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Research Article

Accelerated Orthodontics: A Review

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Abstract:

Nowadays, there is an increased tendency for researches to focus on accelerating methods for tooth movement due to the greater demand for adults for a shorter orthodontic treatment duration. Unfortunately, long orthodontic treatment time has many disadvantages like higher predisposition to caries, gingival recession, and root resorption. This increases the demand to increase tooth movement with the least possible disadvantages. Several modalities have been reported for accelerating the tooth movement. Thus, accelerating orthodontic tooth movement and the resulting shortening of the treatment time would be quite beneficial.

Keywords: accelerated orthodontic tooth movement, corticotomy, peizocision, micro-osteoperforation(MOPs).

Introduction:

There is an increased demand for fast orthodontic treatment, especially by adult patients. This has led researchers to focus on accelerated tooth movement with the aim of reducing treatment duration while maintaining treatment efficiency. The approach that researchers select to accelerate the rate of movement depends on interpretation of the data on the biology of tooth movement.

Orthodontic tooth movement occurs because of a mechanical stimuli which is 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]. Orthodontic tooth movement can be controlled by the amount of the applied force and the biological responses from the PDL [2]. 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.

Three types of bone cells play a significant role in the biology of tooth movement: osteoblasts, osteocytes, and osteoclasts. Osteoblasts are mononuclear cells found along bone surfaces. They are derived from mesenchymal stem cells in the bone marrow and synthesize collagenous and non-collagenous proteins that comprise the organic bone matrix, known as osteoid. Inactive osteoblasts, particularly in the adult skeleton, are called bone-lining cells. These cells are quiescent until growth factors or other anabolic stimuli induce their proliferation and differentiation into cuboidal osteoblasts. Osteoblasts are the main cells participating in the anabolic phase of orthodontic tooth movement with a limited role during the catabolic phase.

The mechanism by which mechanical stimulation activates osteocytes is not clear. Bone loading under physiologic condition results in strain, or deformation, in the bone matrix and the osteocyte lacunae and canaliculi. Some investigators suggest that it is the strain magnitude in the matrix, rather than in the lacunae or canaliculi, that triggers bone remodeling. These responses to mechanical load activate osteocytes to secrete key factors, such as prostaglandins, nitric oxide, or insulin-like growth factors (IGFs), which then activate osteoclasts and osteoblasts in a tightly synchronized biological phenomenon called bone remodeling.

Osteoclasts control the rate of bone resorption during orthodontic treatment and, therefore, the rate of tooth movement. However, osteoclasts do not function independently. In fact, they require signals from several other cell types for their maturation, activation, and ability to perform targeted, site-specific bone resorption. The consequences of unregulated osteoclast activation would be catastrophic as bone resorption would proceed unchecked producing weakened bone and fractures. Consequently, osteoclasts cannot be direct targets of orthodontic forces. Instead, the upstream events that control osteoclast formation and activation must be the main targets.

Methods of Acceleration:

The basis for clinical procedures such as corticotomy-assisted orthodontics, piezocision-aided orthodontics, and surgery-first orthodontics is the direct injury to the both alveolar bones (maxillary arch and mandibular arch) AOTM by inducing regional acceleratory phenomenon (RAP), as a wound-healing process [3,4]. A surgical technique was introduced by Bichalmyr [5] for faster correction of severe maxillary protrusion with available orthodontic appliances. Wedges of alveolar bone were removed to decrease the volume of the bone through the radicular parts of the maxillary teeth in anterior region. Kole [6] suggested a technique of creating bony blocks (bone-teeth unit) through the corticotomy to enhance the faster tooth movement. For the next fifty years this concept prevailed until Wilcko and co-workers [7], reported a transient demineralization -remineralization procedure enchanting after corticotomy, which was termed as a periodontally accelerated osteogenic orthodontics (PAOO). The PAOO is an amalgamation of selective decortications and facilitated orthodontic techniques along with alveolar augmentation. This technique shortens the treatment time to 33% the time of conventional treatment duration in orthodontics. This concept was based on a similar technique, as regional acceleratory phenomena (RAP). This method is a local response to a lethal stimulus which describes a

process of tissue formation faster than the usual local regeneration process. Enhancing a variety of healing stages, this RAP makes healing occur 2-10 times earlier than regular healing [8]. However, this is an old technique and very invasive hence, this was not accepted by all patients. Hence, latest procedures like corticision, piezosurgery, fiberotomy and microosteoperforations had demonstrated.

