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Use of Vibration in Orthodontics
A Review

Dr. Aakash Shah[1]

[1] *Post-graduate student, Department of Orthodontics and Dentofacial Orthopedics, K.M. Shah Dental College and Hospital, Gujarat, India.*

ABSTRACT

In the pursuit of increasing treatment efficiency and decreasing treatment duration, vibratory stimulation has been advocated as a possible adjunct to orthodontic appliances to increase the rate of tooth movement. Following this, a new device called the Acceledent has become commercially available, and is aimed at decreasing treatment duration by accelerating periodontal and bony tissue remodelling with low magnitude high frequency vibration. Surgical methods, regardless of technique, are still invasive to some degree, and hence have their associated complications. Hence, non-invasive methods have come to the force. Vibration was mostly investigated and gave the most promising results. The concept of using physical approaches came from the idea that applying orthodontic forces causes bone bending (bone bending theory) and bioelectrical potential develops. The concave site will be negatively charged attracting osteoblasts and the convex site will be positively charged attracting osteoclasts

Keyword : - Pain, Vibration, Orthodontics, Tooth movement.

1. Introduction

Vibration therapy has been increasingly studied in the medical field and has been successful in improving or maintaining bone and muscle mass in cases such as mobility impaired patients [1], decreased bone density [2], [3] and in surgical healing [4], [5]. Stimulation of bone in an animal study using high frequency, low magnitude vibration has also been found to successfully stimulate an increase in cortical bone6. When compared to low frequency 1Hz, high amplitude 3000 micro strain signals, vibration failed to be anabolic [6]. In a long term animal study, 20 minute daily sessions of high frequency (30 Hz) and low level 0.3g (earth's gravitational) force, stimulated 43% increase in bone density in the proximal femur [7].

In orthodontics, early animal studies on high frequency, low magnitude vibration were aimed at increasing the rate of orthodontic tooth movement by accelerating periodontal and bony tissue modelling/remodelling [8], [9]. Many authors have also hypothesised that vibration may also be a means of decreasing dental pain or pain associated with orthodontic adjustments [10], [11].

Vibration in orthodontics has been applied with the main aim of increasing the rate of orthodontic tooth movement by accelerating the periodontal and bony tissue modelling and remodelling processes. This has the benefit of decreasing the duration that a patient has fixed appliances on their teeth. In the literature, increased treatment duration has been associated with an increased risk of caries [12], periodontal problems [13] as well as a higher risk of root resorption [14-16]. Vibration has the advantage of minimal side effects in comparison to other methods of accelerating tooth movement such as local or systemic medicines and has proven to be a safe low impact alternative that enhances bone remodeling in the medical field.

A new device called Acceledent has been introduced to the market and aims to achieve an increased rate of tooth movement by enhancing bone remodeling using pulsating forces. Invented by Dr Jeremy Mao, it is intended to be used by a patient in conjunction with fixed orthodontic appliances or removable sequential aligner treatment for 20 mins per day. It vibrates at a frequency of 30Hz and has force amplitude of 20 grams. Although vibration in conjunction with orthodontics may accelerate bone and periodontal tissue remodelling, there is very limited research on the effect of this accelerated remodelling on the root surface of teeth.

2. WHAT IS VIBRATION?

Vibration, otherwise known as high frequency, low magnitude stimulation, is defined as a mechanical stimulus characterised by an oscillatory motion.

The key descriptors of vibration include:

i) Frequency (measured in Hz; the number of Hz indicates the number of complete up and down movement cycles per second)

ii) Amplitude (the extent of the oscillatory motion, measured in mm)

iii) Direction of the vibration movement.

3. THE USE OF VIBRATION IN DENTISTRY AND ORTHODONTICS:

High frequency, low magnitude vibration has been applied in the field of orthodontics with the main aim of increasing the rate of orthodontic tooth movement by accelerating periodontal and bony tissue modelling/remodelling. Many authors have also hypothesised that vibration may also be a means of decreasing orofacial pain or pain associated with orthodontic adjustments.

