

Vibration therapy in orthodontics: Realizing the benefits

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Introduction to vibration therapy—multiple potential benefits

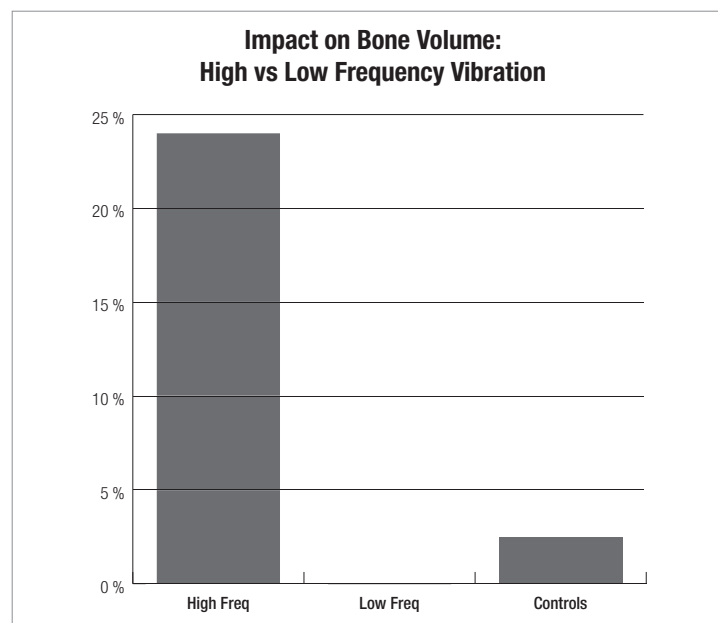
Accelerated orthodontics and vibration therapy to fast track orthodontic tooth movement (OTM) have been hotly debated topics in the orthodontic industry in recent years. Periodontally Accelerated Osteogenic Orthodontics (PAOO) techniques such as osteotomy, open flap corticotomy, and piezocision have been shown to decrease treatment time.¹ Unfortunately, these classical approaches have had limited patient acceptance because of their invasiveness and side effects.² In the last several years, micro-osteoperforation, which takes advantage of the same biological regional acceleratory phenomenon as these classical techniques, has been gaining rapid clinical adoption because of the simplicity of its chairside microinvasive nature.³

There is also growing evidence that the application of mechanical energy-based therapies such as vibration can stimulate and accelerate bone formation and possibly bone remodelling.⁴⁻⁷ Orthodontic tooth movement, caused by the application of light continuous forces that induce bone formation and remodelling, could logically be accelerated by the application of vibrational force, with the benefit of reducing the overall treatment time. Since 2008, AcceleDent (OrthoAccel Technologies) has offered a daily use vibration device, offering the promise of accelerated orthodontic treatment based on delivering mechanical stimulation to the dentition. At this point, research on the efficacy of this device in accelerating OTM has been mixed, and clinicians debate its value.

The debate on vibration therapy as it applies to accelerated orthodontics in general, and the effectiveness of the AcceleDent device specifically, should consider other factors in evaluating efficacy. First, there is a distinct possibility that frequency optimization of the devices concerning bone formation/remodelling has

not been established. AcceleDent operates in a low frequency range, however, research points towards the benefit of high frequency in bone modulation. Secondly, current research indicates that high frequency low magnitude (HFLM) vibration therapy as applied to orthodontic treatment may have multiple potential benefits, including, but not limited to, accelerated OTM.

This article will discuss these additional benefits, including faster more efficient aligner therapy when used as a nightly seating tool, relief of normal



orthodontic discomfort from new tight fitting aligners and routine adjustments to fixed appliances, and enhancement of orthodontic retention. Additionally, it will touch upon evidence that HFLM vibration is useful in increasing bone density and trabecular bone thickness suggesting applications in implant dentistry and prosthodontics.

Graphic 1: Relative impact of frequency on bone morphology
Increases in bone volume for high frequency subjects was 25% higher than controls; low frequency subjects were not statistically different than controls.

Current vibration devices used in orthodontic therapy

As mentioned previously, the most common, commercially available, vibration device for orthodontic treatment is AcceleDent manufactured by OrthoAccel Technologies (Fig. 1). This device delivers a vibrational frequency of 30 Hz and requires 20 minutes per day user wear time.



Fig. 1: AcceleDent from OrthoAccel Technologies
Delivers a vibrational frequency of 30 Hz requiring 20 minutes daily wear time.

