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Periodontally Accelerated Tooth Movement: A Review

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Review Article

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ABSTRACT

The comprehensive orthodontic treatment usually lasts between 18-24 months. The treatment duration depends on the patient and the related complexities of the treatment. The longer treatment duration escalates the risk of dental caries, esthetic problems such as white spot lesions or leads to root resorption and periodontal destruction. There are various approaches to modulate the tooth movement that will shorten the orthodontic treatment time. These approaches manipulate the pathways that alter the tooth movement and the alveolar housing. The prevailing interdisciplinary alliances of periodontics for accelerating orthodontic tooth movement consists of procedures broadly categorized as; (A) Surgical mode that includes Periodontally Accelerated Osteogenic Orthodontics (PAOO) with classic Corticotomy, Piezocision, Modified Corticotomy, and Laser Corticotomy; (B) Mechanical or physical mode that includes Low-level laser therapy (LLLT), Electric current Vibration, Cyclic vibration and (C) Chemical modes that includes Osteocalcin and Corticosteroids, Parathyroid hormone (PTH), Thyroxin, Relaxin, Vitamin D3. Each of these procedures intends to accelerate the orthodontic tooth movement and contributes to curtail the conventional orthodontic treatment time. The ongoing development moves orthodontic therapy nearer to the goal of being optimal, with teeth being moved competently, not leading to any patient discomfort or damage to the teeth or their supporting structure. This review describes the surgical, chemical and mechanical, or physical modalities that accelerate the tooth movement and effectively shortens the orthodontic treatment time.

Keywords: Accelerated Osteogenic, Corticotomy, Orthodontics, Periodontics Review, Periodontally.

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Introduction

The periodontium is a dynamic tissue and its capability to undergo remodeling provides an advantage to conventional orthodontic therapy. The average treatment time for comprehensive orthodontic treatment is 18 to 24 months. There is an increased tendency for the operator to focus on methods to accelerate the tooth movement. The need to accelerate the tooth movement may be due to the increased demand by adults seeking orthodontic treatment in a shorter time period. Apart from the patient inconvenience, long orthodontic treatment time poses several drawbacks such as increased predisposition to dental caries, high chances of gingival recession, and root resorption. This mandates implementation of the optimal method to accelerate the tooth movement with the least possible consequences. A number of methods for accelerating tooth movement exist to meet the needs of patients and orthodontists. The interdisciplinary approach of periodontic and orthodontic branches in accelerating tooth movement can shorten the conventional orthodontic treatment time. The periodontal surgeries aiding in tooth movement stimulate the natural pathway that on induction of trauma to a particular area of tooth movement elevates the level of cytokine and chemokine release thus aids in accelerating the tooth movement. Various approaches for inducing different degrees of trauma have proven to affect the rate of tooth movement.[1] These approaches include Periodontally Accelerated Osteogenic Orthodontics (PAOO) which is a procedure that scars the alveolar bone housing surgically. The different techniques of performing PAOO are Classical surgical Corticotomy, Piezocision, Modified Corticotomy, and Laser. Apart from the surgical mode of stimulating tooth movement, there are artificial techniques to increase the number of osteoclasts. These modalities include locally or systemically inducing, applying physical stimulus or chemical factors to increase osteoclasts activity independent of the orthodontic forces.[2] The various approaches are as illustrated in Figure 1.

