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Accelerated Orthodontics– An overview

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Abstract

Orthodontic treatment is the reorganization of skeletal and/or dental tissues. Prolonged treatment duration is one of the main concerns of patients undergoing with fixed orthodontics. This extended orthodontic treatment in such particular cases has several drawbacks to the patients such as increased predisposition to root resorption, dental caries and gingival recession, etc. Consequently, researchers introduced few methods to accelerate the velocity of the tooth movement without any drawbacks. These kind of methods used in orthodontics were popular as accelerated orthodontics. Accelerated orthodontics could be possible by mechanical stimulation or device assisted therapy, surgical therapy and by the use of pharmacological agents. The purpose of the present manuscript was to describe and evaluate the methods used in accelerated orthodontics.

Keywords: Accelerated orthodontics; Conventional orthodontic treatment; Corticotomy; Tooth movement

Introduction

The movement of tooth orthodontically happens under mechanical forces depends upon the alteration of the tissues surrounding its radicular part. These mechanical force creates a response in cellular component of surrounding periodontal ligament (PDL), that creates resorption in bone on pressure side and deposition of bone on the either side (tension side) [1]. This is an inflammatory process and the rate limiting factor for tooth movement is bone resorption at the bone and periodontal ligament interface [2]. Orthodontic movement can be controlled by the size of the applied force and the biological responses from the periodontal ligament [3]. This orthodontic force would cause inflammation around the periodontal ligament due to changes in blood flow, leading to the secretion of different inflammatory mediators like colony-stimulating factors, cytokines, growth factor, arachidonic acid metabolites and neurotransmitters. As a result of these secretions, remodelling of the bone occurs [4, 5].

Macrophage colony stimulating factor (M-CSF), Receptor activator of nuclear factor kappa B ligand (RANKL), and osteoprotegerin (OPG) by osteoblasts play key roles in tooth movement has been showed in **Figure 1**. RANKL binds to its receptor, RANK (Receptor activator of nuclear factor kappa B), on the surface of osteoclastic cells at developmental stage. The RANKL/RANK binding is very critical for the function, differentiation, and survival of osteoclasts. 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 [6-8]. The purpose of this article is to review and critically analyze the different methods used for accelerating orthodontic tooth movement (AOTM) shown in **Figure 2**, indications, contraindications and their practical applications in clinical practice.

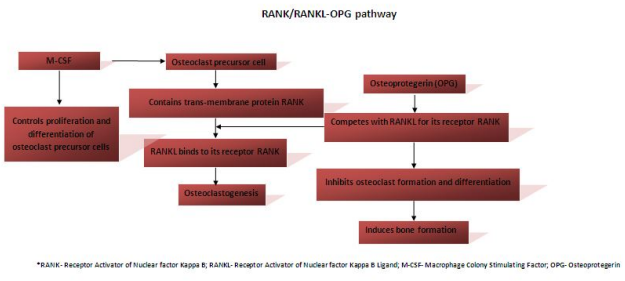

Figure 1 Flow diagram of t Receptor activator of nuclear factor kappa B ligand (RANKL), Receptor activator of nuclear factor kappa B (RANK), and osteoprotegerin (OPG) pathway in accelerated orthodontic tooth movement.

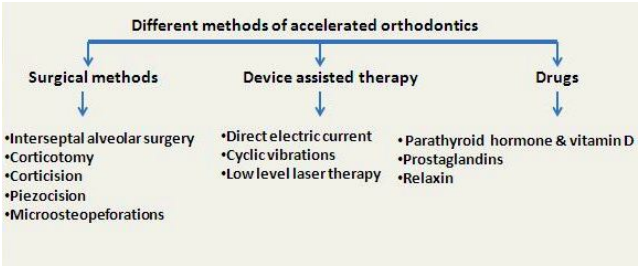

Figure 2 Description of various methods used in accelerated orthodontics.

AOTM has been preferred for its numerous prospective benefits like shorter treatment duration, differential tooth movement, enhanced envelope of tooth movement, improved post treatment stability and reduced side effects [9]. Attempts to AOTM can be dated back to the 1890s, where Cunningham at a Chicago Dental Congress, described "luxation or immediate method in the treatment of irregular teeth". Cunningham [9] confined his treatment to palatally inclined maxillary lateral incisors with vertical inter-dental bone cuts and without the benefit of anesthesia. Subsequently there are various methods described in the literature on AOTM. The reported studies on accelerated orthodontics were analyzed based on evidence described by National Health and Medical Research Council [10].

Literature Review

Surgical methods

Direct injury to the both alveolar bones (maxillary arch and mandibular arch) AOTM by inducing regional acceleratory phenomenon (RAP), as a wound-healing process, which is the basis for clinical procedures such as corticotomy-assisted orthodontics, piezocision-aided orthodontics, and surgery-first orthodontics [11,12]. Bichlmayr [5] introduced a surgical technique for hasty rectification 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 [13] 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 [14], 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 procedure increases the alveolar bone volume after orthodontic treatment by using bone grafts consists of decalcified freeze-dried bone allograft (DFDBA). This technique decreases the treatment time to 33% the time of conventional treatment duration in orthodontics. This concept was based on a similar technique, which was described as regional acceleratory phenomena (RAP) earlier. This method is a local response to a lethal stimulus that 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 [15]. However, this is an old technique and very invasive hence, this was accepted by all patients. Hence, latest procedures like corticision, piezosurgery, fiberotomy and microosteoperforations had demonstrated **(Tables 1)**.

