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Accelerated orthodontics: Getting ahead of ourselves

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Abstract--Orthodontic treatment is possibly, in terms of duration, the lengthiest dental procedure performed. Lengthy orthodontic treatment prompts many patients, especially adults, to either avoid treatment or to seek shorter alternative solutions with compromised results. Extended orthodontic treatment duration may also be associated with an increased risk of root resorption, periodontal disease, dental caries and loss of patient motivation. Accelerating orthodontic tooth movement has long been desired for its multiple potential benefits including shorter treatment duration, improved post treatment stability and reducing side effects associated with prolonged treatment. When an orthodontic force is delivered to a tooth certain mechanical, chemical, and cellular events take place within the paradental tissues resulting in architectural alterations that bring about tooth movement. By increasing body's response to the orthodontic forces, tooth movement can be accelerated and treatment time can be reduced. Attempts to accelerate tooth movement date back to the 1890s; almost contemporary with Angle's groundbreaking work in modern orthodontics. Today, accelerated orthodontics may be accomplished by several approaches that include invasive, minimally invasive and non-invasive procedures. Invasive approach includes interseptal alveolar surgery and corticotomy while minimal invasive methods include modifications of surgical procedure such as peizocision, corticision and microosteoperforations. The non-invasive

methods include use of pharmacological agents and various physical devices such as laser therapy and pulsatile stimulation. These methods have been successfully proven to reduce treatment times by up to 70%. The purpose of this article is to review the successful approaches and to highlight the current trends and techniques in accelerated tooth movement.

Keywords---accelerated orthodontics, corticotomy, laser therapy, microosteoperforations, piezocision.

Introduction

Orthodontic treatment in the present day requires meeting the demands of creating functional harmony in occlusion and improving the aesthetic outlook. We live in a fast paced world where the treatment duration has made the field of orthodontic treatment revolve around it. However, a puzzling challenge that has not been completely solved in clinical orthodontics is the prolonged treatment time, being on an average 2 to 3 years. Overcoming this challenge will dramatically improve the quality of orthodontic care and motivate more people towards the concept of orthodontic treatment. Lengthy orthodontic treatment prompts many patients, especially adults, to either avoid treatment or to seek shorter alternative solutions with compromised results.

Fixed orthodontics could last for 24 to 36 months which further poses the risk of complications associated with the treatment such as external root resorption, periodontal problems and patient compliance. Orthodontists are persistently motivated towards developing potential strategies to enhance the rate of orthodontic tooth movement without compromising the treatment outcome. The purpose of this article is to review and critically analyze the different methods used for accelerating orthodontic tooth movement (AOTM), indications, contraindications and their practical applications in clinical practice.

Currently popular methods to accelerate the tooth movement and thus shorten the duration of treatment time can be categorized as follows:

METHODS FOR ACCELERATED ORTHODONTICS

<i>Invasive</i>	<i>Minimal invasive</i>	<i>Non-invasive</i>
Interseptal alveolar surgery (Distraction Osteogenesis)	Piezocision & Discision	Cyclic Vibrations
Conventional Corticotomy	Microosteoperforation (Alveocentesis)	Low Level Laser Therapy (Photo biomodulation)
PAOO, Wilckodontics		Drug Therapy

Historical Perspective

Surgical intervention to affect the alveolar housing, and thereby tooth movement has been described in different forms over the past 100 years. Heinrich Kole was the first to describe corticotomy-facilitated orthodontics in 1959¹. He believed that the continuity and thickness of the denser layer of cortical bone offers the most resistance to rapid tooth movement. Kole attributed the accelerated tooth movement by selective corticotomy to moving “blocks of bone” and this interpretation of the rapid tooth movement prevailed until Wilcko’s publication in 2001. Wilcko discovered that the rapid tooth movement was due to transient localized demineralization- remineralization process in the bony alveolar housing and was not the result of bony block movement as suggested by Kole². Wilcko et al combined the refined corticotomy-facilitated orthodontic technique with alveolar augmentation using particulate bone graft and named the orthodontic and periodontal aspects of this procedure the accelerated osteogenic orthodontics (AOO) technique, and more recently, the periodontally AOO (PAOO) surgical technique, respectively, reduce the orthodontic treatment time to 1/3rd the time of conventional orthodontics in majority of cases³.