4. VIBRATION AND THE RATE OF ORTHODONTIC TOOTH MOVEMENT:

The orthodontist's aim is to achieve their treatment objectives for a patient as well as limit the duration of treatment and the amount of time a patient has braces on their teeth.

Roberts et al [17] considered bone resorption at the PDL surface to be the rate limiting factor in orthodontic tooth movement. A maximal rate of molar translation in the maxilla is approximately 2mm per month of space closure in a rapidly growing child or 1mm per month of space closure in a non growing adult [18]. Clinically and experimentally there have been many attempts to increase the rate of orthodontic tooth movement, whether it be by reducing friction in the orthodontic appliances [19], adjunctive medicinal or hormonal therapies (local or systemic) [20] and more recently surgical corticotomy techniques [21].

Previous research into these strategies has revealed some disadvantages. Systemic medicines can be non-specific and may produce unwanted side effects in addition to accelerating tooth movement. Local injection of drugs can complicate treatment and may cause discomfort for patients. Corticotomy techniques are invasive and increase patient discomfort.

Vibration has the advantage of minimal side effects in comparison to medicinal treatments. It also has proven to be a safe low impact alternative that enhances bone remodelling in the medical field. Research on vibration and orthodontic tooth movement has mainly been applied to animal studies, in particular, rats. It is difficult to extrapolate the results of animal studies to humans due to differences in PDL and alveolar bone morphology and physiology. However, even with these short comings, rats are still generally considered to be a good model to study orthodontic tooth movement [22]. Darendeliler et al 2007 [8] studied the effect of high frequency low magnitude vibration in 44 wistar rats using magnets and a pulsed electromagnetic field. They hypothesised that since the literature has noted an increase in anabolic activity in bone from high frequency low magnitude vibration, it may also increase the rate of tooth movement. The study was designed to allow a pulsed electromagnetic field to interact with Nd-Fe-B magnets bonded onto the molar teeth of the rat subjects. This interaction caused a mesiodistal vibration stimulus on the studied teeth. Having split the sample into 4 groups, they compared the effect of vibration alone; vibration compared with vibration and coil spring; PEMF alone compared with PEMF and coil spring; and vibration and coil spring compared with PEMF and coil spring. The results showed coil springs, either with sham or active magnets move the molar teeth more than magnets alone regardless if a PEMF was present. Under a PEMF, the coil spring produced significantly more tooth movement than the coil-magnet group, as did the magnet group compared to the sham magnet group. The authors concluded that the PEMF induced vibration may enhance the effect of mechanical and magnetic forces on tooth movement.

In another laboratory study by Nishimura et al [9] in 2008, molar vibration in the rat model significantly increased the rate of tooth movement when compared to a non vibration control sample. This study was performed on a sample of 42 wistar rats with an experimental duration of 21 days. Their vibration protocol (60Hz, $1.0 m/s^2$) was based on measuring the natural frequency of the rat first molar. The natural frequency or otherwise known as the resonance frequency was defined as the maximum recorded velocity in the resonance curve and was thought to be the force that applied the largest amplitude of vibration to the periodontal tissues. Vibration Stimulation was only applied for 8 minutes which was determined in a previous pilot study of theirs to be the shortest period required to activate the periodontal ligament.

In addition to reporting an increased rate of tooth movement, the authors also demonstrated the activation of the RANK-RANKL signalling pathway in response to the loading of resonance vibration. The safety of vibration was addressed by investigating the effect on root resorption. No significant differences in root resorption were found between the vibration and non vibration groups. In fact, they noted that a trend of less root resorption was found in the vibration group. The authors theorised that vibration may prevent hyalinisation of tissues in the PDL; however, further research is necessary to determine the exact mechanisms that take place.

