

## A Review on Methods of Accelerating Orthodontic Tooth Movement

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### Review Article

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**Abstract:** Accelerating the rate of tooth movement is desirable to patients because it shortens treatment time and also to orthodontists because treatment duration has been linked to an increased risk of gingival inflammation, decalcification, dental caries, and root resorption. Orthodontic treatment is based on the premise that when force is delivered to a tooth and thereby transmitted to the adjacent investing tissues, certain mechanical, chemical, and cellular events take place within these tissues, which allow for structural alterations and contribute to the movement of that tooth. Conventionally, duration of orthodontic treatment can range anywhere between 1-3 years. Numerous techniques and materials have been suggested to reduce treatment times such as laser irradiation, corticotomy and pulsed electromagnetic fields. The purpose of this article is to view the successful approaches in tooth movement and to highlight the newest technique in tooth movement.

**Keywords:** Accelerated orthodontics, treatment, photobiomodulation, piezosurgery.

### INTRODUCTION

Orthodontic tooth movement occurs in the presence of a mechanical stimuli sequenced by remodelling of the alveolar bone and periodontal ligament (PDL). Bone remodelling is a process of both bone resorption on the pressure site and bone formation on the tension site [1, 7].

Orthodontic tooth movement can be controlled by the size of the applied force and the biological responses from the PDL [8].

The force applied on the teeth will cause changes in the microenvironment around the PDL due to alterations of blood flow, leading to the secretion of different inflammatory mediators such as cytokines, growth factors, neurotransmitters, colony-stimulating factors, and arachidonic acid metabolites. As a result of these secretions, remodeling of the bone occurs [3, 9].

There are three phases of tooth movement: the initial phase, which is characterized by rapid movement after the application of force; followed by a lag period, where little or no movement and the last phase, where gradual or sudden increase of movement occurs [10]. The early phase of tooth movement involves acute inflammatory responses characterized by leucocytes migrating out of blood capillaries and producing cytokines, which stimulates the excretion of prostaglandins and growth factors [11]. The acute phase is followed by the chronic phase that involves the

proliferation of fibroblast, endothelial cells, osteoblasts, and alveolar bone marrow cells remodeling process [3].

Today, it is still very challenging to reduce the duration of orthodontic treatments. It is one of the common deterrents that faces orthodontist and causes irritation among adults plus increasing risks of caries, gingival recession, and root resorption [12].

Several factors can play a role in the length of treatment and include case severity, an extraction or non-extraction approach, clinical expertise, and patient cooperation. For example, research has indicated that the correction of Class II relationships takes approximately five months longer than Class I occlusions with the severity of the overjet explaining 46% of the variability in treatment duration. Overcoming this challenge will not only dramatically improve the quality of orthodontic care, but also

motivate more people towards the concept of orthodontic treatment [15, 22].

A number of attempts have been made to create different approaches both preclinically and clinically in order to achieve quicker results, but still there are a lot of uncertainties and unanswered questions towards most of these techniques. Most attempts can broadly be categorized into:

1. Biological Approach.
2. Surgical Approach.
3. Physical Approach.

### **Biological approach**

Extensive experiments have been carried out exogenously on molecules such as prostaglandin E (PGE2), cytokines that include lymphocytes and monocytes-derived factors, receptor activator of nuclear factor kappa B ligand (RANKL), and macrophage colony-stimulating factor (M-CSF) in order to create ways to enhance tooth movement [2-4].

### **Effect of cytokines on tooth movement**

High concentration of cytokines such as interleukins IL-1, IL-2, IL-3, IL-6, IL-8 and tumour necrosis factor alpha (TNF) were found to play a major role in bone remodelling; moreover, interleukin-1 (IL-1) stimulates osteoclast function through its receptor on osteoclasts. It was also found that mechanical stresses due to orthodontic treatment increased the production of prostaglandin PGE and IL-1 beta in the periodontal ligament [4]. Other cytokines which are also involved in the acceleration of tooth movement are RANKL, which is a membrane-bound protein on the osteoclasts that bind to the RANK on the osteoclasts and causes osteoclastogenesis. On the other hand, osteoprotegerin (OPG) competes with RANKL in binding to osteoclasts to inhibit osteoclastogenesis. The process of bone remodelling is a balance between (RANKL-RANK) system and OPG compound [5, 6].