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 in further if required [16-39].

Table 1 Studies performed using surgical methods.

Author	Technique	Type of study	Level of evidence	Type of study
Liou et al. [20]	Interseptal alveolar surgery	Cross sectional study	Level 3	Human
Sukurica et al. [21]	Interseptal alveolar surgery	Cross sectional study	Level 3	Human
Ren et al. [17]	Interseptal alveolar surgery	Randomised clinical trail	Level 2	Animal
Leethanakul et al. [22]	Interseptal alveolar surgery	Randomised clinical trial	Level 2	Human
Fischer et al. [25]	Corticotomy	Randomised clinical trail	Level 2	Human
Lee et al. [26]	Corticotomy	Randomised clinical trail	Level 2	Human
Mostaffa et al. [12]	Corticotomy	Randomised clinical trail	Level 2	Animal
Aboul-ela et al. [27]	Corticotomy	Randomised clinical trail	Level 2	Human
Shoreibah et al. [28]	Corticotomy	Randomised clinical trail	Level 2	Human
Kim et al. [31]	Corticision	Cross sectional study	Level 3	Animal

Jofre et al. [32]	Corticision	Case series	Level 4	Human
Murphy et al. [33]	Corticision	Cross sectional study	Level 3	Animal
Vercelotti et al. [35]	Piezocision	Case series	Level 4	Human
Dibart et al. [36]	Piezocision	Case series	Level 4	Human
Teixeria et al. [39],	MOP's	Randomised clinical trail	Level 2	Animal
Alikhani et al. [38]	MOP's	Randomised clinical trail	Level 2	Human
Level 2- Randomised Clinical Trials. Level 3- Cross-Sectional, Case Control and Cohort Studies. Level 4- Case Series. MOP'S- Microosteoperforations.				

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 [16].

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 reduced [17]. Bone distal to canine undermined inter-septally by 1 to 1.5mm **(Figure 3).**

Distraction device used is a custom made, intraoral, tooth-borne device, manufactured from stainless steel [18].

Figure 3 Surgical cuts at extraction site represented on a teaching model.

Based on intersepatal 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 week [19]. In some cases 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. Several authors conducted human [20-22] and animal trails [17] **(Table 2)** by placing a custom-made distraction device and reported that alveolar surgery to be an effective and safe way to aid orthodontic tooth movement. Clinical trials on humans showed that periodontal distraction aided by surgical undermining of the inter-septal bone 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).

Table 2 Levels of evidence described by National Health and Medical Research Council (www.nhmrc.gov.au-2009).

Level	Design
I	Systematic review of Randomized controlled trials(RCTs)
II	Randomized controlled trials
III-1	A pseudo-randomised controlled trial
III-2	A comparative study with concurrent controls: Non randomised, experimental trial Case-control study Cohort study
III-3	A comparative study without concurrent controls: Historical control study Two or more single arm study Interrupted time series without a parallel control group
IV	Case series with either a post-test or pre-test/post-test outcomes

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 [24].

Procedure: Elevation of full thickness of buccal and/or lingual mucoperiosteal flaps. Positioning the corticotomy cuts using piezosurgical aurnamenterium or micromotor under irrigation and it is followed by placement of a graft material, in required sites to enhance the thickness of the bone [24] **(Figure 2)**.

Advantages: Bone can be augmented and periodontal defects would be 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.

Various authors [12,25-28] 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. All the studies published on corticotomy were randomized clinical trials [12,25-28] among those one study [12] was animal study rest were involved with humans [25-28].

Corticision: Kim and co-workers [31] established a technique called corticision with minimal surgical intervention 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.

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. The surgical injury should be 2 mm from the papillary gingival margin in order to preserve the alveolar crest and should be 1 mm beyond the mucogingival junction. The blade should be pulled out by a swing motion. Clinical studies were conducted on humans [32] and animals [31,33] and concluded corticision effectively fastens tooth movement similar to corticotomy and is advantageous because of its less invasiveness. Among the published studies on cortision two were case control studies [31,33] and other was case series [31,32].

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. [34] Vercelotti and Podesta [35] 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 [36] 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 [34]. 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. Only two human trials [35,36] were reported on the procedure.

Dibart and co-workers [36,37] 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 PropelTM, 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 [38]. 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. Two RCTs were reported on microosteoperforations among these one was animal study [38] and other was human trial [39].

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.

Device assisted therapy or mechanical stimulation methods: Direct electric currents, resonance vibration, low level laser therapy, static magnetic field, and pulsed electromagnetic field, were the methods used to accelerate tooth movement. 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 bioelectrical potential is created when there is application of discontinuous forces, which leads to the idea of trying cyclic forces and vibrations **(Table 3)** [40-54].

