Accelerated Tooth Movement- A review
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Abstract
Nowadays, there is an increased tendency for researches that focus on accelerating methods for tooth movement. This is due to the huge demand for adults for a shorter orthodontic treatment time. Unfortunately, long orthodontic treatment time poses several disadvantages like higher predisposition to caries, gingival recession, and root resorption. This increases the demand to find the best method to increase tooth movement with the least possible disadvantages.

Keywords: accelerated tooth movement, corticotomy, piezoelectric currents, Cytokine Expression.

Introduction
Time has been recognized as the 4th dimension in orthodontics. It has immense importance not only in orthodontic treatment planning but also has become one of the major contributing factors in patient compliance. Hence an orthodontist should not be responsible to provide esthetics but also be able to complete his treatment plan within a time limit.

This has given rise to the concept of accelerated tooth movement. The ideology behind accelerated tooth movement was to increase tooth movement thus reducing the overall treatment time.

Tooth movement is caused due to the application of a mechanical force that leads to remodeling changes in the parodontal tissues. This movement occurs due to the cellular responses in the PDL and alveolar bone.[1,2] Studies at cellular, molecular, and tissue-level on the biologic mechanism of tooth movement suggest that a mechanical force is just one of the stimulus for inducing tooth movement.[3] The use of pharmaceutical, electromagnetic, laser and surgical stimuli in combination with the mechanical force for accelerating orthodontic tooth movement has attracted the interest of many orthodontists.

Many such techniques are described below as methods for increased tooth movement.

Corticotomy assisted tooth movement
Extensive injury to the cortical plate bone is known as corticotomies. This procedure is currently being used to accelerate orthodontic tooth movement in private practice.

The corticotomy accelerates tooth movement by inducing a response in the alveolar bone by demineralizing the bone around the dental roots. Once the bone has demineralized, there is a three- to four-month window of opportunity where the teeth can be moved rapidly through the demineralized bone matrix before remineralization of the alveolar bone commences. Frost in 1989[4,5] first described this bone response is called “regional acceleratory phenomenon” or RAP. It was initially coined to describe rare cases of fracture healing.

In this method, tooth movement involves surgical incision through the alveolar bone. To determine whether teeth move by distraction osteogenesis or...
by regional accelerated phenomenon (RAP). An osteotomy frees a bony segment to be distracted with tooth-borne distractors or aligned with orthodontic wires and springs.

Wilcko et al in 2001\(^{16}\) stated that selective buccal and lingual decortication of alveolar bone has been used to accelerate orthodontic tooth movement. Bogoch et al. in 1993\(^{17}\); Schilling et al. in 1998\(^{18}\) postulated that osteoclast and osteoblast cell populations shift in number, resulting in an osteopenic effect. Iino et al. in 2007\(^{19}\) observed that corticotomy-assisted tooth movement is associated with a lack of hyalinization and early tartrateresistant alkaline phosphatase staining.

Lee et al in 2008\(^{10}\) hypothesized that a distraction site under orthodontic tension can be created which will be similar to the long bone by both corticotomies and osteotomies in alveolar bone. The osteotomies produced changes resembling a distal distraction site, while the corticotomies produced a regional loss of bone supporting the dental roots, typical of regional accelerated phenomenon.

The cause for differences in bone response to corticotomy vs. osteotomy probably lie in the enhanced mobility of the osteotomized segment and the fracture-like healing vs. the post-corticotomy healing produced by the openings into the marrow vascular spaces. These openings expose the surgical site to an enhanced healing potential along with maintaining the involved segment in a stable state.

The use of RAP in dentistry can result from local trauma. Several studies suggested that use of as corticotomy used in periodontal surgery by Nyman et al., 1978,\(^{11}\) orthodontic force by Verna et al., 1999,\(^{12}\) implant in Roberts, 1988,\(^{13}\) and infection and systemic change in bone due to menopause and PTH treatment by Frost, 1989.\(^{14,5}\) In the rat model, a local RAP response was associated with increased systemic inflammation markers (Schilling et al., 1998).\(^{9,8}\) The RAP response was divided into an initial phase of maximally stimulated bone formation, where woven or fibrous bone was produced to span a cortical gap.

