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Acceleration of Tooth Movement during Orthodontic Treatment-A Frontier in Orthodontics

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Abstract:

Aim:
The purpose of this review is to view the successful approaches in accelerated tooth movement and to highlight the newest technique in tooth movement.

Background:
Orthodontics has been developing greatly in achieving the desired results both clinically and technically.Continous modification of wires and brackets as a result of bio mechanical efficiencies in orthodontics has greatly improved.However,these biomechanical systems may have reached their limit and their is a need to develop new methods to accelerate teeth movement.It is still very challenging to reduce the duration of orthodontic treatments.It is one of the common deterrents that orthodontist faces and causes irritation among adults and increasing risks of caries,gingival recession and root resorption.A lot of approaches have been done to achieve quicker results,but still there are some uncertainties towards most of the techniques.The purpose of this review is to view the successful approaches in accelerated tooth movement and to highlight the newest technique in tooth movement.

Key Words: Bone resorption, Orthodontic treatment, Rapid orthodontics.

INTRODUCTION:

In present era there is precipitously increase in demand for orthodontic treatment especially among adult patients. The greatest challenge amongst the patients undergoing orthodontic treatment is the increased treatment duration. Fixed orthodontic treatment usually lasts up to 2 to 3 years which further increase the risk of periodontal problems, root resorption etc. Orthodontic tooth movement occurs in the presence of a mechanical stimuli sequenced by remodeling of the alveolar bone and periodontal ligament (PDL). Bone remodeling is a process of both bone resorption on the pressure site and bone formation on the tension site. Orthodontic tooth movement can be controlled by the size of the applied force and the biological responses from the PDL. 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. Orthodontic force induces a cellular response in the periodontal ligament, which brings about bone resorption on the pressure side and bone deposition on the tension side. This happens via induction of osteoclasts via the RANK-RANKL pathway and presence of various inflammatory mediators such as IL-1, IL-8, TNF-alpha etc(1).Clinicians are constantly striving towards developing strategies to enhance the rate of orthodontic tooth movement. Present article aimed to discuss various surgical and non- surgical techniques to expedite the process for orthodontic treatment.

Various methods to accelerate orthodontic tooth movement can be discussed under the following categories:

1. Surgical Methods.
2. Physical/ Mechanical stimulation methods.
3. Molecular Methods
4. Drugs

DRUGS:

Various drugs have been used since long to accelerate orthodontic tooth movement, and have achieved successful results.These include vitamin D, prostaglandin, interleukins, parathyroid hormone, misoprostol etc. But, all of these drugs have some or the other unwanted adverse effect. For example, vitamin D when injected in the PDL increases the levels of LDH and CPK enzymes; prostaglandin causes a generalized increase in the inflammatory state and causes root resorption. Hence, as of today, no drug exists that can safely accelerate orthodontic tooth movement.(18,19)

PHYSICAL AND MECHANICAL STIMULATION METHODS:

Another approach in accelerating tooth movement is by using device-assisted therapy . This technique includes direct electric currents, pulsed electromagnetic field, static magnetic field, resonance vibration, and lowlevel laser which was mostly investigated and gave the most promising results. 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 concave site will be negatively charged attracting osteoblasts and the convex site will be positively charged attracting osteoclasts as detected by Zeng in his measurements on dog alveolar bone. The bioelectrical potential is created when there is application of discontinuous forces, which leads to the idea of trying cyclic forces and vibrations. It has been found that applying vibrations for different duration per day accelerated tooth movements between 15% and 30% in animal experiments(1).

CYCLICAL FORCE DEVICE EFFECT ON TOOTH MOVEMENT

This concept is done by using the cyclical force device in patients and achieved 2 to 3 mm/month of tooth movement. The vibration rate was 20 to 30 Hz and used for 20 min/day. Further results needed to be investigated to clearly identify the range of Hertz that can be used in these experiments to get the maximum desired result(2).

DIRECT ELECTRIC CURRENT EFFECT ON TOOTH MOVEMENT:

Another approach is to use direct electric current. This technique was tested only on animals by applying direct current to the anode at the pressure sites and cathode at the tension sites (by 7 V), thus, generating local responses and acceleration of bone remodeling as shown by group of investigators . Their studies were more successful than the previous attempts because electrodes were placed as close as possible to the moving tooth. The bulkiness of the devices and the source of electricity made it difficult to be tested clinically. Several attempts were made to develop biocatalytic fuel cells to generate electricity intraorally by the use of enzymes and glucose as fuel . Further development of the direct electric device and the biocatalytic fuel cells is needed to be done so that these can be tested clinically. (3,4)

LOW-LEVEL LASER THERAPY :

