

Accelerated Orthodontics: A Frontier in Orthodontic Treatment

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Abstract: The time span of orthodontic treatment is the principal concern of many orthodontic patients. Unfortunately, long orthodontic treatment time poses several disadvantages like a higher predisposition to dental caries, gingival recession and root resorption.

Consequently, researchers introduced few methods to accelerate the velocity of the tooth movement. These kind of methods became popular as accelerated orthodontics. Orthodontic treatment involves the response of the tissues surrounding the tooth on which the force is being applied that happens on a chemical, cellular and mechanical level. So to enhance the body's response to these orthodontic forces, various ways were found to accelerate the treatment. This article reviews the biology of tooth movement and discusses various methods like surgical methods-osteotomy and corticotomy and physical methods like low level lasers, direct electric current effect and their promising results along with their limitations.

Keywords: Accelerated Orthodontics; Corticotomy; Lasers

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I. Introduction

Orthodontics has developed tremendously over the years in achieving the desired results both clinically and technically. This was made possible by using new technologies, like stimulation software that can assist in treatment planning and translational products. In addition, continuous modification of wires and brackets as a result of the biomechanical efficiencies in orthodontics has greatly improved. However, these biomechanical systems may have reached their limit and there is a need to develop new method to accelerate teeth movement. The major challenge Orthodontics faced was to reduce the duration of orthodontic treatment. The best solution to shorten treatment time is to speed up the rate of tooth movement. A number of attempts have been made to create different approaches in order to achieve quicker results, but still there are a lot of uncertainties and unanswered questions towards most of these techniques.

Methods to accelerate orthodontic tooth movement can be broadly divided under the following categories:-

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

Biological approach

Effect of cytokines on tooth movement:-High concentration of cytokines such as interleukins IL-1, IL-2, IL-3, IL-6, IL-8, and tumor necrosis factor alpha (TNF) were found to play a major role in bone remodelling. Interleukin-1 (IL-1) stimulates osteoclast function through its receptor on osteoclasts. It was also seen that mechanical stress caused due to orthodontic treatment increased the production of prostaglandin PGE and IL-1 beta in the periodontal ligaments.

Other cytokines which are involved in the acceleration of tooth movement are RANKL, which is a membrane-bound protein on the osteoblasts that bind to the RANK on the osteoclasts and causes osteoclastogenesis.^{2,4} On the other hand, osteoprotegerin (OPG) competes with RANKL in binding to osteoclast to inhibit osteoclastogenesis. The process of bone remodeling is a balance between (RANKL-RANK) system and OPG compound.^{5,6} In relation to this, a study was conducted in 2006 using biological molecules in the

acceleration of tooth movement and 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. On the other hand, the transfer of OPG gene inhibited orthodontic tooth movements.⁷ In another study it was found that juvenile teeth move faster than adults, which is due to the lower amount of RANKL/OPG ratio in the gingival crevicular fluid (GCF) in adult patients measured by the enzyme-linked immunosorbent assay method.

Also a correlation was found among RANK, OPG, and root resorption during orthodontic teeth movement, and patients with root resorption produced a large amount of RANKL in the compressed site.^{8,9}

Prostaglandin effect on tooth movement: - Prostaglandin (PG), a pancreatic hormone is an inflammatory mediator that acts on nearby cells and stimulates bone resorption by increasing directly the bone resorbing cells i.e. osteoclasts. Various in vivo and in vitro experiments have shown clearly the relation between PGs, applied forces, and the acceleration of tooth movement. Yamasaki^{10,11} was among the first to investigate the effect of local administration of prostaglandin on rats and monkeys. In addition, experiments done in rats¹² have shown that injections of exogenous PGE2 over an extended period of time caused acceleration of tooth movements. It was further stated that the acceleration rate was not affected by single or multiple injections or between different concentrations of the injected PGE2. However, a correlation was found between root resorption and 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.¹³

Human trials were done with chemically produced PGE2 with split-mouth design and in first premolar extraction cases. In these experiments the rate of distal retraction of canines was 1.6-fold faster than the control side.¹⁴

Effect of Vitamin D3 on tooth movement: - Vitamin D and especially its most active metabolite which is 1,25-dihydroxyvitamin D3 (1,25(OH)2D3) together with parathyroid hormone and calcitonin, regulates the amount of calcium and phosphorus in humans.

Another experiment was done by Collins MK and Sinclair PM (1988)¹⁵ on cats where they injected vitamin D metabolite on the PDL for several weeks and 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 study¹⁶ was done in 2004 to investigate the comparison between local injection of vitamin D and PGEs on two different groups of rats. It was found that there is no significant difference in acceleration between the two groups. However, the side which was injected by vitamin D had greater number of osteoblasts on the pressure side as compared to PGE2 side; which indicates that vitamin D may be more effective in bone turnover as compared to PGE2.

