Review Article

Accelerated Orthodontics – A Review

Shailesh Shenava[1], U S Krishna Nayak[2], Vivek Bhaskar[3], Arjun Nayak[4]

[1]M.D.S, Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, Terna Dental College and Hospital, Mumbai, India, [2]M.D.S, Professor and Head, Department of Orthodontics and Dentofacial Orthopaedics, A.B.Shetty Memorial Institute of Dental Sciences, Mangalore, India, [3]Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, A.B.Shetty Memorial Institute of Dental Sciences, Mangalore, India, [4]Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, A.B.Shetty Memorial Institute of Dental Sciences, Mangalore, India

Corresponding Author: *Dr. Vivek Bhaskar, Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, A.B.Shetty Memorial Institute of Dental Sciences, Mangalore, India. E-mail: vivek.libra@gmail.com*

Abstract

The duration of orthodontic treatment is the primary concern of most patients. Unfortunately, long orthodontic treatment time poses several disadvantages like higher predisposition to dental caries, gingival recession and root resorption. Therefore this increases the demand to find the best method to increase rate of tooth movement with the least possible disadvantages. Orthodontic treatment is based on the premise that when force is delivered to a tooth and thereby transmitted to the adjacent investing tissues, certain mechanical, chemical, and cellular events take place within these tissues, which allow for structural alterations and contribute to the movement of that tooth. Conventionally, this process is slow and orthodontic treatment times can range anywhere between 12-48 months. By enhancing the body's response to these forces, tooth movement can be accelerated. Many methods are available to accelerate tooth movement, such as surgical methods (corticotomy, piezosurgery etc), mechanical/ physical stimulation methods (vibration, lasers), drugs, magnets etc. These methods have been successfully proven to reduce treatment times by up to 70%. Hence, this article aims to review the latest methods to accelerate orthodontic tooth movement.

Keywords: Accelerated orthodontic tooth movement, Corticotomy, Microosteoperforations, Lasers, Piezosurgery, Vibration

INTRODUCTION

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.[1-4] Surgical methods have been used since long to accelerate tooth movement. These methods were based on the principle that when the bone is irritated surgically, an inflammation cascade is initiated which caused increased osteoclastogenesis, hence causing faster tooth movement (Regional Acceleratory Phenomenon or Periodontally Accelerated Osteogenic Orthodontics).[5] However, these were invasive and not well accepted by the patients. Hence, newer surgical methods have arrived with the help of piezosurgery, fiberotomy, microosteoperforations etc. which achieve the same results as achieved by conventional corticotomy, but with reduced invasiveness and morbidity.

Mechanical or physical stimulation of the periodontal ligament has also been shown to increase the speed of bone remodelling. Many methods have been used for this purpose, out of which lasers and vibration seem to show most promise. They have been proven to act by inducing osteoclastogenesis by inducing the RANK/RANKL pathway and induction of signalling molecules such as MAPK (Mitogen Activated Protein Kinase), c-fos, and nitric oxide.[6,7] These modalities have also been shown to reduce relapse, and pain and root resorption caused due to orthodontic forces.

Methods to accelerate orthodontic tooth movement can be broadly studied under the following categories:

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

I. Drugs

Various drugs have been used since long to accelerate orthodontic tooth movement, and haveachieved successful results.[8-10] 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.

II. Surgical Methods

- In 1931, Bichlmayr introduced a surgical technique for rapid correction of severe maxillary protrusion with orthodontic appliances. Wedges of bone were first removed to reduce the volume of bone through which the roots of the maxillary anterior teeth would need to be retracted. In 1959, Kole expanded on this philosophy by addressing additional movements, including space closure and crossbite correction. They suggested that bony blocks (bone-teeth unit) were created as a result of the corticotomy, hence causing faster tooth movement. This concept prevailed till 2001, when Wilcko et al showed a transient demineralization-remineralization process taking place after corticotomy.[11] This was termed as PAOO (Periodontally Accelerated Osteogenic Orthodontics). This concept was earlier described by Frost in 1983, and was called as RAP (Regional Acceleratory Phenomenon).[5]

What is RAP or PAOO? How does it work?