Bone is surgically wounded so as to initiate a localized inflammatory response. The presence of cytokines and chemokines through prostaglandin E2 pathway and the RANK/ RANKL pathway causes differentiation of osteoclasts which leads to bone resorption and thus AOTM is possible. It has been reported that this effect lasts for 4 months and this method needs to be repeated, in case faster tooth movement further if required.

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 surrounding alveolar 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 [9]. (fig. 1).

Figure 1. Inter-septal alveolar surgery

Procedure: At the time extraction of first premolars the inter-septal bone distal to the canine is
undermined surgically. Eventually resistance on the pressure site will be decreased. Bone distal to canine undermined inter-septally by 1 to 1.5mm. Based on inter-septal 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. These rapid movements are found to be achieved during the initial phases of tooth movement, especially in the first week. Rapid canine distraction of the dento-alveolar bone may be performed by the same principle of the distraction of periodontal ligament with the addition of more dissection and osteotomies performed at the vestibule, in some cases. Clinical trials on humans showed that this technique would reduce the resistance in the pathway of canine movement more effectively during orthodontic treatment. Among the studies reported on inter-septal alveolar surgery two were cross sectional studies and rest were randomized clinical trials (RCTs).

Corticotomy: A corticotomy is defined as a surgical procedure whereby only the cortical bone is cut, perforated, or mechanically altered without any alteration in the medullary bone. This is performed without the involvement of medullary bone unlike osteotomies which involve the entire thickness of bone [10].

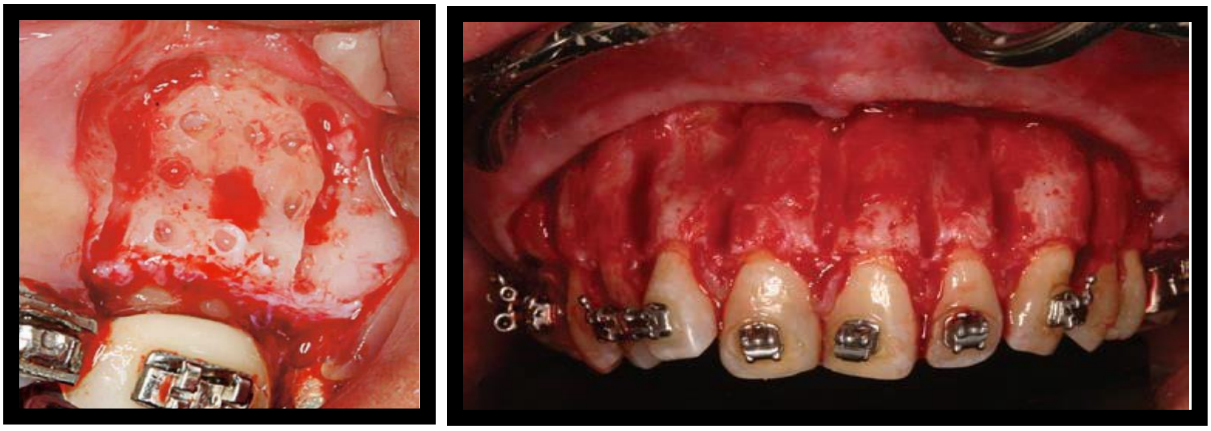

Figure 2: Corticotomy

Procedure: Elevation of full thickness mucoperiosteal flaps of both buccal and/or lingual region. Positioning the corticotomy cuts using piezosurgical armamentarium or micromotor under irrigation and it is followed by placement of a graft material, in required sites to enhance the thickness of the bone [10].

Advantages: Bone can be augmented and periodontal defects would be avoided. Minimal changes in the periodontal attachment apparatus. Shorter treatment time. Less root resorption. Various authors performed clinical trials using corticotomy assisted canine retraction and found reduction in treatment time by 28%-33% and a 2-3-fold increase in velocity of tooth movement when compared with conventional OTM on control side.