This bone eventually remodels into lamellar bone. The initial phase is proceeded by period of predominant resorption. The medullary bone disappears and there is a decrease in the osteoblast number in the medullary bone.

Resorptive activity, as measured by a 22% decrease in \(^{45}\)Ca retention. This occurs during the first week and peaked by day 21.

Ilizarov in 1988\(^{14}\) described osteogenesis as an orthopedic technique for lengthening limbs. Currently, there are many craniofacial applications, including some that use interdental incisions to createdistraction sites as mentioned by Liou et al., 2000; Kisniscu et al., 2002; Iseri et al., 2005; Yen et al., 2005 and Sukurica et al., 2007.\(^{15-19}\) Ilizarov,\(^{14}\) developed the tension force principles of distraction osteogenesis and believed that a corticotomy was the ideal method for creating a distraction site, because the bone marrow is intact during distraction procedures. While important for limb lengthening, it is unclear whether the alveolar bone responds to cortical incisions in the same manner as a long bone.

Considering that it is impossible to control the force magnitude clinically not to produce hyalinization, in the view of a biologic approach rather than a mechanical control, the lag phase of tooth movement can be shortened by stimulating the removal of hyalinized tissue. This can be attributed to the RAP because it stimulates cell-mediated responses around the tooth, thereby providing a favorable microenvironment for tissue remodeling. Various researchers have focused on controlling the microenvironment of the alveolar bone by using the RAP in an attempt to reduce tissue resistance.\(^{8}\) The transient osteoporotic condition involved increased release of calcium, decreased bone density, and increased bone turnover, all of which would facilitate tooth movement.\(^{20}\) This mechanism based on the RAP differed from the classical concept of tooth movement such as the pressure-tension theory,\(^{21}\) bone-bending theory,\(^{22}\) mechanostat theory,\(^{23}\) and bony block movement in corticotomy.\(^{24}\)

It is important that the cortical bone itself is not a barrier or resistance to orthodontic tooth movement. Garg\(^{25}\) emphasized that the RAP is primarily a phenomenon observed in the cortical bone. This new concept of cortical remodeling enabled the continuous advancement of supplemental surgical procedures involving minimal and conservative interventions. Germecet al.\(^{26}\) revealed that single-sided partial corticotomy in the mandible appeared to be sufficient to stimulate rapid tooth movement.
Electric currents, bone remodeling, and orthodontic tooth movement:

The activation of bone cells in mechanically stressed bone is carried out by piezoelectric currents. This “piezoelectric” phenomenon was observed in both in vitro and in vivo. Exogenous electric currents have been employed and have resulted in successful attempts to initiate osteogenesis in intact bones and to enhance bone apposition in healing of uncomplicated or nonunion fractures.

In spite of evidences, little is known about the mechanism which produces the tissue changes seen after the application of electricity. Lavine et al. in 1974 reported that cells in bone fracture sites treated by constant D.C. currents presented an increased number of membrane-bound vesicles, morphologic transition of rough endoplasmic reticulum to ribosome-lined cisternae, and vacuolization of the mitochondria.

Rodan, Bourret, and Norton in 1978 reported that the application of oscillating electric fields to check chondrocytes in vitro resulted in enhancement of the incorporation of 3H-thymidine into DNA. They suggested that Na+ and Ca2+ fluxes were responsible for this effect.