PTH effect on tooth movement: - Parathyroid hormone is produced by the parathyroid glands to regulate serum calcium concentration. PTH affects osteoblasts cellular metabolic activity, gene transcriptional activity, and multiple protease secretions. PTH effects on osteoclasts occur through the production of RANKL, a protein that plays a critical role in osteoclast formation and its activity.

In order to evaluate the effect of PTH on orthodontic tooth movement a study¹⁷ was done on rats by continuous infusion of PTH (1 to 10 µg/100 g of body weight/day) implantation in the dorsocervical region, and it was seen that the molars were moved 2- to 3-fold faster mesially by orthodontic coil spring.

It was seen that the local administration of PTH was more advantageous in causing bone resorption rather than systemically.¹⁸ 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.¹⁹

Surgical approach

In 1931, Bichlmayr introduced a surgical technique for rapid correction of severe maxillary protrusion with orthodontic appliances. Wedges of bone were first removed to reduce the volume of bone through which the roots of the maxillary anterior teeth would need to be retracted. In 1959, Krole expanded on this philosophy by addressing additional movements, including space closure and crossbite correction. They suggested that bony blocks (bone-teeth unit) were created as a result of the corticotomy, hence causing faster tooth movement. The surgical technique has been documented in many case reports. It is a clinically effective technique used for adult patients, where duration of orthodontic treatment may be critical in selected groups of patients. The PDL and alveolar bone remodeling are the important parameters in tooth movement, and bone turnover is known to increase after bone grafting, fracture, and osteotomy. Several surgical approaches that have been tried in order to accelerate tooth movement were interseptal alveolar surgery, osteotomy, corticotomy, and Piezosonic technique.

Inter-septal alveolar surgery: Inter-septal alveolar surgery or distraction osteogenesis involves controlled and gradual displacement of surgically created fractures which is termed as sub-periosteal osteotomy by incremental traction that results in simultaneous expansion of soft tissue and the bone volume due to mechanical stretching of the osteotomy site. It is divided into the distraction of the dentoalveolar bone or distraction of periodontal ligament.²⁰

In the rapid canine distraction of PDL, at the time of extraction of first premolars; the interseptalbone distal to the canine is undermined surgically; thereby reducing the resistance on the pressure site. Later the compact bone is replaced by the woven bone; which makes tooth movement easier and quicker due to reduced resistance of the bone. The retraction of the canine is done by the activation of an intraoral device directly after the surgery. It has been shown that it took 3 weeks to achieve 6 to 7 mm of full retraction of the canine to the socket of the extracted first premolars.²¹ It was also seen that these rapid movements are during the initial phases of tooth movement especially in the first week.

Rapid canine distraction of the dentoalveolar bone is done by the same principle of the distraction of PDL, with the addition of more dissection and osteotomies performed at the vestibule. It is seen that both techniques accelerated tooth movement with no evidence of significant root resorption, ankylosis, and root fracture.

Corticotomy and osteotomy: Osteotomy is when a segment of the bone is cut into the medullary bone and is separated and then moved as a unit. A corticotomy is defined as a surgical procedure where only the outer cortical bone is cut, perforated or modified. The medullar bone is left intact. This is in contrast to an osteotomy where the surgical cut perforates both cortical and medullar bone.

Corticotomy was first tried in orthodontics by Kole,²² where he stated that tooth movements were achieved between 6 and 12 months. The technique was further used by Grenerson²³ who used this for open bites treatments.

In 2001 Wilcko²⁴ stated that the acceleration of tooth movement was not due to the bony block movement as postulated earlier by Kole; it was rather a process of bone remodeling taking place at the surgical site, which was called regional acceleratory phenomenon (RAP). He developed patent techniques which were called accelerated osteogenic orthodontics (AOO) and periodontal accelerated osteogenic orthodontics (PAOO).

Advantages

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

Disadvantages

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

Piezocision:- This is a minimally invasive procedure which involves flapless method in combining piezosurgical cortical micro-incisions with selective tunneling that allows for soft-tissue or bone grafting.²⁵ Vercelotti and Podesta²⁶ established the use of piezosurgery instead of burs, in conjunction with the conventional flap elevations to create an environment conducive for the rapid tooth movement. This technique is quite invasive as it requires extensive flap elevation and osseous surgeries, with post-surgical discomfort. This technique has not been widely accepted by patient community. Subsequently, Dibart²⁷ introduced piezocision with less invasiveness to this procedure.