Cruz et al in 2004 were the first to carry 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 of 34% greater than the control canines over a period of 60 days⁴. An alternative surgical approach to accelerate tooth movement was introduced by Park et al in 2006 known as ‘corticision’ which was considered to be a micro-invasive technique⁵. Vercelotti and Podesta in 2007 introduced the use of piezosurgery, instead of burs, in conjunction with the conventional flap elevations to create an environment conducive to rapid tooth movement⁶. Dibart et al in 2009 described a minimally invasive procedure piezocision, which used a piezoelectric knife instead of mallet to give labial/buccal cortical incisions with no involvement of palatal or lingual cortex⁷.

A new micro-invasive technique called alveocentesis was introduced in 2011, which stimulates cytokine activity thereby, accelerating alveolar bone remodeling. This new technique called the PROPEL system has been developed and patented for use as a simple, in-office procedure to stimulate alveolar bone remodeling. The microosteoperforations created by PROPEL system harnesses the body’s own biology to create a cytokine effect and allows the teeth to move into clinically desired position in a more predictable and faster manner⁸.

Invasive Procedures

Interseptal alveolar surgery

Interseptal alveolar surgery or distraction osteogenesis involves controlled and gradual displacement of surgically created fractures which is termed as subperiosteal 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 ligament⁹.

Procedure: At the time extraction of first premolars the interseptal bone distal to the canine is undermined surgically¹⁰ by 1 to 1.5mm (Figure 1). Distraction device used is a custom made, intraoral, tooth borne device (Figure 2), manufactured from stainless steel¹¹. Based on interseptal alveolar surgery, the compact bone is replaced by the woven bone, and tooth movement is easier and quicker due to reduced resistance of the bone. It was found that these rapid movements are during the initial phases of tooth movement, especially in the first week¹².



Figure 1: Osteotomy cuts for interseptal alveolar surgery



Figure 2: Distraction Osteogenesis device

Corticotomy

It is a surgical procedure whereby only the cortical bone is cut, perforated, or mechanically altered without any alteration in the medullary bone unlike osteotomies which involve the entire thickness of bone¹³.

Procedure: Full thickness buccal and or lingual mucoperiosteal flaps are elevated. Corticotomy cuts are positioned using piezosurgical armamentarium or micromotor under irrigation (Figure 3) and may be followed by placement of a graft material, at the corticotomy sites to enhance the thickness of the bone if required¹³.

Advantages

- Bone can be augmented and periodontal defects avoided
- Minimal changes in the periodontal attachment apparatus

- Minimal treatment duration and increased rate of tooth movement
- Less root resorption

Disadvantages

- Expensive and comparatively invasive procedure.
- May cause post-operative pain and swelling.
-



Figure 3: Corticotomy technique

Paoo, Wilckodontics

In 2001, Wilcko et al introduced a method which combines corticotomy surgery and alveolar bone grafting which is referred to as accelerated osteogenic orthodontics or recently termed as periodontally accelerated osteogenic orthodontics (PAOO)². This procedure which enables rapid tooth movement is due to a healing event that was described by Frost¹⁴ and termed as regional acceleratory phenomenon (RAP). The two main features of RAP include decreased regional bone density and accelerated bone turnover, which are believed to facilitate orthodontic tooth movement.

By enhancing the various healing stages, corticotomy-facilitated tooth movement makes healing occur 2–10 times faster than normal physiologic healing². PAOO is a modified corticotomy facilitated orthodontic technique with the addition of alveolar augmentation which has an advantage of increasing the volume of alveolar bone and allows for correction of preexisting bony dehiscence and fenestrations (Figure 4a & 4b). Autogenous bone graft, allograft or xenograft, demineralized freeze dried bone allograft (DFDBA) and alloplastic materials can be used. Initiation of orthodontic force should not be delayed more than two weeks after PAOO surgery.