Several early studies on the AcceleDent device seemed to demonstrate higher rates of OTM than the established norms.⁸⁻¹⁰ However, there are other more recent studies that have failed to establish the advantages of the same therapy. A study by Woodhouse et al. (2015) analyzed the AcceleDent device to demonstrate its effect on OTM in extraction cases. They found that the supplemental vibrational force did not significantly increase rates of orthodontic alignment with a fixed appliance.¹¹ Another comprehensive report on vibration therapy by investigators Yadav et al. (2015) concluded that low frequency mechanical vibration using AcceleDent had no significant effect in accelerating tooth movement.¹²

The recent studies regarding the apparent ineffectiveness of AcceleDent may be explained by the relatively low vibrational frequency of the device. For purposes of this discussion low and high frequency are defined as:

- Low frequency—less than or equal to 45 Hz;
- High frequency—greater than or equal to 90 Hz.

In a 2010 study by Judex and Rubin, ovariectomized rats were subjected to either low or high frequency vibration. Bone formation rates for subjects treated with high frequency were 159% greater when compared to controls, whereas bone formation for low frequency subjects was not significantly different than controls. Trabecular bone volume and thickness were also significantly higher for subjects treated with high frequency.¹³ Similarly Alikhani et al. found a statistically higher rate of alveolar bone formation (+190%) at higher frequencies, with a 5 min/day application. In short, the most pronounced osteogenic effects of vibration seem to occur well above the AcceleDent's low vibrational frequency.^{14,18}

Practically speaking, five minutes of daily wear time may be beneficial, as it will reduce the dependency on significant patient compliance. In order to realize the maximum benefits of vibration therapy, shorter wear times would logically increase compliance, and improve results. Given all other factors being equal, the studies suggest that a higher frequency device would deliver equivalent amounts of HFA Energy to the dentition in a significantly reduced timeframe.

The future of vibration therapy: Expanded application, multiple benefits

The apparent limitations of current commercially available vibration devices should not diminish the potential importance of vibration therapy. Setting aside applications such as implant dentistry and prosthodontics suggested by the osteogenic properties associated with vibration therapy, there are at least four important clinically beneficial orthodontic applications that can be anticipated. These potential applications are: 1) as a nightly clear aligner seating device; 2) analgesia; relief from normal discomfort associated with orthodontic treatment; 3) accelerated orthodontic tooth movement; 4) and enhancement of retention to minimize orthodontic relapse. What follows is a brief examination of each of the four applications of HFLM vibration as an orthodontic therapy.

Improved aligner seating

The importance of properly seated aligners, to efficient tooth movement in aligner therapy is clearly understood. Improperly seated aligners can slow treatment, forcing patients to back track to previous trays, and create unintended collateral tooth movements, with a consequence being time consuming and costly refinements. Seating recommendations range from using 'chewies', to biting on hard objects. Some clinicians advise seating only when trays are new (immediately post change), while others recommend daily seating. With the current seating modalities, it is unlikely that patients consistently seat aligners fully. A seating protocol, that takes only five minutes nightly, delivering a range of other patient benefits, would insure that aligners are fully seated throughout treatment. Consistent proper aligner seating, would likely result in more efficient, faster aligner treatment, even absent biomechanical acceleration caused by vibration itself.

Non-pharmacological analgesia

Discomfort or pain is a common side effect of orthodontic treatment. The forces applied to the dentoalveolar complex which are required to move teeth, compress the periodontal ligament (PDL) causing inflammation. Pain is most notable when seating a new aligner, or immediately after wire changes and adjustments, when pressure on the PDL is at its greatest, and diminishes as the aligner material expands, and/or the dentition comply. In a study accepted in September 2015 by the Angle Orthodontist for future publication, Lobre et al found in a randomized clinical trial that vibration therapy 'resulted in significantly lower perceived pain and less OTC medication use.'¹⁵ One theory is that vibration restores normal circulation to the PDL, which is otherwise restricted by compressive forces. Increased blood flow intercepts the ischaemic response and limits inflammation.

Accelerated OTM

It is well established that bone undergoes formation and resorption in response to external loading such as gravitational forces, as well as to internal loading such as muscular activity.¹⁶ Recent research with both animal and human models have demonstrated anabolic responses such as bone growth and changes in bone mineral density in response to vibration.^{6,7,17} Since OTM is fundamentally based on bone remodelling (formation and resorption) there is little doubt that HFLM vibration has the potential to favorably impact OTM.

In a recent split-mouth randomized trial involving bilateral maxillary canine distraction after first premolar extraction on 15 human subjects, Leethanakul et al. (2015) investigated the impact of vibration on accelerated tooth movement, as well as on cytokine activity related to osteoblast and osteoclast differentiation (specifically IL-1 β levels in GCF). The patients applied vibration to the experimental canine using a commercially available electric toothbrush operating at high frequency (125 Hz). This study found significantly increased tooth movement (~+61%) accompanied by a threefold increase in average IL-1 β levels.¹⁸