Procedure: This is a combination of microincisions limited to the buccal gingiva that allows the use of a piezoelectric knife to give osseous cuts to the buccal cortex and initiate the RAP without involving palatal or lingual cortex. The procedure allows for rapid tooth movement without the downside of an extensive and traumatic surgical approach while maintaining the clinical benefit of a soft-tissue or grafting concomitant with a tunnel approach. Dibart and co-workers^{27,28} established a minimally invasive flapless procedure, combining micro incisions, piezoelectric incisions and selective tunneling that allows for hard- or soft-tissue grafting. They concluded that piezocision allows a rapid correction without the drawbacks of traumatic conventional corticotomy procedures in severe malocclusion cases. They later combined this technique with invisalign and found to be more effective and esthetic.

Microosteoperforations (MOPs): A device called Propel™, was launched by Propel Orthodontics to further reduce the invasive nature of surgical irritation of bone and this procedure was popularized as alveocentesis, which literally translates to puncturing bone.²⁹ The device has an adjustable depth dial adjustable at 0 mm, 3 mm, 5 mm, and 7 mm of tip depth and indicating arrow on the driver body. This device comes as ready-to-use sterile disposable device.

Procedure: A soft tissue flap was raised in the premolar and molar region and small perforations of about 0.25 mm are made using a round bur and hand piece through the cortical bone.

Contemporary status of surgical methods: Surgical methods are invasive procedures and patient cooperation is much needed. Inter-septal alveolar surgery, corticotomy and corticision are more invasive and expensive with needed surgical cuts and osteotomies. Post-operative complications are sometimes present with pain, swelling and patient discomfort. Recent techniques in surgical methods such as piezocision and microosteoperforations are less invasive with comparatively less complications, but more research should be done in using those techniques for accelerating the orthodontic tooth movement.

Physical approach

Direct electric current: Electrical current has been tested experimentally on the animal models and have shown in accelerating orthodontic tooth movement. Direct current or electrical currents generated piezoelectrically thereby enhance the orthodontic tooth movement.

Procedure: An electric appliance that provides direct electric current was placed in the extracted tooth region, generated bio electric potentials causing local responses and acceleration of bone modelling. This procedure was performed by some researchers^{30,31} on living animals and found to be effective in tooth movement. Subsequently, Kim³² performed a clinical trial on humans and found 30% acceleration of tooth movement when compared to conventional technique.

Cyclic vibrations: The use of cyclic vibratory method is to place light alternating forces on the teeth via mechanical radiations. The initial response of cells to mechanical stress *in vitro* appears within 30 minutes.

Procedure: Signals from the force sensor and the accelerometer were transferred into the vibration controller. The amplified signal was then transferred to the vibrator, causing its excitation. The vibration was applied by the control signal through the power amplifier controlled by the output signal from the accelerometer, thereby maintaining the acceleration at 1.0 meter per square second (m/s²). A vibration-imposed system consists of a vibration controller, charge amplifier, vibrator, force sensor and accelerometer. The top of the vibrator was fixed on the tooth with an adhesive.

The vibration tests were carried out for 5 minutes, and the resonance curves were displayed as frequency-force relationships on the monitor of the vibration controller. Clinical trials were conducted by various researchers³³⁻³⁷ on human population using oral vibrating devices such as Accledent™, AcceleDent® and electric tooth brushes and found to be effective in increasing the rate of tooth movement.

Low-level laser therapy: Photo biomodulation or low-level laser therapy (LLLT) is one of the most promising approaches today. Laser light stimulates the proliferation of osteoclast, osteoblast and fibroblasts, and thereby affects bone remodeling and accelerates tooth movement. The mechanism involved in the acceleration of tooth movement is by the production of ATP and activation of cytochrome C³⁸ and improve the velocity of tooth movement via RANK/RANKL and the macrophage colony-stimulating factor and its receptor expression. Studies performed by numerous investigators^{39,40} found LLLT has the potential to increase the rate of tooth movement. Whereas a study done by Limpanichkul W et al⁴¹ in 2006 did not found a significant result and concluded that the LLLT at the surface level in their study (25 J/cm²) was probably too low to either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement. The difference amongst these studies seems to arise from variations in frequency of application of laser, intensity of laser, and method of force application on the tooth.

II. Conclusion

Acceleration of tooth movement while orthodontic treatment is of increasing demand now a days because of patient's interest to get the treatment completed in less span of time and to decrease the number of visits. Also, adult orthodontics has more demand as the number of adult patients is getting increased. In general, all these techniques had drawbacks and uncertainties that made them not commonly used clinically. However, there has been a rapid increase in the interest levels of product companies to enhance the effects of biology in orthodontics and they are a step closer to quicker orthodontic treatment making them the next frontier for orthodontics and its success.

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