5. ACCELEDENT DEVICE:

Following on from the findings of these studies, a device called the Acceledent, has reached the market and aims to achieve an increased rate of tooth movement by enhancing bone remodelling using pulsating forces. Its inventor, Dr Jeremy Mao previously investigated the effects of cyclic forces on suture growth. He based his studies on a model suggested by Meikle et al 1979 which concluded that cranial sutures models mimic the forces that the periodontal ligament and other sutures of the cranium are exposed to during orthodontic tooth movement [23].

The Acceledent vibration variables are based on Dr Rubin’s studies [24], [25] on whole body vibration with a frequency of 30Hz and amplitude of 20g. The Acceledent is prescribed to be used for 20 mins per day during orthodontic treatment and can be used as an adjunct to fixed appliance or aligner treatment.

With the release of this new device, research on the effectiveness and safety of vibration in humans for orthodontic tooth movement will be performed.

6. PAIN AND VIBRATION:

Pain is a common experience and concern for patients who undergo any form of dental treatment. Pain following an orthodontic adjustment has been reported to be quite prevalent and may affect patient compliance with treatment [26]. Pain associated with orthodontics may also adversely affect the level of patients’ plaque control [27].

The usual method of dealing with discomfort is with the use of analgesics. NSAIDS have been reported to decrease the rate of tooth movement and thus possibly increase orthodontic treatment times. In a systematic review on the effect of medicines on orthodontic tooth movement, it was suggested that paracetamol was the analgesic of choice as it didn’t affect the rate of tooth movement [20].

Other alternatives to analgesics for pain control include chewing gum after adjustments [28] or the use of lower force levels. Even if lower force levels are used, Lim et al showed that pain was still experienced by most patients. More recently low level laser therapy, transcutaneous electrical nerve stimulation and vibratory stimulation have been shown to be effective post orthodontic adjustment [29].

When using Vibratory stimulation it is thought that the vibration acts to interfere with the pain pathways, in particular, the interaction between large fibres and small pain-carrying fibres [11]. It also appears to re-establish the blood supply and intercept the ischemic response [10].

7. FUTURE DIRECTIONS:

Vibration is a relatively new field. Although it has been studied increasingly in the medical field for the treatment of mobility impaired patients, decreased bone density and in surgical healing, little is known about the potential benefits for the orthodontist. Initial studies on the effect of vibration on orthodontic tooth movement and the craniofacial structures have so far been limited to animal studies.

With the introduction of Acceledent, the use of vibration in orthodontics may transfer from the theoretical, experimental use to common day usage.

Different vibration protocols and different vibration devices should be tested for optimal orthodontic tooth movement and safety. In the medical field, low magnitude high frequency has been reported to be effective while high magnitude low frequency has not.

Compliance in using the device has been an issue. Currently it is recommended for use 20 minutes per day. Testing in the field of duration of use for Acceledent could improve compliance if it is shown that shorter durations of use yield similar benefits.

If vibration is able to accelerate remodelling of the bony alveolus around a tooth, it could possibly accelerate the repair of root resorption cavities. Histological or micro CT studies could be used to determine if vibration is able to decrease root resorption as well as accelerates healing as well.

The main aim of Acceledent is to increase the rate of orthodontic tooth movement. Future research is needed to assess the efficacy of its claims with a clinical trial. It must be proven that Acceledent works to a clinically significant degree before it can be a widely accepted treatment adjunct. Acceledent has been advertised to work with all orthodontic appliances including lingual fixed appliances, labial fixed appliances and removable thermoplastic appliances. Clinical studies may be carried out to determine their efficacy is different between the appliances. Finite element analysis studies of Acceledent vibration may give clues to the potential spread of vibration not just to the teeth but also to the craniofacial skeleton as a whole. This may allow for research into the most effective design of the device.

8. CONCLUSIONS

Vibration in orthodontics is still in its infancy. Initial studies for increasing the rate of tooth movement have been promising. The reduction of pain associated with orthodontic adjustment when using vibration is another positive in its use.

With the introduction of the Acceledent device, the use of vibration in orthodontics could become more widely spread. More clinical trials will be needed to fully access the efficacy of Acceledent as well as its safety.

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