- Regional Acceleratory Phenomena (RAP) 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).[5]
- Many studies have reported an increase in the activity of inflammatory 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.[1-4]
- 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,[12] and the procedure needs to be repeated, in case faster tooth movement is still required.

The various surgical methods available are:

1. Corticotomy

The conventional corticotomy procedure involves elevation of full thickness mucoperiosteal flaps, bucally and/or lingually, followed by placing the corticotomy cuts using either micromotor under irrigation, or piezosurgical instruments. This can be followed by placement of a graft material, wherever required, to augment thickness of bone. In 2001, Wilcko et alreported that a surface-computed tomographic evaluation of corticotomized patients clearly showed a transient localized demineralization-remineralization process consistent with the accelerated wound-healing pattern of the regional acceleratory phenomenon.[11]

Advantages

a. It has been proven successfully by many authors, to accelerate tooth movement.
b. Bone can be augmented, thereby preventing periodontal defects, which might arise, as a result of thin alveolar bone.

Disadvantages[13]

a. High morbidity associated with the procedure.
b. Invasive procedure.
c. Chances of damage to adjacent vital structures.
d. Post-operative pain, swelling, chances of infection, avascular necrosis.
e. Low acceptance by the patient.

- Park et al in 2006, and Kim et al in 2009, introduced the corticison technique, as a minimally invasive alternative to surgically injure the bone without flap elevation.

They used a reinforced scalpel and mallet to go through the gingiva and cortical bone. This technique did induce RAP effect, but had drawbacks such as; inability to place grafts, and the malleting procedure was shown to cause dizziness after surgery.[14]

2. Piezocision

- To reduce the morbidity associated with conventional corticotomy, Dibart et al in 2009, introduced a flapless method of corticotomy, using piezosurgery.[13]
- In the technique described by them, the surgery was performed 1 week after placement of orthodontic appliance, under local anaesthesia. Gingival vertical incisions, only bucally, were made below the interdental papilla, as far as possible, in the attached gingiva using a No.15 scalpel. These incisions need to be deep enough so as to pass through the periosteum, and contact the cortical bone. Next, using ultrasonic instrumentation (they used a BS1 insert Piezotome), to perform the corticotomy cuts to a depth of 3 mm through the previously made incisions. At the areas requiring bone augmentation, tunnelling is performed using an elevator inserted between the incisions, to create sufficient space to accept a graft material. No suturing is required, except for the areas, where the graft material needs to be stabilized. Patient is placed on an antibiotic, mouthwash regimen.

Advantages

a. Minimally invasive.
b. Better patient acceptance.

Disadvantages

a. Risk of root damage, as incisions and corticotomies are "blindly" done.

- To reduce the risk of root damage, however, Jorge et al in 2013,[14] suggested a method, called MIRO (Minimally Invasive Rapid Orthodontic procedure) by using metal wire as a guide to placement of the incisions, and subsequently the corticotomy cuts. He placed metal guides in between each tooth, perpendicular to the main arch wire, and took digital radiographs, to ensure that the metal guides did not project over the tooth roots. Once this was confirmed, incisions and piezoelectric corticotomy was done using the pins as a guide.