Figure 4a: Modified corticotomy (Wilckodontics)



Figure 4b: Bone graft in place (Wilckodontics)

Clinical Considerations Of Regional Acceleratory Phenomenon

Indications

- Class I malocclusion with moderate to severe crowding
- Class II malocclusion requiring extraction/expansion
- Mild Class III cases

Contraindications

- Patients with active periodontal disease
- Inadequately performed endodontic treatment
- Patients with a history of prolonged corticosteroid usage
- Patients on medication that interfere with bone metabolism such as bisphosphonates or NSAIDS

Advantages

- Proven successful by many authors to accelerate tooth movement
- Bone can be augmented, thereby preventing periodontal defects, which might arise due to thin alveolar bone
- Widens the scope of malocclusion treatment by enhancing the limits of tooth movement
- Enhances post orthodontic stability

Disadvantages

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

Minimal Invasive Procedures

Piezocision

Reflecting the full thickness flap for corticotomy was considered too invasive. To overcome this drawback, Dibart et al (2009) presented a flapless method of

corticotomy using piezosurgery⁷. The surgery was performed one week after placement of orthodontic appliance under local anesthesia in the technique described by them. Gingival vertical incisions, only buccally, were made below the interdental papilla in the attached gingiva using a No. 15 scalpel (Figure 5a). This procedure's main objective was to create an incision deep enough to pass through the periosteum and contact the cortical bone. A BS1 insert Piezotome was used to perform the corticotomy cuts through the incisions made to a depth of 3 mm (Figure 5b). Once again, if bone reinforcement is required, it can be done by using an elevator at the areas requiring bone augmentation. The elevator is inserted between the incisions to create 'tunnels' to establish sufficient space to accept the graft material. Suturing is not usually required unless the graft materials need to be stabilized. The patient is placed on an antibiotic & mouthwash regimen¹⁵.

Advantages

- Minimally invasive
- Better patient acceptance

Disadvantages

- Risk of root damage

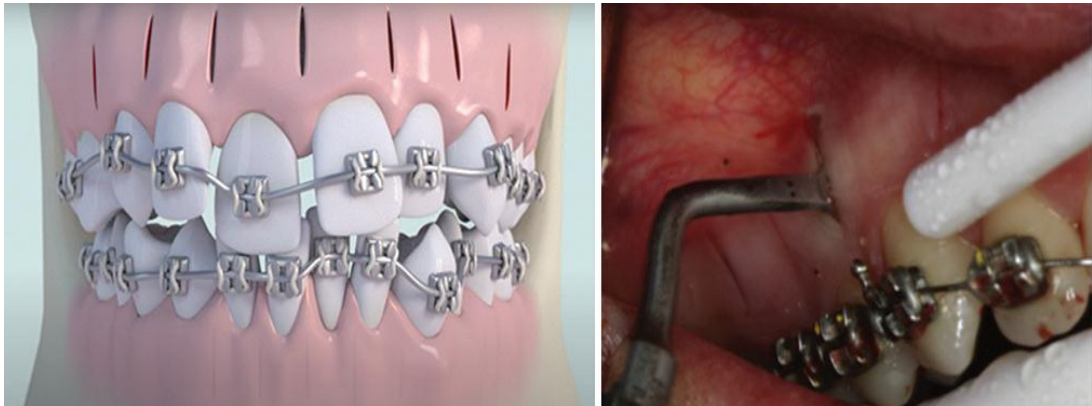


Figure 5(a): Vertical gingival incisions made buccally (b) Performing piezocision with a piezotome

Microosteoperforations (MOPs)

To achieve an orthodontic movement quickly enough with minimum invasion in the bone's surrounding tissues, Propel Orthodontics introduced a device called 'PROPEL'. The procedure involves puncturing the bone to speed up the tooth movement. This process is called Alveocentesis. Micro osteoperforations stimulate the expression of inflammatory markers, leading to an increase in osteoclastic activity, thus increased tooth movement rate. This technique requires a ready to use sterile disposable device (Figure 6a). An indicating arrow on the driver's body and adjustable depth dial is present on the device, which can be positioned to 0 mm, 3 mm, 5 mm, and 7 mm of tip depth, depending on the operation area¹⁶. (Figure 6b)

Procedure: A soft tissue flap is raised and small perforations of about 0.25 mm are made using a round bur and hand piece or simply the PROPEL device through the cortical bone. Two cases requiring RCTs were reported as complication of microosteoperforations, among these one was animal study¹⁶ and other was human trial¹⁷.