In relation to this, using biological molecules in the acceleration of tooth movement [17] has been shown in two unique experiments in which it was demonstrated that the transfer of RANKL gene to the periodontal tissue induced prolonged gene expression for the enhancement of osteoclastogenesis and acceleration of tooth movements in rats. In another study, it was found that teeth move faster in young patients than they do in adults. This can be attributed to the lower amount of RANKL/ OPG ratio in the gingival reticular fluid (GCF) in adult patients which is measured by the enzyme-linked immunosorbent assay method. RANK, OPG and root resorption showed a correlation during orthodontic teeth movement. It was observed that patients with root resorption seemed to produce a larger amount of RANKL in the compressed site [18, 38].

### **Prostaglandin effect on tooth movement**

Prostaglandins (PGs) are inflammatory mediators and can be considered paracrine hormones that impact nearby cells; thereby stimulating bone resorption by increasing the number of osteoclasts. In vivo and in vitro experiments were conducted to show clearly the relation between PGs, applied forces, and the acceleration of tooth movement.

Yamasa ki [13, 14] was among the first to investigate the effect of local administration of prostaglandin in rats and monkeys. In addition, experiments [2] done in rats have shown that injections of exogenous PGE2 over an extended period of time caused acceleration of tooth movements. Furthermore, the acceleration rate was not affected by single or multiple injections or between different concentrations of the injected PGE2. However, root resorption was very clearly related to the different concentrations and number of injections given. It has also been shown that the administration of PGE2 in the presence of calcium stabilizes root resorption while accelerating tooth movement [16]. Chemically produced PGE2 has also been studied in human trials with split-mouth experiments in the first premolar extraction cases. In these experiments, the rate of distal retraction of canines was 1.6-fold faster than the control side.<sup>15</sup>

### **Effect of vitamin D3 on tooth movement**

Vitamin D3; 1, 25 dihydroxycholecalciferol is a hormonal form of vitamin D and plays an important role in calcium homeostasis with calcitonin and parathyroid hormone (PTH). Another set of investigators [19] conducted an experiment where they have injected vitamin D metabolite on the PDL of cats for several weeks; it was found that vitamin D had accelerated tooth movement at 60% more than the control group due to the increase of osteoclasts on the pressure site as detected histologically. A comparison between local injection of vitamin D and PGEs on two different groups of rats was also done. It was found that there is no significant difference in acceleration between the two groups. However, the number of osteoclasts on the pressure side which was injected by vitamin D was greater than on the PGE2 side. This indicates that vitamin D may be more effective in bone turnover [20].

### **PTH effect on tooth movement**

Continuous infusion of PTH (1 to 10µg/100g of body weight/day) implantation in the dorsocervical region which made the molars move 2 to 3 fold faster mesially by orthodontic coil spring. [23] Some studies have shown that locally injected PTH induces local bone resorption and hence it is more advantageous to give PTH locally rather than systemically [38] It was also confirmed that a slow release local application of PTH was very efficient when a daily injection of PTH was dissolved in gel medium caused 1.6-fold faster acceleration of teeth compared to daily injection of PTH

dissolved in saline which did not cause any acceleration [23].

### Surgical approach

It is a clinically effective technique used for adult patients, where duration of orthodontic treatment may be critical in selective groups of patients. The PDL and alveolar bone remodelling are important parameters in tooth movement, and bone turnover is known to increase after bone grafting, fracture, and osteotomy [24].

Various surgical approaches that have been tried to accelerate tooth movement include osteotomy, corticotomy and piezocision technique.