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

Corticision: Kim and co-workers established a technique with minimal surgical intervention called corticision which is also called as minimally invasive rapid orthodontics (MIRO). Corticision was initiated as a supplemental dento-alveolar surgery in orthodontic therapy to achieve AOTM with minimal surgical intervention[11].

Procedure: Separation of the inter-proximal cortices with a reinforced scalpel is used as a thin chisel and a mallet transmucosally without reflecting a flap. With 45°-60° an inclination to the gingiva at the long axis of the canine a reinforced surgical blade with a minimum thickness of 400 µm should be located on the inter-radicular attachment. In order to preserve the alveolar crest, the surgical injury should be 2 mm from the papillary gingival margin and 1 mm beyond the mucogingival junction. The blade should be pulled out by a swing motion. Clinical studies were conducted on humans and animals and concluded corticision effectively accelerates the tooth movement similar to corticotomy and is more advantageous because of its less invasiveness. Among the published studies on corticision two were case control studies and other was case series.

Piezocision: This is a minimally invasive procedure involves flapless in combining piezosurgical cortical micro-incisions with selective tunneling that allows for soft-tissue or bone grafting. Vercelotti and Podesta 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, Dibart introduced piezocision with less invasiveness to this procedure.[12]

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[12] 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.

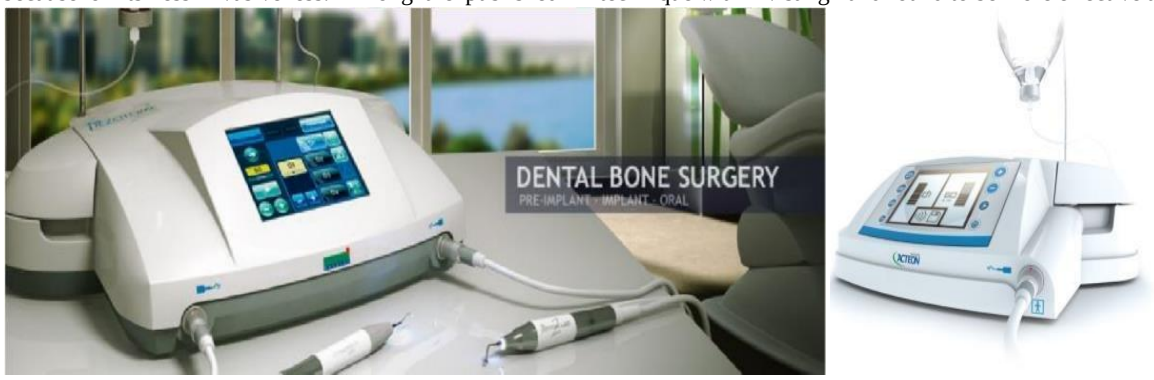

Figure: 3 Piezotome

Microosteoperforations (MOPs): A device used for this method is called as PropelTM, which was launched by Propel Orthodontics. It reduces the invasive nature of surgical irritation of bone. This procedure was initially popularized as alveocentesis, which literally means puncturing of bone. The device has an adjustable depth dial at 0mm, 3mm, 5mm, and 7mm of tip depth and an 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. 1-3 micro-osteoperforations are to be done depending on proximity of anatomical structures. Perforations can be made on buccal or lingual side of both maxillary and mandibular arch in linear or triangular patterns. Two randomized control trial studies were reported on microosteoperforations among these one was animal study and other was a human trial [13].

Figure: 4 Micro-osteoperforations

Contemporary status of surgical methods: Surgical methods are invasive procedures and hence, 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 such as piezocision and microosteoperforations are less invasive with comparatively less complications than the previously used procedures. But more research is required to be done in using those techniques for accelerating the orthodontic tooth movement.

Device assisted therapy or mechanical stimulation methods:

There are various methods used to accelerate tooth movement like direct electric currents, resonance vibration, low level laser therapy, static magnetic field, and pulsed electromagnetic field. The concept of applying orthodontic forces causes bone bending (bone bending theory) and bioelectrical potential gave an idea of using physical approaches.The bioelectrical potential is created when there is application of discontinuous forces, which leads to the idea of trying cyclic forces and vibrations.