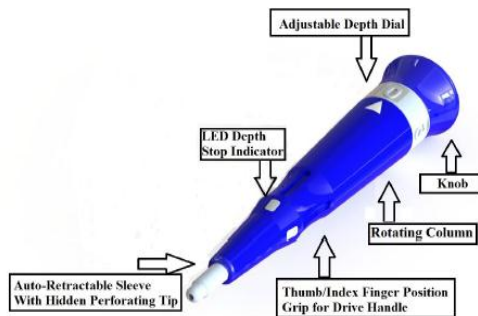


Figure 6(a): PROPEL DEVICE

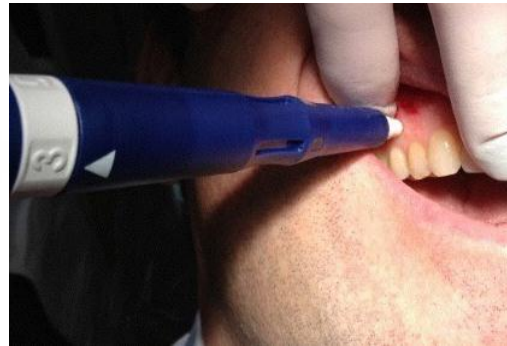


Figure 6(b) Alveocentesis using PROPEL

Non Invasive Procedures

Direct electric currents, resonance vibration, low level laser therapy, static magnetic field, and pulsed electromagnetic field, have been employed to accelerate tooth movement. The concept of using physical approaches came from the idea that applying orthodontic force causes bone bending (bone bending theory) and bioelectrical potential develops. The bioelectrical potential is created when there is application of discontinuous forces, which leads to the idea of trying cyclic forces and vibrations.

Cyclic Vibrations

The use of cyclic vibratory method involves placing light alternating forces on the teeth via mechanical radiations. The initial response of cells to mechanical stress in vitro appears within 30 minutes.

Procedure: A vibration-imposed system consists of a vibration controller, charge amplifier, vibrator, force sensor and accelerometer. Signals from the force sensor and the accelerometer are transferred to the vibration controller. The amplified signal is then transferred to the vibrator, causing its excitation. The vibration is 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/s^2). The top of the vibrator is 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 researchers¹⁸⁻²² on human population using oral vibrating devices such as AccleDent™, AcceleDent® (Figure 7) and electric tooth brushes and found to be effective in increasing the rate of tooth movement.

AcceleDent: This is a simple to use, hands free device which has a mouthpiece that is inserted around the existing braces and the activator is turned on for 20 min every day to generate small vibrations (Figure 7). It is a portable device that can be charged similar to any other electronic device.



Figure 7: AcceleDent device

Low-level laser therapy

Photo biomodulation or low-level laser therapy (LLLT) is one of the most promising approaches today (Figure 8). 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 C²³ and improve the velocity of tooth movement via RANK/RANKL (Receptor activator of nuclear factor Kappa-B/ Receptor activator of nuclear factor Kappa-B ligand) and the macrophage colony stimulating factor and its receptor expression.

Studies performed by numerous investigators²⁴⁻²⁸ found LLLT has the potential to increase the rate of tooth movement. Limpanichkul et al²⁵ in their study did not find a significant result with LLLT and concluded that the LLLT at the surface level (25 J/cm²) was probably too low to express either stimulatory effect or inhibitory effect on the rate of orthodontic tooth movement. The variation 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. Six studies have been performed on LLLT; among those five were randomized controlled trials on humans^{4,25-28} whereas one involved a cross sectional animal study²⁴.