### Corticotomy and osteotomy

A corticotomy is defined as a surgical procedure involves elevation of full thickness mucoperiosteal flaps, buccally and/or lingually, then only the outer cortical bone is cut, perforated or modified. The medullary bone is left intact. This is in contrast to an osteotomy where the surgical cut perforates both cortical and medullar bone. It was first tried in orthodontics by Kole [25] where tooth movements were achieved between 6 and 12 months. The technique was further used by others, like Grenerson *et al.*, [26] who used this for open bites treatments. In 2001, Wilcko *et al.*, [27] reported that the acceleration of tooth movement is not due to the bony block movement as postulated by Kole [25]; but rather a process of bone remodelling at the surgical site, which was called regional acceleratory phenomenon (RAP). He developed and patented techniques which were called accelerated oestrogenic orthodontics (AOO) and periodontal accelerated oestrogenic orthodontics. RAP was modified by adding bio-absorbable grafting material over the injured bone to enhance healing. This technique is reported to have postoperative stability and improved retention; however there is a constant need for more research. The only pitfall of these surgical techniques is their invasive nature and the fact that acceleration was seen only in the first 3 to 4 months after which it declines with time [30-37].

### Advantages

- It has been proven successfully by many authors to accelerate tooth movement.
- Bone can be augmented, thereby preventing periodontal defects, which might arise, as a result of thin alveolar bone.

### Disadvantages

- High morbidity associated with the procedure.
- Invasive procedure.
- Chances of damage to adjacent vital structures.
- Post-operative pain, swelling, chances of infection, vascular necrosis.
- Low acceptance by the patient.

### Piezocision technique

One of the latest techniques in accelerating tooth movement is the Piezocision technique. Dibart [28] was among the first to apply the piezocision technique, a flapless method of corticotomy, which starts with primary incision placed on the buccal gingival followed by incisions by Piezosurgical knife to the buccal cortex. As reported by Hassan, [29] piezocision technique did not cause any periodontal damage. Another benefit of this technique is that it can be used with Invisalign, which gives a better aesthetic appearance and less treatment time. Piezocision is a promising tooth acceleration technique because of its various advantages in periodontal, aesthetic, and orthodontic aspects.

### Advantages

- Minimally invasive.
- Better patient acceptance.

### Disadvantages

- Risk of root damage, as incisions and corticotomy if “blindly” done.

To reduce the risk of root damage, however, Jorge *et al.*, in 2013, 2014 suggested a method, called MIRO (Minimally Invasive Rapid Orthodontic procedure) by using a metal wire as a guide to placement of the incisions for corticotomy cuts. He placed metal guides in between each tooth, perpendicular to the main arch wire, and took digital radiographs, to ensure that the metal guides did not project over the tooth roots. Once this was confirmed, incisions and piezoelectric corticotomy were done using pins as a guide.

### Micro-Osteoperforations (MOP)

Further to reduce the invasive nature of surgical irritation of bone, a device called Propel, was introduced by Propel Orthodontics. They called this process as Alveocentesis, which literally translates to puncturing bone [21]. This device comes as ready-to-use sterile disposable device. The device has an adjustable depth dial and indicating arrow on the driver body. The adjustable depth dial can be positioned to 0 mm, 3 mm, 5 mm, and 7 mm of tip depth, depending on the area of operation. Previous animal studies have shown that performing micro-osteoperforations (MOPs) on alveolar bone during orthodontic tooth movement can stimulate the expression of inflammatory markers, leading to increases in osteoclast activity and the rate of tooth movement [39-42].

Mani Alikhani *et al.*, [21], performed a single center single blinded study to investigate this procedure on humans. They used a Ni-Ti closed coil spring, delivering a constant force of 100 g to distalize the maxillary canine after first premolar extraction. The spring was anchored to a TAD distal to the second

premolar, and attached to the canine using a power arm through the vertical slot of the canine bracket [44-47].