Photobiomodulation or lowlevel laser therapy (LLLT) is one of the most promising approaches today. Laser has a biostimulatory effect on bone regeneration, which has been shown in the midpalatal suture during rapid palatal expansion , and also stimulates bone regeneration after bone fractures and extraction site . It has been found that 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, that low-energy laser irradiation enhanced the velocity of tooth movement via RANK/RANKL and the macrophage colony-stimulating factor and its receptor expression. Animal experiments have shown that low-level laser can accelerate tooth movement(5,6). Furthermore, clinical trial attempts were made in which different intensities of laser were used and different results were obtained . Low-level laser therapy can be a very useful technique for acceleration of tooth movement since it increases bone remodeling without side effects to the periodontium. Laser wavelength of 800 nm and output power of 0.25 mW have indicated significant stimulation of bone metabolism, rapid ossification , and also acceleration of tooth movement to 1.5-fold in rat experiments. Lately in a clinical trial study, the laser wavelength they have used in a continuous wave mode at 800 nm, with an output of 0.25 mW, and exposure of 10 s was found to accelerate tooth movement at 1.3-fold higher than the control . In another study done by Kau on 90 subjects (73 test subjects and 17 controls), there was 1.12-mm change per week in the test subjects versus 0.49 mm in the control group. Having said this, there are a lot of contradictory results related to the LLLT. Therefore, more experiments are needed to differentiate the optimum energy, wavelength, and the optimum duration for usage(7).

MOLECULAR METHODS:

Prostaglandins, RANKL, VEGF etc molecules are emerging molecules which enhance tooth movement. Exogenous administration of prostaglandin increases rate of tooth movement by inducing bone resorption. Prostaglandin has a direct action on osteoclasts in increasing their numbers and their capacity to form a ruffled border and effect bone resorption. Prostaglandins couple bone resorption and formation, increasing the turnover of bone cells and thus accelerating the orthodontic tooth movement Gene therapy has also been proved to be useful during orthodontic treatment. RANKL is a membrane bound protein on the osteoblasts that bind to the RANK on the osteoclasts and causes osteoclastogenesis. OPG, protoagonist of RANKL is a decoy receptor produced by osteoblastic cells, which compete with RANK for RANKL binding. The biologic effects of OPG on bone cells include inhibition of terminal stages of osteoclast differentiation, suppression of activation of matrix osteoclasts, and induction of apoptosis(14,15). Thus, bone remodeling is controlled by a balance between RANK RANKL binding and OPG production. It was demonstrated that the transfer of RANKL gene to the periodontal tissue induced prolonged gene expression for the enhancement of osteoclastic activity and acceleration of tooth movements in rats. Thus a balanced delivery of genes such as RANKL and OPG, to the oral tissues can prove to be beneficial in managing the rate of the orthodontic treatment. These modalities have also been shown to reduce relapse, and pain and root resorption caused due to orthodontic forces.(16,17)

SURGICAL APPROACH:

Surgical approach The surgical technique has been documented in many case reports. It is a clinically effective technique used for adult patients, where duration of orthodontic treatment may be critical in selected groups of patients. The PDL and alveolar bone remodeling are the important parameters in tooth movement, and bone turnover is known to increase after bone grafting, fracture, and osteotomy. Several surgical approaches that have been tried in order to accelerate tooth movement were interseptal alveolar surgery, osteotomy, corticotomy, Periodontally accelerated osteogenic orthodontics and Piezocision technique. (8)

INTERSEPTAL ALVEOLAR SURGERY :

Interseptal alveolar surgery or distraction osteogenesis is divided into distraction of PDL or distraction of the dentoalveolar bone; example of both is the rapid canine distraction. The concept of distraction osteogenesis came from the early studies of limb lengthening. Also from surgical treatments of craniofacial skeletal dysplasia, this concept was later adapted in relation to the rapid tooth movement. In the rapid canine distraction of PDL, the interseptal bone distal to the canine is undermined surgically at the same time of extraction of the first premolars, thus, this will reduce the resistance on the pressure site. In this concept 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 Surgical approaches to enhance tooth movement rapid movements are during the initial phases of tooth movement especially in the first week. In this technique the interseptal bone is undermined 1 to 1.5 mm in thickness distal to the canine after the extraction of the first premolar, and the socket is deepened by a round bur to the length of the canine. The retraction of the canine is done by the activation of an intraoral device directly after the surgery. It has been shown that it took 3 weeks to achieve 6 to 7 mm of full retraction of the canine to the socket of the extracted first premolars. Rapid canine distraction of the dentoalveolar bone is done by the same principle of the distraction of PDL, with the addition of more dissection and osteotomies performed at the vestibule. In all the studies done, both techniques accelerated tooth movement with no evidence of significant root resorption, ankylosis, and root fracture. However, there were contradictory results regarding of the electrical vitality test of the retracted canines. Liou reported 9 out of 26 teeth showed positive vitality, while Sukurica reported that 7 out of 20 showed positive vitality after the sixth month of retraction. So there are still some uncertainties regarding this technique. (9)