Direct electric current: Electrical current has been tested experimentally on the animal models and have shown good results with 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 on living animals and found to be effective in tooth movement. Subsequently, Kim performed a clinical trial on humans and found 30% acceleration of tooth movement when compared to conventional technique. Only three studies reported on this technique in the literature; two were animal studies (one was case control study) and cross section study and one RCT involved human trials [14].

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

Procedure: The signals from the force sensor and the accelerometer were transferred into the vibration controller. This 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 researchers on human population using oral vibrating devices such as AccledentTM, AcceleDent® and electric tooth brushes and found to be effective in increasing the rate of tooth movement [15].

Figure: 5 Accledent

Low-level laser therapy: Photo biomodulation or low-level laser therapy (LLLT) is one of the most well-known and promising approaches today. The proliferation of osteoclast, osteoblast and fibroblasts is stimulated by the laser light, and thereby affects bone remodeling and accelerates tooth movement. The mechanism involved in this method is by the production of ATP and activation of cytochrome C. It improves the velocity of tooth movement via RANK/RANKL and the macrophage colony-stimulating factor and its receptor expression. Limpanichkul in their study 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 express either stimulatory 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 [16].

Drugs:

Drugs like parathyroid hormone, vitamin D, prostaglandins and relaxin are the most commonly used pharmacological agents to increase the rate of tooth movement and thus reduces the treatment duration.

Parathyroid hormone: Calcium homeostatsis and bone remodeling in the human body are mainly regulated by parathyroid hormone (PTH). The main function of PTH is calcium reabsorption 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 advantage of this mechanism is taken in accelerated orthodontics to fasten the tooth movement. Soma and coworkers [55,56] had conducted studies on rats and suggested that continuous administration of parathyroid hormone is applicable to accelerate orthodontic tooth movement. Three animal case control studies performed on parathyroid hormone used for AOTM [17].

Vitamin- D: 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 act 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 the periodontal ligament causes an increase in LDH and CPK enzymes. Various experimental studies were performed on rats by various investigators and found that 1, 25-DHCC is more efficient in remodeling of bone during orthodontic tooth movement. The studies so far performed where of short duration and the systemic effects of the hormone in long term such as kidney function and condition of long bones are not taken into consideration. Such disadvantages can be reduced by local administration using controlled release systems. Hence, a safe and effective release system is needed for better clinical use[18].

Prostaglandins: Prostaglandins (PGE) are paracrine lipid inflammatory mediators that act on nearby cells; PGE increase the number of osteoclasts directly which causes bone resorption. Primarily Yamasaki and co-workers [60,61] studied the effect of PGE in animal models by local administration and consequently, same group of researchers performed a clinical trial on humans and found that local administration of PGE, may cause safe and effective orthodontic tooth movement [19].

Relaxin: Relaxin is a hormone which helps widening of the pubic ligaments in females during delivery; similarly, the presence of this hormone in cranial suture and PDL has been demonstrated. The role of relaxin is known for the remodelling of soft tissue rather than bone. Relaxin has the effect of increasing collagen at tension site and decreasing at pressure site. Experimental studies were performed on animal models and the authors concluded that the human relaxin may not accelerate orthodontic tooth movement in rats; it can decrease the level and mechanical strength of PDL, and increase mobility of the tooth at early time points. Mc Gorray and co-workers[20] in their clinical trial found local doses of relaxin might have been too low to affect tooth movement or short-term relapse..Most of the pharmacological agents are restricted to the experimental studies because of their adverse effects either with systemic or local administration. Further studies are needed to be performed for their safe clinical use. But, all of these drugs have some or the other unwanted adverse effect. Hence, as of today, no drug exists that can safely accelerate orthodontic tooth movement.

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. And even the adult orthodontics has gained more demands as the adult patients are increasing day by day for the orthodontic treatment. Surgical techniques are more invasive and costly but are more beneficial with fewer side effects. Hence, recent techniques such as piezocision, micro-osteoperforations has the more demand in future. Less invasive surgical techniques can be safely used to accelerate tooth movement with increased patient compliance. 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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