Gingival crevicular fluid (GCF) samples were collected from each subject to evaluate the level of inflammatory response. GCF was collected before orthodontic treatment, immediately before the start of canine retraction, and at each subsequent visit, between 10 AM and 12 noon [48]. These samples were taken from the distobuccal crevices of the maxillary canine. GCF samples were collected with filter-paper strips (Oral flow, Smithtown, NY) inserted 1 mm below the gingival margin into the distobuccal crevices of the canine for 10 seconds [49]. Cytokine levels were measured using a custom protein array for the following cytokines: CCL-2 (MCP1), CCL-3, CCL-5(RANTES), IL-8 (CXCL8), IL-1a, IL-1b, IL-6, and TNF- $\alpha$  (Raybiotech, Norcross, Ga) according to the manufacturer's instructions. The distance between the canine and the lateral incisor was assessed before and after canine retraction at 3 points: incisal, middle, and cervical thirds of the crowns. All cast measurements were made using an electric digital caliper (Orthopli Corp, Philadelphia, Pa) with an accuracy of 0.01 mm. They concluded their study by stating that [51-53]: MOPs significantly increased the expression of cytokines and chemokines known to recruit osteoclast precursors and stimulate osteoclast differentiation.

### **Physical approach**

Surgical methods, regardless of technique, are still invasive to some degree and hence have their associated complications. Hence, non-invasive methods have come into light. The concept of using physical approaches came from the idea that applying orthodontic forces causes bone bending (bone bending theory) and bioelectrical potential develops. It has been found that applying vibrations for different duration per day accelerated tooth movements between 15% and 30% in animal experiments. These modalities include lasers, vibration, direct electric current etc [54].

### **Photo-bio modulation**

Photo-bio modulation or low-level laser therapy (LLLT) is one of the most promising approaches today. Laser has a bio-stimulatory effect on bone regeneration, which has been shown in the midpalatal suture during rapid palatal expansion [55] and also stimulates bone regeneration after bone fractures the extraction site [56, 57]. Laser light has been seen to stimulate the proliferation of osteoclast and fibroblasts, and thereby affects bone remodelling and accelerates tooth movement. The mechanism involved in the acceleration of tooth movement is by the production of ATP and activation of cytochrome C, which was seen when low energy laser irradiation enhanced the velocity of tooth movement via RANK/RANKL and the macrophage colony-stimulating factor and its receptor expression. In 2004, it was Cruz *et al.* who carried out a human study on the

effect of low-intensity laser therapy on orthodontic tooth movement. They showed that the irradiated canines were retracted at a rate 34% greater than the control canines over 60 days [50].

Gauri Doshi Mehta *et al.*, in 2013 [50], in a split mouth design, used a laser at 800 nm for 10 sec on the canine, both buccally and lingually, which had to be distalized after first premolar extraction. They used a Ni-Ti closed coil spring delivering a constant force of 150 g from the first molar tube hook to the power arm of the canine bracket and also secured with a ligature tie to the bracket. The laser type used was a semiconductor (aluminium gallium arsenide) diode (model LA3D0001.1; LAMBDA S.p.A., Vicenza, Italy) emitting infrared radiation with a wavelength of  $808 \pm 10$  nm operated according to the manufacturer's recommendations. They also aimed to study the analgesic properties of laser therapy. For analgesic purposes, the settings were adjusted to a wavelength of 800 nm, a continuous wave mode, an output power of 0.7 mW, and an exposure time of 30 seconds.

For biostimulation, the parameters were set at a wavelength of 800 nm, a continuous wave mode, an output power of 0.25 mW, and an exposure time of 10 seconds. The total energy density (dose) at each application was 8 J ( $2 \times 40 \text{ s} \times 100 \text{ mW}$ ). After 6 months, the laser side (experimental) and the control side canines were examined with periapical radiographs, which showed no undesirable changes in the adjacent periodontal ligaments and alveolar bones. Vitality tests of the retracted canines were also positive.