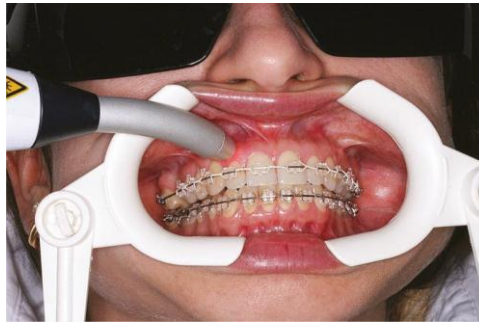


Figure 8: LLLT (Low Level Laser Therapy)

Drugs

Orthodontic forces cause fluid movement in the periodontal ligament space and distortion of the matrix and cells. There is release of molecules which initiate bone remodeling for tooth movement. There are a number of researches on pharmacological agents that act as biomodulators for increased orthodontic tooth movement. (Figure 9)



Figure 9: Injection of a biomodulator in the periodontium.

Prostaglandins

Prostaglandins (PGE) are paracrine lipid inflammatory mediators that act on nearby cells; PGE increase the number of osteoclasts directly which causes bone resorption. Yamasaki et al studied the effect of PGE in animal models by local administration²⁹ as well performed a clinical trial on humans³⁰ and found that local administration of PGE may cause safe and effective orthodontic tooth movement.

Parathyroid Hormone

Calcium homeostasis and bone remodeling in human body are mainly regulated by parathyroid hormone (PTH). The main function of PTH is calcium re-absorption from small intestine and thus increases the serum calcium concentration. It causes absorption of calcium ions from bone and thus leads to bone resorption. This mechanism is taken advantage in accelerated orthodontics to fasten the tooth movement. Soma et al^{31, 32} conducted experiments on rats and suggested that continuous administration of PTH is applicable to accelerate orthodontic

tooth movement. Three animal case control studies³¹⁻³³ have been reported on use of parathyroid hormone for AOTM.

Vitamin D3

Vitamin D has similar function as parathyroid hormone by calcium re-absorption. 1,25 dihydroxy vitamin D₃, is the active form of vitamin D that acts on small intestine causing calcium reabsorption. It has a similar action on bone and thus leads to bone resorption. Local administration of vitamin D into PDL causes increase in LDH (lactate dehydrogenase) and CPK (creatine phosphokinase) enzymes. Several experimental studies performed on rats by various investigators³³⁻³⁵ have found 1, 25-DHCC to be more efficient in remodeling of bone during orthodontic tooth movement.

Relaxin

Relaxin is an ovarian hormone that belongs to the insulin superfamily. It helps in the widening of the pubic ligaments in females during delivery. Relaxin stimulates bone cell activity and connective tissue turnover. It is mainly known for the remodeling of soft tissue rather than bone³⁶. Results of a randomized clinical trial performed on humans using recombinant human relaxin showed no significant difference between the placebo control group and the relaxin group regarding the acceleration of tooth movement and relapse³⁷.

Clinical Application For The Future

Exogenous biological molecules' administration to quicken tooth movement during orthodontic treatments has been mostly tested on animal experiments. However, clinical trials on humans are restricted since they are to be administered in form of local injections, which can be discomforting and painful. However, certain molecules administrations have shown promising results, for example, cytokine, PTH, and Vitamin D play an essential role in bone remodeling and tooth movement. In the physical approach, the LLLT is the most promising method; however, conflicting results are seen. Furthermore, most of these experiments were done for a few weeks only, which is a brief time to notice any adverse effects. The surgical approach is the most tested with known predictions and long lasting results. However, it is invasive and expensive, and patients do not opt for surgery unless it is the only option needed to have the right occlusion. Piezoscision and microosteoperforation techniques are some of the newest methods in accelerating tooth movement, which has good clinical outcomes and are considered the least invasive in the surgical approach.

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. Surgical techniques are more invasive and costly but are more beneficial with fewer side effects. Hence recent techniques such as piezoscision, micro osteoperforations

have more demand in future. With increasing patient compliance, less invasive surgical techniques can be safely used to accelerate tooth movement. Device assisted therapy is also of high demand but there is a need for further studies about the proper device being used and how far it is useful. Pharmacological methods have more side effects and hence most of them are still in experimental stage. Only limited human trails are available. Accelerating orthodontic techniques can be highly useful for fastening the treatment as in every technique being used; there is increased rate of tooth movement and hence decreasing the treatment time.

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