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Frontier in Orthodontics – Dental Tooth Movement Acceleration

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Abstract **Review Article**

There is an increased tendency for researchers to focus on the methods accelerating tooth movement due to the high demand by adult patients for short orthodontic treatment duration. Unfortunately, longer orthodontic treatment duration poses certain risks such as increase likelihood for caries, gingival recession, and root resorption. This also leads to a higher demand to identify the methods to increase tooth movement with minimum possible side-effects. The purpose of this review is to describe the success approaches in acceleration of tooth movement and to highlight their pros and cons. Biological methods of tooth movement have shown that cytokines, RANKL show good results for accelerating tooth movement and raloxifene is best used for retention as it decreases relapse. Osteotomy and corticotomy are useful in increasing the rate of tooth movement but are invasive. Osteoperforations is less invasive and can give good results for acceleration of orthodontic tooth movement.

Keywords: Accelerating tooth movement; Biology; Biomechanics.

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INTRODUCTION

Orthodontics has progressed greatly in obtaining the preferred results in both clinical aspects and technological aspects. This is seen due to the usage of newer technologies, such as simulation software that can help in treatment planning and translation products [1]. The new-modification of orthodontic-wires and orthodontic-brackets have resulted in improvement in the biomechanical efficiencies in orthodontics. But these systems may have achieved their maximum value and there is a need to find alternative methods for acceleration of tooth movement.

Currently, it is quite challenging to decrease the duration of orthodontic treatment. It is one of the common deterrents that orthodontists face, and it is a common questions asked by patients including adult patients [2]. It also increases the risks of caries, gingival recession, and root resorption. A good number of attempts have been performed to generate newer approaches with laboratory, animal, and clinical studies to obtain faster treatment results [2, 3]. However, there are a lot of uncertainties and unanswered questions regarding these techniques. Most approaches for acceleration of orthodontic tooth movement can be categorized as biological and biomechanical approaches [4, 5]. To better understand these approaches, we need to understand the basics of orthodontic tooth movement and the factors that lead to initiation, inhibition, and delayed tooth movement.

Basics of orthodontic tooth movement

Orthodontic tooth movement takes place in the presence of mechanical stimuli which is sequenced by remodeling of alveolar bone and periodontal ligament (PDL) [6]. Bone remodeling is a process which combines both bone-resorption and bone-deposition. The bone-resorption process predominantly occurs on the compression side of periodontal ligament and bone-formation process occurs on the tension side of periodontal ligament [7]. The rate of orthodontic tooth movement can be modulated by the magnitude of the applied force and the biological responses from the periodontal ligament [8]. When forces are applied on the dental structures, there are alterations sin the microenvironments around the periodontal ligament because of alterations in blood flow, resulting in secretion of various inflammatory mediators like cytokines, growth-factors, neurotransmitters, colony-stimulating-factors, arachidonic-acid-metabolites, etc.[3, 4]. The remodeling of bone occurs as a result of the secretion of these mediators.

Methods of accelerating tooth movement

In majority of clinics, dentist performs all CBCT scans. There are variations in the way the patient is There are different phases of orthodontic tooth movement i) initial phase, ii) lag phase, iii) tooth movement phase. The initial phase of tooth movement is characterized by rapid movement after the application of force. This phase involves acute inflammatory response with leucocytes moving from the blood capillaries and creating cytokines, which lead to stimulation and excretion of prostaglandins and growth factors [6, 8]. This phase is followed by the chronic phase in which there is proliferation of fibroblast, endothelial cells, osteoblasts, and bone-marrow cells [4].

Biological approach for accelerating tooth movement

Several experiments have been performed with these molecules exogenously to accelerate the tooth movement both in animal studies and human studies. Example of these molecules is Prostaglandin E (PGE), cytokines that include lymphocytes and monocytes derived factors, receptor activator of nuclear factor kappa B ligand (RANKL), and macrophage colony stimulating factor (MCSF) [7-10].

Cytokines and tooth movement

Increase amounts of cytokines such as Interleukin IL-1, IL-2.IL-3. IL-6. IL-8. And tumor necrosis factor alpha (TNF-A) plays a vital role in the tooth movement process by way of bone remolding process. An important contribution of IL-1 is that it has a direct stimulating effect on the function of osteoclast [3]. It is also known that application of mechanical stress increases the production of prostaglandin-E and IL-1 in the region of periodontal ligament. These experiments were performed on cats where one canine was tipped distally by 80g of force from hours to days, then immunohistochemistry and microphotometry experiments were performed to evaluate the intensity of PG-E and IL-1 Beta which was found to be higher in tension [10]. Another cytokine which is involved in accelerating tooth movement are RANKL. RANKL is a membrane bound protein on the surface of osteoblasts. It binds to RANK on the surface of osteoclasts and result in osteoclastogenesis [11-13]. In contrast to RANKL, osteoprotegerin (OPG) inhibits osteoclastogenesis. It competes with RANKL in binding to the osteoclast surface receptors [14, 15]. It has been shown that when RANKL is injected into the periodontal tissue, there is increase in osteoclastogenesis and acceleration of tooth movement in rats. Kanzaki *et al*. showed that when OPG gene is introduced, it leads to a decrease in the rate of orthodontic tooth movement [16].