CORTICOTOMY AND OSTEOTOMY :

Osteotomy and corticotomy are also surgical techniques that have been clinically used for many years. Osteotomy is when a segment of the bone is cut into the medullary bone and is separated and then moved as a unit . Corticotomy is one of the surgical procedures that is commonly used in which only the cortical bone is cut and perforated but not the medullary bone,suggesting that this will reduce the resistance of the cortical bone and accelerate tooth movements. It was first tried in orthodontics by Kole , where tooth movements were achieved between 6 and 12 months. The technique was further used by others, for example, Grenerson who used this for open bites treatments, and others in In 2001(10).Wilck reported that the acceleration of tooth movement is not due to the bony block movement as postulated by Kole; it was rather a process of bone remodeling at the surgical site, which was called regional acceleratory phenomenon (RAP). He developed patent techniques which were called accelerated osteogenic orthodontics (AOO) and periodontal accelerated osteogenic orthodontics(PAOO). Also, modification of RAP was done by adding bioabsorbable grafting material over the injured bone to enhance healing. This technique is reported to have postoperative stability and improved retention ,but more studies are still needed to be done. The negativity of these surgical techniques is their invasiveness and the acceleration was only in the first 3 to 4 months and it declines with time to the same level of the controls, as shown by others(11,12).

PERIODONTALLY ACCELERATED OSTEOGENIC ORTHODONTICS:

Regional Acceleratory Phenomena (RAP) or Periodontally accelerated osteogenic orthodontics is local response to a noxious stimulus, which describes a process by which tissue forms faster than the normal regional regeneration process. By enhancing the various healing stages, this phenomenon makes healing occur 2–10 times faster than normal physiologic healing (Frost, 1983).

Many studies have reported an increase in the activity of infl ammatory markers such as chemokines and cytokines in response to orthodontic forces. Chemokines play an important role in the recruitment of osteoclast precursor cells, and cytokines, directly or indirectly, through the prostaglandin E2 pathway and the RANK/RANKL pathway, leading to the differentiation of osteoclasts from their precursors cells into mature osteoclasts. Therefore, it is logical to assume that increasing the expression of these factors, by surgically irritating the bone should accelerate tooth movement.

A histological study showed that selective alveolar decortication induced increased turnover of alveolar spongiosa (Sebaoun et al 2008). Surgery results in a substantial increase in alveolar demineralization, a transient and reversible condition. This will result in osteopenia (temporary decrease in bone mineral density). The osteopenia enables rapid tooth movement because teeth are supported by and moved through trabecular bone. As long as tooth movement continues, there is prolongation of RAP. When RAP dissipates, the osteopenia disappears and the radiographic image of normal spongiosa reappears. Then when orthodontic tooth movement is completed, an environment is created that favors alveolar re-mineralization .

Simply stated, when bone is surgically irritated, a wound is created. This wound initiates a localised inflammatory response. Due to the presence of the inflammatory markers, osteoclasts migrate to the area and cause bone resorption. This effect, however, is temporary, and lasts for about 4 months and the procedure needs to be repeated, in case faster tooth movement is still required(21).

Periodontally accelerated osteogenic orthodontics treatment is appropriate for both adults and adolescents when most of the permanent teeth have erupted.Full treatment quickly resolves the entire scope of the patient's treatment needs, including minor facial reshaping. In conjunction with traditional orthodontics, segmental issues such as forced eruptions of impacted teeth and molar intrusion can be rapidly corrected. Treatment decisions are based on considerations such as severity of the malocclusion, preexisting alveolar deficiencies, extraction vs non-extraction protocols, and patient expectations (20).

PIEZOCISION TECHNIQUE :

One of the latest techniques in accelerating tooth movement is the Piezocision technique. Dibart was among the first to apply the Piezocision technique which starts with primary incision placed on the buccal gingiva followed by incisions by Piezo surgical knife to the buccal cortex . Piezocision technique did not cause any periodontal damage as reported by Hassan .Another benefit of this technique is that it can be used with Invisalign, which leads to a better aesthetic appearance and less treatment time as reported by Keser . Piezocision is a promising tooth acceleration technique because of its various advantages on the periodontal, aesthetic, and orthodontic aspects(13).

CONCLUSION:

Rapid orthodontics is still at its emerging phase and need further research in the form of clinical trials. Surgical means have provided better outcome but being invasive in nature lead to poor patient compliance. Other advanced molecular therapies requires further explorations would prove to be beneficial for both the clinicians and the patients as they have advantages such as reduced rates of relapse, reduced orthodontic pain and reduced root resorption.

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