3. Micro-Osteoperforations (MOP)

- To further reduce the invasive nature of surgical irritation of bone, a device called Propel, was introduced by Propel Orthodontics. They called this process as Alveocentesis, which literally translates to puncturing bone.[15]
- This device comes as ready-to-use sterile disposable device. The device has an adjustable depth dial and indicating arrow on the driver body. The adjustable depth dial can be positioned to 0 mm, 3 mm, 5 mm, and 7 mm of tip depth, depending on the area of operation. Previous animal studies have shown that performing micro-osteoperforations (MOPs) on alveolar bone during orthodontic tooth movement can stimulate the expression of inflammatory markers, leading to increases in osteoclast activity and the rate of tooth movement.
- Mani Alikhani et al (2013)[15], performed a single center single blinded study to investigate this procedure on humans. They used a Ni-Ti closed coil spring, delivering a constant force of 100 g to distalize the maxillary canine after first premolar extraction. The spring was anchored to a TAD distal to the second premolar, and attached to the canine using a power arm through the vertical slot of the canine bracket. Gingival crevicular fluid (GCF) samples were collected from each subject to evaluate the level of inflammatory response. GCF was collected before orthodontic treatment, immediately before the start of canine retraction, and at each subsequent visit, between 10 AM and 12 noon. These samples were taken from the distobuccal crevices of the maxillary canine. GCF samples were collected with filter-paper strips (Oraflow, Smithtown, NY) inserted 1 mm below the gingival margin into the distobuccal crevices of the canine for 10 seconds. Cytokine levels were measured using a custom protein array for the following cytokines: CCL-2 (MCP1), CCL-3, CCL-5(RANTES), IL-8 (CXCL8), IL-1a, IL-1b, IL-6, and TNF-a (Raybiotech, Norcross, Ga) according to the manufacturer's instructions.
    - Alginate impressions were taken at the beginning of the study, immediately before canine retraction, and 28 days after canine retraction began to monitor the rate of tooth movement. The impressions were immediately poured up with plaster (calcium sulfate). Vertical lines were drawn on the cast over the palatal surface of the canine and lateral incisor from the middle of the incisal edge to the middle of the cervical line. The distance between the canine and the lateral incisor was assessed before and after canine retraction at 3 points: incisal, middle, and cervical thirds of the crowns. All cast measurements were made using an electric digital caliper (Orthopli Corp, Philadelphia, Pa) with an accuracy of 0.01 mm. They concluded their study by stating that:
    - MOPs significantly increased the expression of cytokines and chemokines known to recruit osteoclast precursors and stimulate osteoclast differentiation.

- MOPs increased the rate of canine retraction 2.3-fold compared with the control group.
- Patients reported only mild discomfort locally at the spot of the MOPs. At days 14 and 28, little to no pain was experienced.
- MOPs are an effective, comfortable, and safe procedure to accelerate tooth movement during orthodontic treatment.
- MOPs could reduce orthodontic treatment time by 62%.

- However, this was the first study investigating this method, and certain issues were not addressed, such as, effect on root resorption, number of perforations required, long term effects (this study had a duration of only 28 days).

III. Physical/Mechanical Stimulation

- Surgical methods, regardless of technique, are still invasive to some degree, and hence have their associated complications. Hence, non-invasive methods have come to the fore. These modalities include lasers, vibration, direct electric current etc.

Laser

- Saito and Shimizufound that low intensity laser therapy can accelerate bone regeneration in the midpalatal suture during rapid palatal expansion and stimulate the synthesis of collagen, which is major matrix protein in bone. In the last decade, many histologic studies have attempted to determine the effect of low-intensity laser therapy on the histochemical pathways directly associated with orthodontic tooth movement. Increased osteoblastic and osteoclastic activity after low-level laser therapy was observed in vivo and in vitro. The mechanism involved in the acceleration of tooth movement is by the production of ATP and activation of cytochrome C, as shown in that low-energy laser irradiation enhanced the velocity of tooth movement via RANK/RANKL and the macrophage colony-stimulating factor and its receptor expression.[6]
- In 2004, Cruz et alwas the first to carry out a human study on the effect of low-intensity laser therapy on orthodontic tooth movement. They showed that the irradiated canines were retracted at a rate 34% greater than the control canines over 60 days.[16]
- Gauri Doshi Mehta et al in 2013 [16], in a split mouth design, used a laser at 800 nm for 10 sec on the canine, both bucally and lingually, which had to be distalized after first premolar extraction. They used a Ni-Ti closed coil spring delivering a constant force of 150 g from the first molar tube hook to the power arm of the canine bracket and also secured with a ligature tie to the bracket. The laser type used was a semiconductor (aluminium gallium arsenide) diode (model LA3D0001.1;LAMBDA S.p.A., Vicenza, Italy) emitting infrared radiation with a wavelength of 808±10 nm operated according to the manufacturer's recommendations. They also aimed to study the analgesic properties of laser therapy. For analgesic purposes, the settings were adjusted to a wavelength of 800 nm, a continuous wave mode, an output power of 0.7 mW, and an exposure time of 30 seconds. For bio-stimulation, the parameters were set at a wavelength of 800 nm, a continuous wave mode, an output power of 0.25 mW, and an exposure time of 10 seconds. The total energy density (dose) at each application was 8 J (2 × 40 s × 100 mW). After 6 months, the laser side (experimental) and the control side canines were examined with periapical radiographs, which showed no undesirable changes in the adjacent periodontal ligaments and alveolar bones. Vitality tests of the retracted canines were also positive.

Three models were made for each patient. On the models, the mesial cusp tips of first molar and the canine were the reference points. The distance between the first molar and the canine was measured on all 3 models for each patient with a digital caliper accurate to 0.02 mm. These distances were recorded at T0 (after completion of alignment and leveling: day 1 of canine retraction), T1 (at the end of 3 months of canine retraction), and T2 (on completion of canine retraction on the experimental side).

There was a highly significant positive difference in the rates of tooth movement on the experimental side compared with the control side. The mean increase in the rates of tooth movement at 3 months was 54% in the maxillary arch and 58% in the mandibular arch. Mean increase in the rate of tooth movement after canine retraction was 29% in the maxillary arch and 31% in the mandibular arch. There was a significant decrease in the pain score recorded, using a Visual Analog Scale.

In this study, they used the semiconductor with a wavelength of 800 nm, a continuous wave mode, an output power of 0.25 mW, and an exposure time of 10 seconds because the results of Takedaand Bradley et alhad indicated significant bio-stimulatory effects on bone metabolism around this dosage, whereas higher dosages had bio-inhibitory effects, and lower dosage showed nonsignificant results.[16]

- Limpanichkul et al in 2006, however obtained a result that low level laser had no additive effect on orthodontic tooth movement. The reason could be the higher energy density of 25 J per square centimeter that they used.[16]
- Various studies on low level laser therapy, have shown orthodontic tooth movement to be increased by

30-60%. The variations 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.

Vibration

- Nishimura et al in 2008, used a Ni-Ti expansion spring on the 1st molar of Wistar rats, and applied a vibration of 60 Hz, 1 m/s^2. They stated that the rats that received the vibration showed increased orthodontic tooth movement. In the sectioned samples, they showed increased RANKL expression in the fibroblasts and osteoclasts of the periodontal ligament of the rats that received vibration.[17]
- Liu et al in 2009 conducted a study on thirty mice, in which they used an omega shaped Ni-Ti expander to deliver a force of 20 g on the 1st molar. Mechanical vibration (4 Hz for 20 min/day) was applied perpendicular to the occlusal surface of the first molar. This regimen was repeated seven times, every 3 days. Upon micro-CT examination of the jaws of the killed mice, it showed that the mice that received vibration showed 40% more tooth movement.[18]
- Recently, a product by the name Acceledent has arrived at the market, which makes use of this technology. This device consists of an activator, which is the active part of the appliance that delivers the vibration impulses with a USB interface through which it can be connected to a computer to review the patient usage of the appliance, a mouthpiece that contacts the teeth. It is a portable device that can be charged similar to any other electronic device, and has to be worn for 20 minutes a day. Various case studies using this device have shown the treatment times to be reduced by up to 30-40%.

CONCLUSION

Since long, orthodontic patients have been asking for shorter treatment times, and today, we do have methods that can accelerate orthodontic tooth movement safely. The current methods such as piezocision, microosteoperforations, lasers and vibration have reduced or eliminated the invasive nature of previous procedures used to achieve the Regional Acceleratory Phenomenon. Also, they come with additional advantages such as reduced rates of relapse, reduced orthodontic pain and reduced root resorption.

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