Interventions that can decrease tooth movement

Raloxifene is an agent that can affect bone modeling and remodeling. It is a selective estrogen receptor modulator (SERM). Raloxifene is used in post-menopausal women to decrease the bone loss [17]. It has been reported to decrease the amount of tooth movement with orthodontic force [18]. The mechanism of action of raloxifene is due to a reduction in the number of osteoclasts. It specifically decreases Interleukin-6 (IL-6) and IL-1 beta and increase TGF-B [17, 19]. These mechanisms lead to increase in bone density and bone volume after administration of raloxifene [18]. Raloxifene administration in rats has shown a decrease in the amount of relapse after orthodontic tooth movement [18]. Therefore, there might be a potentially use of raloxifene for the retention after orthodontic tooth movement.

Surgical Approach for accelerating tooth movement

Surgical approach for orthodontic treatment includes corticotomy, osteotomy, osteoperforations, interseptal alveolar bone surgery, as well as piezocision. The mechanism of action with surgical insults is dependent on the periodontal ligament and alveolar bone remodeling. These are the factors that have been found to increase with bone grafting, fracture, and osteotomy. Corticotomy and osteotomy are the surgical procedures that have been used in clinical practice for several years for correction of various deformities. Osteotomy is a procedure when a segment of bone is cut into the medullary bone and separated and moved [20, 21]. Corticotomy is a procedure in which only the cortical bone is cut and perforated and not the medullary bone [22]. In both these procedures, the surgical flap is reflected and then the cuts are made. Sometimes bone grafting is also performed in addition to the corticotomy cuts as performed by Wilcko *et al*.[23-25]. The osteoperforation technique does not involve reflection of a surgical flap but to do perforations through the mucosa into the bone [26]. Osteoperforations in rats have shown an increase in the rate of tooth movement [26]. Increasing the magnitude of force with osteoperforations has shown an even greater increase in the rate of tooth movement [8]. However, osteoperforations when performed close to the teeth have also shown an increase in root resorption [26]. Mehta *et al*. showed in a mice model that when osteoperforations are performed farther too molar teeth by 5 mm, accelerated tooth movement can be achieved without significant root resorption [26]. These findings are exciting as they can potentially eliminate the side effect of root resorption with such surgical procedures. Piezocision technique is a method in which primary incision is placed on the buccal gingiva followed by incisions with piezo surgical knife to the buccal cortex [27]. It can be used with Invisalign as reported by Keser and can lead to acceleration of tooth movement [28].

Biomechanical approach for accelerating orthodontic tooth movement

The orthodontic bracket-wire interaction is important in determining that tooth movement occurs without any hindrances. Innovations in orthodontic

biomechanics such as self-ligating brackets have initially claimed that they can reduce the friction in the arch wire and bracket interface. This may allow for faster alignment of teeth during the initial stage. However, such brackets require higher time in finishing and detailing phase of orthodontic treatment. Mini-implants have shown to affect orthodontic biomechanics and influence the type of tooth movement. Mini-implants can be used for expansion of narrow maxilla with palatal expansion appliances known as mini-implant supported palatal expansion appliance (MARPE) [29]. Different designs of MARPE appliance can be used to move the teeth and palatal bone in transverse direction without surgery [30]. Therefore, it can lead to decreased orthodontic treatment time as it saves the time for surgery [31]. Such appliances lead to less extrusion of maxillary molars than other palatal expansion appliances which is beneficial for patients with anterior open bite [32]. Mini-implants can be used for to retract the anterior teeth enmass instead of separate canine retraction. This saves time as the teeth are retracted in one phase rather than in two different phases [33]. Mini-implants can be used in class III malocclusions with MARPE appliances and intermaxillary elastics to correct the malocclusion rapidly and effectively [34]. Mini-implants can be used in Class II malocclusions with functional appliances for controlling lower incisor flaring [35]. Certain appliance design for specific conditions can help to manage the malocclusion in a quick manner. U-MARPE appliance can be used to correct unilateral crossbite patients without side effects on the normal side [36]. This saves considerable time for the clinician and resolves the malocclusion effectively [36]. Fixed functional appliances are such appliance that allows for class II correction along with fixed orthodontic braces. Thus, both the sagittal discrepancy and other factors of malocclusion such as crowding, spacing, and space closure can be undertaken simultaneously to decrease the treatment time [37, 38].

Orthodontic treatment should not only be focused on accelerating tooth movement but also on effectively achieving the treatment objectives. Identifying the right biomechanics to be used for the patient according to its growth and age is a critical factor for treatment success. The cervical vertebral maturation index, hand wrist radiograph, and patient's third molar can be used for identification of skeletal maturity [39]. If growth is remaining, then appropriate biomechanics should be used to positively influence the growth and treat the malocclusion [40]. After treatment completion, appropriate retention is necessary to prevent relapse and maintain the achieved results [41].

CONCLUSIONS

Overall, all the techniques have certain advantages and drawbacks and therefore, good clinical skills are required for using such techniques clinically. These approaches can be based on biology of tooth movement or biomechanical aspects of tooth movement. Both these approaches can be used appropriately according to clinical indications to decrease the duration of orthodontic treatment. Some of the new approaches such as osteoperforations at different distances and using mini-implants have a lot of advantages over older techniques and are sure to stay in orthodontic treatment armamentarium for a long time.

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