It can be hypothesized that vibration, amplifies the familiar osteoblast-osteoclast cellular response causing bone formation and resorption, when the teeth are under force (i.e. from fixed appliances and aligners). In the absence of force, vibration causes new bone apposition only, which has potential implications for the retention phase (see below). Note that the frequency of the device creating the accelerated tooth movement in the Leethanakul study was in that high frequency range shown to have superior effects on alveolar bone formation by Judex and Rubin, and Alikani et al.^{13,14}

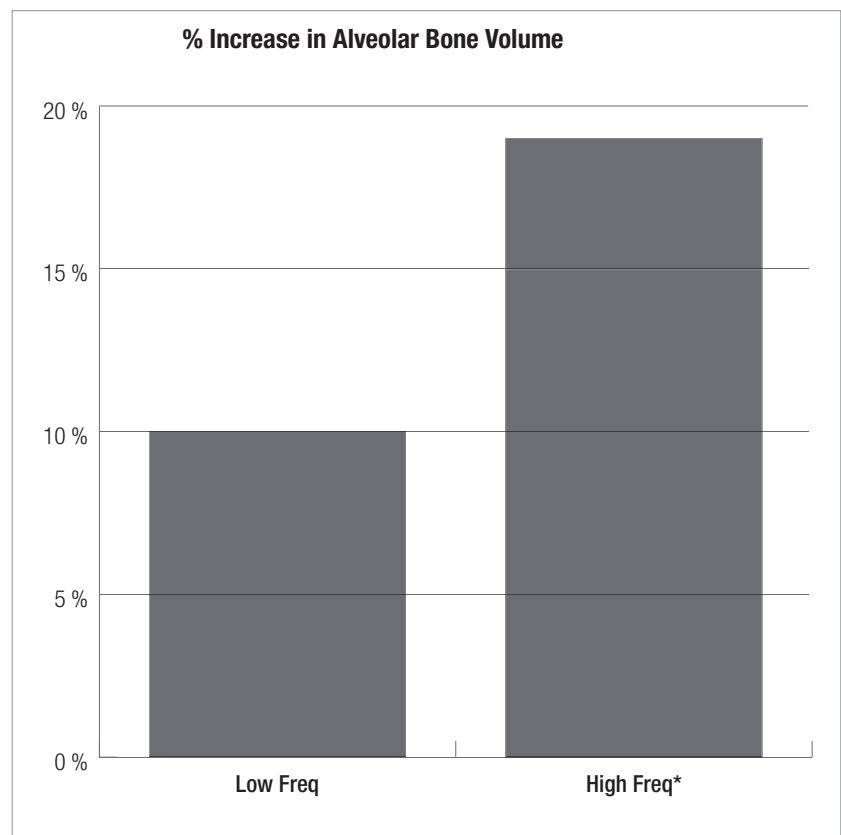
Enhanced retention

Vibration therapy warrants the attention of the scientific community to further explore its effect during the orthodontic retention phase. Scientific literature documents that the primary reason for orthodontic relapse is the inability of collagen fibers (Transseptal fibers and PDL) to reorganize quickly after the completion of orthodontic treatment and the delay in new bone apposition.¹⁹ Studies suggest that vibration can have potentially favorable impacts on both bone formation and reorganization of the PDL fibers.

A study from Rubin et al (referred above) states that vibration therapy by itself has always been anabolic, which means it led to bone apposition and a decrease in bone resorption. Reports have documented an increase in bone density, bone formation, Type-1 colla-

gen and non-collagenous matrix protein expression in response to the therapy.¹⁴

Recent studies by Yadav et al (2015) and Alikhani (2012) (both referred above), have demonstrated that vibration therapy improved not only bone density, but also restored the integrity and thickness of the collagen fibers. With evidence suggesting that vibration therapy positively impacts both bone morphology and the PDL fibers, vibration during the retention phase may play a significant role in preventing orthodontic relapse.



Conclusions

1. The current debate over vibration therapy and its impact on accelerated orthodontic tooth movement, should consider other potential benefits of this therapy including applications for aligner seating, relief of normal orthodontic pain, enhanced retention and applications to implant dentistry and prosthodontics.
2. It can be hypothesized that a vibration device operating in the high frequency range would likely be most effective in creating OTM as well as offering shorter wear times impacting compliance. The most commonly available commercial device operates at a frequency that is below thresholds having statistical significance in creating orthodontic tooth

Graphic 2: Higher Frequencies are more anabolic

Alikani et al found high frequency vibration to be most efficient at accelerating bone growth.

* Statistically different from controls and low frequency subjects

movement as documented in several recent studies, and requires a relatively long, 20 minutes daily wear time.

3. The strong supporting data concerning the positive effects of vibration therapy on bone formation, bone density and collagen fibre reorganization leads us to believe that this modality of treatment may revolutionize the concept of orthodontic retention.
4. The effects of high frequency vibration therapy may be useful in modifying the bone density to the clinician's advantage in implant placement or to maintain the thickness of bone trabeculae in edentulous patients undergoing prosthodontic treatment.

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