Three models were made for each patient. On the models, the mesial cusp tips of first molar and the canine were the reference points. The distance between the first molar and the canine was measured on all 3 models for each patient with a digital caliper accurate to 0.02 mm. These distances were recorded at T0 (after completion of alignment and leveling: day 1 of canine retraction), T1 (at the end of 3 months of canine retraction), and T2 (on completion of canine retraction on the experimental side). There was a highly significant positive difference in the rates of tooth movement on the experimental side compared with the control side. The mean increase in the rates of tooth movement at 3 months was 54% in the maxillary arch and 58% in the mandibular arch. Mean increase in the rate of tooth movement after canine retraction was 29% in the maxillary arch and 31% in the mandibular arch. There was a significant decrease in the pain score recorded, using a Visual Analog Scale.

In this study, they used the semiconductor with a wavelength of 800 nm, a continuous wave mode, an output power of 0.25 mW, and an exposure time of 10 seconds because the results of Takeda and Bradley *et al.*, had indicated significant bio-stimulatory effects on bone metabolism around this dosage, whereas higher

dosages had bio-inhibitory effects, and lower dosage showed nonsignificant results. Limpanichkul *et al.*, in 2006 [48], however obtained a result that low level laser had no additive effect on orthodontic tooth movement. The reason could be the higher energy density of 25 J per square centimetre that they used. Various studies on low level laser therapy, have shown orthodontic tooth movement to be increased by 30-60%. The variations amongst the studies seems to arise from variations in frequency of application of laser, intensity of laser, and method of force application on the tooth [58].

#### **Direct electric current effect on tooth movement**

Direct electric current application is a promising approach to accelerate tooth movement. This technique was tested only on animals by applying direct current to the anode at the pressure sites and cathode at the tension sites (by 7V) thus generating local responses and acceleration of bone remodelling as shown by group of investigators [44]. Their studies were more successful than the previous attempts because electrodes were placed as close as possible to the moving tooth. The bulkiness of the devices and the source of electricity made it difficult to be tested clinically [59].

Several attempts were made to develop biocatalytic fuel cells to generate electricity intraoral by the use of enzymes and glucose as fuel. Further development of the direct electric device and the biocatalytic fuel cells is needed in order to test this clinically [60].

#### **Vibration**

Nishimura *et al* in 2008, used a Ni-Ti expansion spring on the 1st molar of Wistar rats, and applied a vibration of 60 Hz, 1 m/s<sup>2</sup>. They stated that the rats that received the vibration showed increased orthodontic tooth movement. In the sectioned samples, they showed increased RANKL expression in the fibroblasts and osteoclasts of the periodontal ligament of the rats that received vibration [43]. Liu *et al.*, in 2009 [64] conducted a study on thirty mice, in which they used an omega shaped Ni-Ti expander to deliver a force of 20 g on the 1st molar. Mechanical vibration (4 Hz for 20 min/day) was applied perpendicular to the occlusal surface of the first molar. This regimen was repeated seven times, every 3 days. Upon micro-CT examination of the jaws of the killed mice, it showed that the mice that received vibration showed 40% more tooth movement. Recently, a product by the name AcceleDent has arrived at the market, which makes use of this technology. This device consists of an activator, which is the active part of the appliance that delivers the vibration impulses with a USB interface through which it can be connected to a computer to review the patient usage of the appliance, a mouthpiece that contacts the teeth. It is a portable device that can be charged similar to any other electronic device, and has to be worn for 20 minutes a day. Various case studies using this device

have shown the treatment times to be reduced by up to 30-40% [61-63].

#### **CONCLUSION**

Orthodontic patients have been asking for shorter orthodontic treatment times, and today, we now have methods and resources of superior quality which not only enable us to provide quick, but also comfortable orthodontic treatment to both children and adults.

The surgical techniques have most of the human trials and also show very favorable and long term effects adding to the stability and retention of the orthodontic therapy. However the invasiveness and cost of these might make it little less viable option for the patients. Microosteoperforation, Piezocision on the other hand are the least discomfoting among all the surgical procedures and this will make them more commonly used procedures in future

Although these techniques have drawbacks and uncertainties associated with them, they are a step closer to quicker orthodontic treatment making them the next frontier for orthodontics and its success.

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