Brighton and Friedenberg in 1974 observed alterations in oxygen consumption and tissue pH near the cathode. Davidovitch, Z., Korostoff, E., Shanfeld, J., Montgomery, P., and Finkelson investigated the role of cyclic nucleotides in the mechanism of cell activation by external electric currents in vivo was investigated earlier. Cyclic nucleotides were selected as the main target of that investigation because of their implication as intracellular ‘second messengers’ in the action of specific bone cell activators, such as parathyroid hormone and calcitonin, on their target cells. By using immunohistochemical techniques, we discovered that external electric currents increased bone and PDL cyclic nucleotide contents, a step leading toward heightened enzymatic phosphorylation reactions, synthetic and secretory activities, and an enhanced rate of tissue remodeling. Earlier the involvement of adenosine 3′,5′-monophosphate (cyclic AMP, CAMP) in the periodontal tissue response to orthodontic treatment and concluded that mechanical forces might not be the most efficient means to activate PDL and alveolar bone cells. That conclusion, coupled with the recent observation that electric current can activate a large number of cells in a small, well-delineated area, led to hypothesize that the application of electric currents to periodontal tissues during orthodontic treatment will potentiate the effect of the mechanical forces and lead to an enhanced rate of cell activation, tissue remodeling, and tooth movement.

Cytokine Expression and Accelerated Tooth Movement:

An aseptic inflammatory response is induced by orthodontic forces. Krishnan and Davidovitch, 2006; Meikle, 2006 studied the early stages of tooth movement, there is an increase in vascular permeability and cellular infiltration of leukocytes. Ren and Vissink, 2008; Krishnan and Davidovitch, 2009 suggested that migrated immune cells along with native cells such as fibroblasts and osteoblasts produce inflammatory cytokines that include lymphocyte and monocyte-derived factors, colony-stimulating factors, growth factors, and chemotactic factors.

Alhashimi et al., 2000; Garlet et al., 2007; Ren et al., 2007 studied the high concentrations of inflammatory cytokines such as interleukin-1 (IL-1), IL-2, IL-3, IL-6, IL-8, tumor necrosis factor-α (TNFα), interferon-α (IFNα), and osteoclast differentiation factor that were found in the gingival crevicular fluid surrounding moving teeth and found the osteoclast differentiation factor in the gingival crevicular fluid surrounding moving teeth.

The role of cytokines during tooth movement is not clear. Saito et al., in 1998 suggested that cytokines and other inflammatory markers, such as prostaglandin E2, studied the high concentrations of inflammatory cytokines such as interleukin-1 (IL-1), IL-2, IL-3, IL-6, IL-8, tumor necrosis factor-α (TNFα), interferon-α (IFNα), and osteoclast differentiation factor that were found in the gingival crevicular fluid surrounding moving teeth and found the osteoclast differentiation factor in the gingival crevicular fluid surrounding moving teeth.

Studies by Frost, 1983; Shih and Norrdin, 1985; Yaffe et al., 1994 positively agreed that demonstrated that bone injury which causes cytokine release leads to an accelerated bone turnover and a decrease in regional bone density. This may by one possible mechanism through which inflammatory cytokines may affect bone remodeling is through recruitment of osteoclast precursors from the circulation, their maturation and activation.

Glantschnig et al., 2003; Seidenberg and An, 2004; Yao et al., 2008, Uematsu et al., 1996; Basaran et al., 2006.
suggested that the cytokines that promote osteoclast formation and activation, such as IL-1, IL-6, and TNFá, have also been found in crevicular fluid during orthodontic tooth movement.

The effect of cytokine expression on bone remodeling is important, since the rate of tooth movement correlates with the efficiency of bone remodeling in the alveolar process. Studies by Yoshimatsu et al., 2006 of knockout mice deficient for TNFá receptors showed a slower rate of tooth movement in response to orthodontic forces. Previous reports by Arias and Marquez-Orozco, 2006 have shown that anti-inflammatory medication can decrease the rate of tooth movement.

It is important to remember that inflammation is known as 'a two-sided sword', and while it can work as a benefit by accelerating bone remodeling and tooth movement, if uncontrolled, it may also have a destructive effect on the periodontium and tooth structure. Root resorption in response to osteoperforation is undergoing investigation.

References:


