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Accelerated orthodontics: the Sports Mode in Orthodontics

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ABSTRACT
Orthodontic treatment is a tedious complex procedure that demands increased duration to complete the treatment. On varying, the complexity of malocclusion increases the time to complete orthodontic tooth movement. Prolonged duration and the adverse effects of orthodontic treatment forced the population to seek alternative treatment modalities. Researchers have employed numerous methods to accelerate the rate of orthodontic tooth movement. As these modalities are introduced into the field of orthodontics, increase bone turnover rate which corresponds to the acceleration of orthodontic tooth movement. This would decrease the treatment duration by 6 to 12 months. Non-surgical and surgical modalities for accelerating the rate of tooth movement have been discussed in this article.

Keywords: orthodontic tooth movement, bone turnover, malocclusion

I. INTRODUCTION

The prolonged duration of orthodontic treatment concerns patients, primarily adults, which leads them to seek alternative treatment options with compromised results. Comprehensive orthodontic treatment takes an average period of 24 months to be completed. However most patientsexpect a shorter duration of treatment.[1] The long course of orthodontic therapy is associated with adverse sequelae such as discomfort, pain, white spot lesions, dental caries, and increased root resorption.[2-6]

Orthodontic tooth movement is described as an interaction of biological and biomechanical factors such as the status of the periodontium, duration, type of force application, and regional cellular and molecular activity.[7]

Various treatment modalities are proposed to shorten the treatment duration for comprehensive orthodontic care. These are broadly categorized into non-surgical and surgical methods. Non-surgical methods include self-ligating brackets[8], customized appliances[9], medications[10-15](Relaxin, vitamin D, parathyroid hormone, prostaglandins, PRP injections[16,17]), microvibrations[18-21], low-intensity laser[22-24], LIPUS therapy[25], photobiomodulation[26,27], electromagnetic fields[28] and direct electric currents.[29]

Surgical methods include micro-osteoperforation[30], piezocision[31], corticotomy[32], and interseptal alveolar surgery.[33,34] These methods could accelerate the rate of tooth movement.

Regional acceleratory phenomenon (RAP)

Regional acceleratory phenomenon (RAP) was first described by Harold Frost[35] which denotes a tissue reaction to different noxious stimuli. This is due to the induction of osteoclasts via the RANK-RANKL pathway and the presence of various inflammatory mediators such as IL-1, IL-8, TNF-alpha etc.[35]

The different cells taking part in RAP are composed of 4 phases: activation, resorption, reversal and formation.[35] In the activation phase, bone-lining cells become cuboidal in shape, preosteoblasts, and present receptor activator of nuclear factor K (RANK) ligand (RANKL), on the cell surface.[35] Bone resorption cease about 2 weeks, by which the osteoclasts undergo programmed cell death or apoptosis.[35] At the reversal phase, mononucleated phagocyte cells complete the resorption and deepen the lacunae.[35]

In the reversal phase, preosteoblasts migrate into the resorbed cavity and differentiate later into osteoblasts. Mature osteoblasts secrete osteoprotegerin, a free-floating decoy receptor belonging to the tumour necrosis factor family.[35] It can bind the RANKL, which prevents the further activation of the preosteoclasts.[35]

Non-surgical methods of accelerating tooth movement

1. Drugs

During orthodontic treatment, certain drugs are prescribed for the management of pain from force application to biological tissues,temporomandibular joint (TMJ) disorders and infections throughout the course of treatment.

Non-Steroidal Anti-inflammatory drugs (NSAIDs)

Acetylsalicylic acid inhibits COX activity which ceases the production of prostaglandins (PGs).[37] Salicylate therapy decreases bone resorption by inhibiting PGs' synthesis and affect the differentiation of osteoclasts from their precursors.[37] Therefore, it is recommended that

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patients undergoing orthodontic treatment should be advised not to take aspirin during orthodontic treatment.[37]

Among NSAIDs, acetaminophen is effective in managing pain and discomfort associated with orthodontic treatment. Paracetamol is a weak COX-1 and COX-2 inhibitor and its action are more on the periphery rather than acting on the central nervous system.[37]

COX-2 inhibitors such as celecoxib and etoricoxib selectively block COX-2 inhibitors and impede the synthesis of prostaglandins (PG) that cause pain and swelling.[37] These drugs can be safely employed during orthodontic treatment.

Vitamin D

Vitamin D along with its active metabolite (1,25 Dihydroxycholecalcifeol), parathyroid hormone (PTH) and calcitonin regulate the amount of serum calcium and phosphorus levels.[38] Collins and Sinclair[39] demonstrated that intraligamentary injections of vitamin D metabolite caused an increase in the rate of orthodontic tooth movement during canine retraction with light forces. Kawakami et.al[10]concluded that local application of vitamin D could re-establish alveolar boneafter orthodontic treatment.[10]

Fluoride

Fluoride is used for the treatment of osteoporosis by increasing bone mass and mineral density.[40]In spite of its anticariogenic action,may prolong the duration of orthodontic tooth movement.[40]

Bisphosphonates (BPN)

Bisphosphonates (BPNs) have extreme chemical affinity to the solid-phase surface of calcium phosphate.BPNs inhibits hydroxyapatite aggregation, dissolution, and crystal formation.[39] A study conducted by Igor et.al[41] concluded that BPNs decrease the rate of orthodontic tooth movement.[41]

Immunomodulatory drugs

Immunomodulatory drugs like Leflunomide, TNFantagonists (Etanercept), and interleukin antagonists (Anakinra) have been extensively used for the treatment of rheumatoid arthritis.[39] These drugs modulate nuclear factor kappa – Beta, IL – 6, MMPs and PGE2, that are essential for the bone remodelling process.[39]

Anticonvulsants

Phenytoin:

One of the adverse effects of phenytoin is gingival hyperplasia that involves the interdental papilla. This leads to the application of orthodontic mechanics and maintaining oral hygiene at a difficult scenario.[39]

Alcohol abuse:

Alcohol crosses the placental barrier thereby result in psychological or behavioural problems.[39]Ethanol inhibits the hydroxylation of vitamin D3 in the liver leading to altered calcium homeostasis.[39] Davidovitch et al.[42]concluded that chronic alcoholics develop high risk of root resorption during orthodontic treatment.[42]

2. Hormones

Estrogen

Estrogen is considered to be the most important hormone affecting bone metabolism in women.[39] It inhibits the production of cytokines that involves bone remodelling. A study conducted by Tyrovola[43] concluded that estrogens decrease the rate of orthodontic tooth movement thereby prolonging the duration of treatment.[43]

Thyroid hormones

Thyroid hormones such as Thyroxine (T3) increase the rate of orthodontic tooth movement due to increased bone remodelling activity.[39]
Low dosage of thyroxine administration for a short period lowers the frequency ofroot resorption.[39]

Relaxin

Liu et.al.[13]conducted an animal study where they concluded that relaxin increases the rate of orthodontic tooth movement.Stewart et.al[12] used intraligamentary injections of Relaxin to relieve rotational memory in the connective tissues of maxillary lateral incisors.[39]

Parathyroid hormone

PTH affects osteoblasts' cellular metabolic activity, gene transcriptional activity, and multiple protease secretion.[39] Its effects on osteoclasts involves the production of RANK-L Receptor activator of nuclear factor kappa –B ligand), a protein responsible for osteoclasts' formation and activity. Soma et.al[11] conducted an animal study which concluded that PTH induce an increase in bone turnover rate.[11]

Corticosteroids

Corticosteroids inhibit the osteoblasts and decrease bone formation.[39] A decrease in bone

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formation is due to increased PTH levels caused by the inhibition of intestinal calcium absorption.[39]On long term usage results in osteoporosis which is an adverse effect of use of corticosteroids.[39]

Prostaglandins (PGs)

PGs stimulate bone resorption and root resorption, decrease collagen synthesis, and increase cAMP.[39] They stimulate bone resorption by increasing the number of osteoclasts and activating already existing osteoclasts.[39] A lower concentration of PGE2 (0.1 μg) appears to be effective in enhancing tooth movement. The main side effect associated with local injection of PGs is hyperalgesia due to the release of noxious agents.[39]

Echistatin and RGD peptides

Administering local injection of integrin inhibitors like echistatin and RGD (Arginine–Glycine–Aspartic acid) peptides in rats inhibits tooth movement. Dolce et.al[44]concluded that there is a substantial reduction in root resorption after the administration of Echistatin during orthodontic treatment.[44]

Self-ligating brackets (SLB)

In the mid-1930s, the Russell attachment was an attempt to enhance clinical efficiency by reducing ligation time.[9] SLBs can be dichotomized into those with a spring clip that can press against the archwire (active) and those with a passive system of ligation, in which the clip, ideally, does not press against the wire.[8]

Case series published byEhsani et.al[45] Eberting et.al[46] and Tagawa D[47]concluded that treatment with SLB was faster, required fewer visits and resulted in a better outcome than treatment with the conventional appliance.[48] The faster treatment time by SLB is due to low resistance to sliding, secure and full archwire engagement.[48] Two systematic reviews[49,50] concluded that there is insufficient evidence to support the view that treatment with self-ligating brackets results in fewer visits or shorter treatment.[48]

Direct electric currents

Direct electric currents can alter the electrical states of bone and cartilage. They induce increased rates of cell division and metabolism whichlead to the rapid healing of bony and cartilaginous defects.[51] Basset[52] proposed that tissue integrity and function could be restored by applying electrical or mechanical energy to the area of injury.[52]It is believed that orthodontic tooth movement is accompanied by site-specific bone remodelling with inflammation.[52]

Darendeliler et.al[51] conducted an animal study to evaluate the effect of pulsed electromagnetic field vibration (PEMF) on orthodontic tooth movement. The experiment concluded that PEMF-induced vibration enhanced the rate of orthodontic tooth movement. [51]

Kim et.al[53]demonstrated the effect of electrical current on the accelerating rate of orthodontic tooth movement in orthodontic patients. The study concluded that an electrical current of 20 μA for 5 h daily could shorten the orthodontic therapy.[53]

Magnetic fields

Magnetic fields aid to increase the rate of orthodontic tooth movement.[55,56] On the activation, bone remodelling occurs by an increase in the activity of osteoblastsleading tobone deposition.[55] A recent study by Showkatbakhsh[28] et.al demonstrated that application of pulsed electromagnetic field (1 Hz), during the retraction of canine to first premolar extraction site resulted in the accelerated tooth movement.[28]

Tengku et.al[57]conducted a study where difference is reported, but an increased root resorption of the treated teeth.[57] In addition, the source of electricity is a disadvantageon clinical use. Enzyme batteriescan resolve this issue in the future.[54]

Low-intensity laser irradiation therapy (LLLT)

LLLTs are an excellent modality to accelerate orthodontic tooth movement. They have a great advantage on wound healing, fibroblastic proliferation, synthesis of collagen and acceleration of orthodontic tooth movement.[54] Aluminum-gallium-arsenide (Ga-Al-As) diode lasers are currently used for interventions to have a higher depth of tissue penetration.Thisallows clinicians to use instruments at a great efficiency.[54] Therefore, different wavelengths and energy outputs of laser devices were tested in different studies.[54]

Shimizu[22] observed that LLLT with a Ga-Al-As infrared diode laser device (wavelength: 830 nm; continuous wave at 100 mW; power density: 35.3 J/s/cm 2) couldenhance bone formation in the midpalatal suture of rats during rapid palatal expansion.[54]

Fujita et al.[24]conducted an animal study to examine the effect of LLLT and light-emitting diode (LED) irradiation on orthodontic tooth movement. The authors concluded thatthe rate of tooth movement was significantly greater in the laser irradiation group.[24]

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Cruz et al.[23] conducted a split-mouth design study of 11 subjects, between 12 and 18 years of age who received intervention during the retraction of upper canine teeth for every 30 days.[23] The study concluded by an increased rate of orthodontic tooth movement in the treated group.[23]

Photobiomodulation

Photobiomodulation is an upcoming dental technique,where exposure to light stimulates cellular function for beneficial clinical effects.[55] The light spectrum falls in the infrared frequency.[54] The technique is based on activation of cytochrome oxidase c or complex IV –enzyme which is upregulated by infrared light.[54]

Based on the observation that healing of dental extraction sites seemed to occur more quickly when the sites were exposed to light, a patent application for the use of tissue-penetrating light to speed tooth movement was filed in late 2010, and an intraoral device (Biolux [Biolux Research Ltd, Vancouver, Canada]) was marketed 3 years later.[58] It provides light with an 800- to 850-nanometer wavelength (just above the visible spectrum) adjacent to the alveolar bone.[58]This stimulates intracellular enzymes which increases cellular activity in the PDL and bone.

Vibration-induced devices

Recently these appliances, such as Acceledent and Tooth Masseuse deliver vibrational forces. They are found to accelerate tooth movement which is a boon to the field of orthodontics.[58]Theydeliver a high-frequency vibration (30 Hz) to the teeth for approximately 20 minutes per day.[58]

Pavlin et.al[18] conducted a randomized control trial (RCT) in 2015 to evaluate the rate of closure of a maxillary first premolar extraction site with sliding mechanics.[18] The researchers reported an average rate of 1.16 mm/month with AcceleDent and 0.79 mm/ month without it.[18] The second trial conducted by Woodhouse et.al[21] was a three-arm RCT to evaluate the rate of alignment of crowded lower incisors in lower first premolar extraction cases with a fixed orthodontic appliance alone, with a sham device with no vibration, or with an AcceleDent device.[21] The study concluded that vibrational force cannot increase the rate of initial tooth movement in conjunction with a preadjusted edgewise fixed appliance.[21]

Therapeutic Ultrasound: SmileSonica Aevo

The most recent entry into the tooth acceleration market is low-intensity therapeutic ultrasound—the Aevo device, now being marketed by SmileSonica of Canada.[58] The theory is that increased blood flow in the PDL would speed up bone remodelling and tooth movement.[58]Howevertherewere no convincing demonstration of effectiveness to accelerate tooth movement.[58]

Surgical methods to accelerate orthodontic tooth movement

1. Corticotomy

The concept of corticotomy was given by Heinrich Kole in 1959.[59] It is a surgical modality to accelerate orthodontic tooth movement to reduce the treatment time.[59] The procedure of corticotomy begins with placing corticotomy cuts made through the cortex connected with horizontal osteotomy cuts at the interproximal regions.[59]osteotomy is limited only interdentally on the buccal and lingual sides of cortical bone for the orthodontic movement of teeth in malposition.[59]

Steps involved in corticotomy:

- Raising of flap
- Decortication
- Particulate grafting
- Flap closure
- Application of Orthodontic force

On the day of surgery, the archwire is removed in the maxilla and mandible and oral prophylaxis was carried out.[34] A dose of 2g Amoxycillin was taken orally by patients 30 minutes before surgery.[34] If the patient is allergic to amoxicillin, erythromycin or clindamycin can be given.[34]Chlorhexidine mouthwash is given to carry out asepsis.

A proper flap design is essential for any surgical procedure.[34] After administration of LA, crevicular incisions are given buccally and lingually extending 2 or 3 teeth beyond the apex.[34] The flaps are raised beyond the apex of the teeth.[34]Care was taken not to perforate flap or interpapillary tissue as well as neurovascular bundles.[34]After flap elevation decortication of bone adjacent to the malpositioned teeth is performed by using low speed no 1 or 2 round diamond bur under copious irrigation by saline.[34]The vertical corticotomies are connected with a semicircular-shaped corticotomy in the apical region.[34]

The cortical perforations are made in selective areas to increase blood supply to the graft material.[34]

Gantes et. al in 1990[60] performed corticotomy procedures for five adult patients who exhibited Class II div 1 or div 2. The study

concluded that all five patients exhibited reduced treatment time.

Wilcko et al. in 2001[61] performed two case reports with his new surgery technique known as Wilckodontics. The new surgical approach comprise buccal and lingual full-thickness flaps, partial decortication of the cortical plates, bone grafting/augmentation, and primary flap closure.[61]Orthodontic adjustments were carried out for every two weeks prior to the surgery which shows a promising results.[61]

Corticision

The term corticision was introduced by Park et al[62].This technique involves cutting the bonewithout reflection of a surgical flap using a scalpel and mallet.[62]This technique induced RAP leading to rapid tooth movement.[62]

Piezocision

The term 'piezocision' was introduced by Dibartand Keser[63]. This technique is minimally invasiveto create a surgical injury without flap reflection.[63] This approach combines microincisions on the buccal gingivaeto initiate the RAP.[63]This technique has an advantage for hard-tissue or soft-tissue grafting to correct gingival recessions ordeficiencies of bone.[63]

Piezocision is an innovative surgical technique to accelerate orthodontic tooth movement without anynegative impact of conventional surgical approaches.[63]

Micro osteoperforations (MOP)

Micro-osteoperforations (MOPs), a minimally invasive technique, have better compliance and are an economically feasible option for patients than other surgical methods.[34] Unlike corticotomy and piezocision, they do not require extensive surgical procedures.[34] Micro osteoperforations can be carried out by using a device called PROPEL or miniscrews.[34]The biologicalaspect of MOPs are to increase theexpression of cytokines to stimulate bone resorption.[34]

Rapid tooth movement is carried out by creating transmucosal holes in the cortical bone trigger bone remodelling.[34]The first-generation Propel device was a single-use, sterile, disposable device.It had a light-emitting diode (LED) depth stop indicator that illuminated once the desired perforation depth was achieved.[34]

The second-generation Propel device has a heavier built with metal handle and disposable screw tips with marks to indicate depth of the perforation.[34]The third generation consists of a disposable screw tip, an automatic electric torque driver and a contra-angle.[34]The technique is performed by the orthodontist and can be performed in a standard dental setting using a traditional aseptic protocol.[34]The PROPEL device has markings of 3 mm, 5 mm, and 7 mm lengths for varying lengths of disposable tips that corresponds to the depth of the MOP. [34]

The perforations can be performed through the gingiva in the selected area at a stipulated depth.[34] The perforations should be administered on the attached keratinized tissue. Ideally, three micro-osteoperforations should be buccally or lingually performedin each interdental space.[34]The perforations can be made in a linear or triangulardistribution. The perforations are performed on the cortical plate at a desired length by gentle rotational movement. The MOP device is removed by rotational movements.[34]

Minor bleeding may occur after performing the procedure, especially in the alveolar mucosa which can be controlled using normal hemostatic agents.[34] In general, minor discomfort is reported.Analgesics are usually not required after MOP but if pain control is required acetaminophen can be prescribed.

Alikhani et al. in 2013[65]conducted a randomized split-mouth study to evaluate the rate of canine retraction with or without MOPs on the upper arch. They studied the effect of MOPs in the stimulation of inflammatory markers at different time points, followed by the assessment of the pain and discomfort of the patients during the study.[65] Cytokine levels were assessed using a custom protein array.[65] The study concluded that MOPs significantly increased the expression of cytokines and chemokines. The rate of canine retraction was increased by 2-3 folds.[65] Patients reported mild discomfort locally at the spot of the MOPs with a decline in pain on days 14 and 28.[65]

Feizbakhsh et al. in 2018[66] performed a single-blinded prospective split-mouth clinical trial to evaluate the application of the MOP technique on the rate of canine retraction in both the maxilla and mandible.[66] The authors concluded that MOPs could accelerate the rate of tooth movement and reduce the treatment period.[66]

II. CONCLUSION

Accelerated orthodontics is still a relatively new horizon and researchers have yet to seek a single most ideal and prudent technique for the patient.The surgical techniques show anexcellentlong-term effectcompounding to the stability and retention of orthodontic therapy.[67]

A systematic review by El Angbawi et al.[19] carried out a systematic review stating that non-surgical methods of accelerating orthodontic tooth movement are inferior to surgical methods.

On theday-to-day orthodontic clinical practice, micro osteoperforation brings to sense due to its less invasive nature, clinical time and trauma. Keep in mind the exorbitant cost of PROPEL device makes it unrealistic to carry out for every orthodontic appointment. Certain authors utilize miniscrews to carry out MOPs.

On contrary, the invasive nature and cost make a less viable option for the patients. On the bright side once adapted to any of these techniques upon the clinician's choice and patient's preference, prove to be beneficial in reducing orthodontic treatment time.

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OTM	Orthodontic tooth movement
RAP	Regional acceleratory phenomenon
SLB	Self-ligating brackets
MOP	Micro osteoperforations
LED	Light emitting diode
LLLT	Low-level laser therapy
PG	Prostaglandins
RCT	Randomized control trial
NSAID's	Non-steroidal anti-inflammatory drugs
TNF-α	Tumour necrotic factor alpha
RANK	Receptor activator of nuclear factor kappa
RANKL	Receptor activator of nuclear factor kappa ligand
IL	Interleukins
PTH	Parathyroid hormone
FAS	Foetal alcohol syndrome
BPN	Bisphosphonates
COX	Cyclooxygenase

LIST OF ABBREVIATIONS