscillation in force magnitude (i.e. to cyclic forces) than to constant forces.[37] Animal studies using cyclic forces of 0.3–5 newtons (N) have demonstrated increased bone remodelling and the delivery of cyclic forces by a vibrational device applied to molar teeth in the presence of standard static forces from an orthodontic spring resulted in a significant increase in tooth movement compared to no adjunctive device use. There was also a trend towards less root resorption when cyclic forces were applied.[20,21,27] Cyclic forces have been used for other parts of the body, such as the Juvent system that is used to counteract lost bone and muscle. A second device using cyclic forces was introduced to relieve the discomfort associated with orthodontic adjustments and was found to be safe and effective.[26]

## CONCLUSION

Short durations of extremely small magnitude, high-frequency mechanical stimuli can promote anabolic activity in the adult skeleton.[39] Certain exercises can induce osteogenesis and improve bone strength. Experimental protocols that insert "rest" periods to reduce the effects of desensitization can double anabolic responses to mechanical loading.[39-41] Recovery periods restore mechanosensitivity to dynamically loaded bone Here, it is determined that whether such signals can influence trabecular and cortical formative and resorptive activity in the growing skeleton; is the newly formed bone of high quality and would the insertion of rest periods during the loading phase enhance the efficacy of the mechanical regimen. Site specifically attenuate the declining levels of bone formation and maintain a high level of matrix quality. If WBV prove to be efficacious in the growing human skeleton, they may be able to provide the basis for a non-pharmacological and safe means to increase peak bone mass and ultimately reduce the incidence of osteoporosis or stress fractures later in life.[42]

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