Table 3 Studies performed using mechanical stimulation.

Author	Technique	Type of study	Level of evidence	Type of study
Zengo et al. [40]	Direct electric current	Case control study	Level 3	Animal
Davidovitch et al. [41]	Direct electric current	Cross sectional study	Level 3	Animal
Kim et al. [42]	Direct electric current	Randomised clinical trail	Level 2	Human

Nishimura et al. [43]	Vibration	Cross sectional study	Level 3	Animal
Liu et al. [44]	Vibration	Cross sectional study	Level 3	Animal
Kau et al. [45]	Vibration	Randomised clinical trail	Level 2	Human
Pavlin et al. [46]	Vibration	Randomised clinical trail	Level 2	Human
Leethanakul et al. [47]	Vibration	Randomised clinical trail	Level 2	Human
Kawasaki et al. [49]	LLLT	Cross sectional study	Level 3	Animal
Cruz et al. [50]	LLLT	Randomised clinical trail	Level 2	Human
Limpanichkul et al. [51]	LLLT	Randomised clinical trail	Level 2	Human
Youssef et al. [52]	LLLT	Randomised clinical trail	Level 2	Human
Doshi mehta et al. [53]	LLLT	Randomised clinical trail	Level 2	Human
Genc et al. [54]]	LLLT	Randomised clinical trail	Level 2	Human
Level 2- Randomised Clinical Trials. Level 3- Cross-Sectional, Case Control and Cohort Studies. LLLT- Low Level Laser Therapy				

Direct electric current: Electrical current has been tested experimentally on the animal models and have shown ATOM. Direct current or electrical currents generated piezoelectrically thereby enhance the OTM.

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 [40,41] on living animals and found to be effective in tooth movement. Subsequently, Kim [42] 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) [40] and cross section study [41]) and one RCT [42] involved human trials.

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 researchers [43-47] 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. Two cross sectional animal studies [43,44] done on cyclic vibration.

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 C [48] 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 [49-54] found LLLT has the potential to increase the rate of tooth movement. Limpanichkul [51] 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 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 performed on LLLT among those five were RCTs [50-54] done on humans and one study involve d cross sectional animal study [49].

Drugs: Parathyroid hormone, Vitamin D, Prostaglandins and Relaxin are the most commonly used pharmacological agents to increase the rate of tooth movement and thus decrease the treatment duration **(Table 4)** [55-66].

Table 4 Studies performed using drugs for accelerated orthodontics.

Author	Year	Type of study	Level of evidence	Type of study

Soma et al. [55]	Parathyroid hormone	Case control study	Level 3	Animal
Soma et al. [56]	Parathyroid hormone	Case control study	Level 3	Animal
Collins et al. [57]	Vitamin D	Case control study	Level 3	Animal
Kale et al. [58]	Vitamin D	Case control study	Level 3	Animal
Kawakami et al. [59]	Vitamin D	Case control study	Level 3	Animal
Yamasaki et al. [60]	Prostaglandins	Case control study	Level 3	Animal
Yamasaki et al. [61]	Prostaglandins	Case control study	Level 3	Animal
Yamasaki et al. [62]	Prostaglandins	Randomised clinical trail	Level 2	Human
Selfi et al. [63]	Prostaglandins	Case control study	Level 3	Animal
Liu et al. [64]	Relaxin	Case control study	Level 3	Animal
Madan et al. [65]	Relaxin	Case control study	Level 3	Animal
Mc Gorray et al. [66]	Relaxin	Randomised clinical trail	Level 2	Human

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 mechanism is taken advantage in accelerated orthodontics to fasten the tooth movement. Soma and co-workers [55,56] conducted experiments on rats and suggested that continuous administration of PTH is applicable to accelerate orthodontic tooth movement. Three animal case control studies [55-57] performed on parathyroid hormone used for AOTM.

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 in to PDL causes increase in LDH and CPK enzymes. Experimental studies were performed on rats by various investigators [57-59] and found 1, 25-DHCC to be 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 decreased by local administration using controlled release systems. Hence, a safe and effective release system is needed for better clinical use.

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. Subsequently, Selfi and co-workers [63] investigated PGE2 in association with the calcium ions in controlling root resorption whereas significant increase in orthodontic tooth movement. Overall four studies were reported on PGE among those three were animal studies [60-62] and one was RCT [63].

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 remodeling 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 [64,65] and the authors concluded that the human relaxin may not accelerate orthodontic tooth movement in rats; it can reduce the level of PDL, reduce the mechanical strength of PDL, and increase mobility of the tooth at early time points. Mc Gorray and co-workers [66] in their clinical trial found local doses of relaxin might have been too low to affect tooth movement or short-term relapse. Only three studies were available on the use of relaxin are two case control studies done on animals [64,65] and one RCT involved humans [66].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 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.

Discussion and 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 piezocision, micro osteoperforations has the 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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