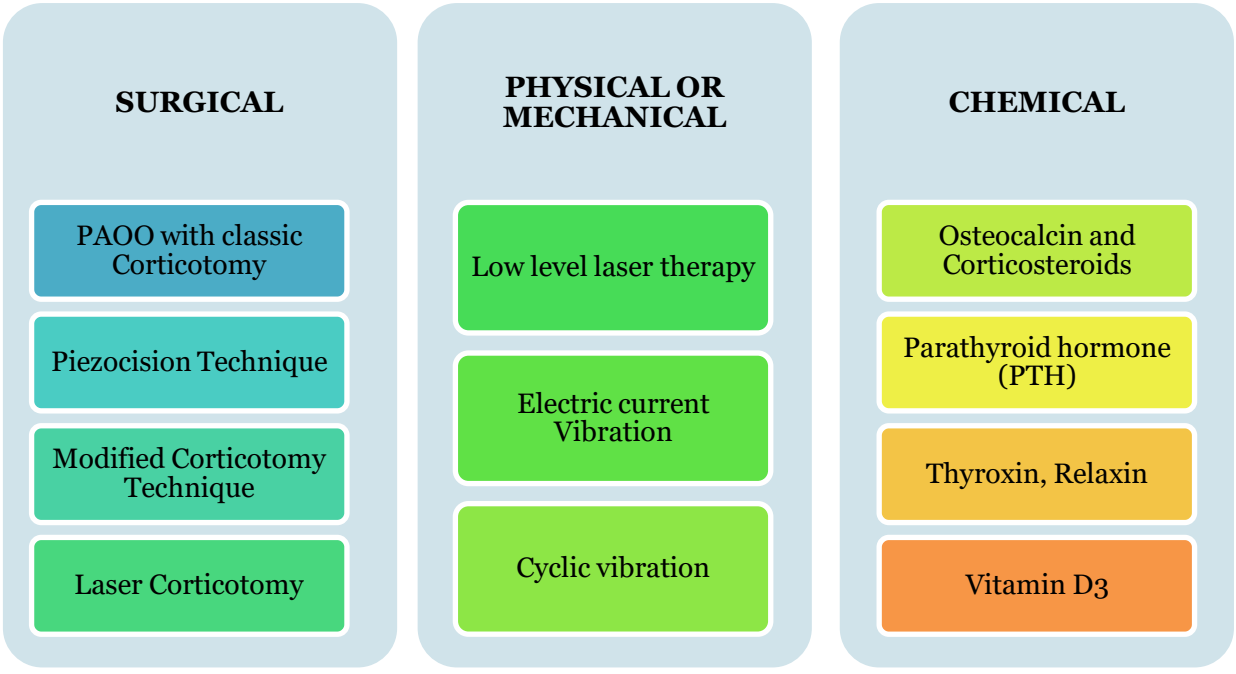

Figure 1: Various modalities to accelerate the orthodontic tooth movement.

1.0 Surgical Mode of Accelerating Orthodontics Tooth Movement

The higher esthetic demand has resulted in an increasing number of patients seeking orthodontic treatment in adulthood. This has led to the orthodontists pursuing modes to accelerate the tooth movement to reduce

the treatment time. The technique of Periodontally Accelerated Osteogenic Orthodontics (PAOO) is also known as Wilckodontics, named after its founders, Wilcko brothers Dr. Thomas Wilcko, a periodontist, and Dr. William Wilcko, an orthodontist in 1995.[3] The Periodontally Accelerated Osteogenic Orthodontics (PAOO) combines the following surgical procedures; the selective alveolar corticotomy, particulate bone grafting, and the application of orthodontic forces.

1.1 Historical background

The summary of the history of the surgical mode of accelerating tooth movement is listed in the table below, where a description has been provided of the evolution of the surgical approach for accelerating the tooth movement.

YEAR	AUTHOR	EVENT
1893	Cunningham	"Luxation or the immediate method in the treatment of irregular teeth"
1893	LC Bryan	"The Corticotomy facilitated tooth movement"
1950	Dr Gabriel Ilizarov,,	"Distraction osteogenesis (DO)"
1953	HenrichKole	"Corticotomy facilitated orthodontics" and "bony block movement" theory.
1970	Düker	Beagle dogs experiment that boosted the belief of maintenance of healthy crestal bone following corticotomy cuts.
1995	Wilcko brothers	"Accelerated Osteogenic Orthodontics" (AOO) and later called it PAOO

Table 1: Historical background of surgical mode of accelerating tooth movement

1.2. Biomechanics of PAOO

In PAOO technique, cortical bone is scarred surgically on both labial and lingual sides, followed by bone grafting.[4] The tissue of alveolar bone releases rich deposits of calcium and new bone begins to mineralize within 20-55 days. The tooth movement is accelerated when the alveolar bone is in a transient state, as the bone is comparatively softer and less resistant to orthodontic forces. The movement occurring after performing PAOO technique differs from the conventional periodontal ligament cell-mediated tooth movement. The literature indicates that the site of Corticotomy shows localized osteoporosis state, which is a part of a healing event known as a regional acceleratory phenomenon (RAP), given by orthopedist Harold Frost in 1983. Dr. Frost observed a direct relationship between the degree of injuring a bone and the intensity of its healing response. The regional acceleratory phenomenon involves a temporary burst of localized soft and hard tissue remodeling that is regeneration which restores the bone to its normal state. The RAP involves the local response of tissues to noxious stimuli which results in a faster than normal regional regeneration or remodeling process. The tissue response to PAOO differs in duration, intensity, and size with the magnitude of the stimuli. The extent of RAP depends on the type of tissue which varies with different individuals. The effect of PAOO usually endures for about four months span, so maximum utilization of orthodontic therapy is carried out in this tenure. This phenomenon causes bone healing to occur 10-50 times faster than normal bone turnover.

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1.3 Age Factor for PAOO

The candidates for PAOO could be patients of any age with a healthy periodontal situation. The literature suggests PAOO has been carried out in individuals ranging from 11 to 77 years. It is particularly useful in adult patients where there is increased chance that hyalinization will occur during treatment.[5]

1.4 Indications of PAOO

Periodontally Accelerated Osteogenic Orthodontics is indicated in patients with Angle's Class I malocclusion with moderate to severe crowding, Angle's Class II malocclusion cases that require extraction, mild Angle's Class III cases. It can be indicated to facilitate the eruption of impacted teeth, in cases with molar intrusion and Open bite correction, molar uprighting, molar distalisation, and arch expansion cases.

1. 5 Contraindications of PAOO

Periodontally Accelerated Osteogenic Orthodontics is contraindicated in patients with Severe Angle's class III cases, active cases of periodontal disease, or gingival recession. PAOO is not an alternative for surgically assisted palatal expansion in the treatment of severe posterior cross-bite. It should not be used in bimaxillary protrusion with a gummy smile, the abnormal skeletal relationship between jaws. It is also contraindicated in patients with systemic conditions such as uncontrolled diabetes mellitus, compromised immune system, uncontrolled Osteoporosis, or other bone diseases. The long-term use of anti-inflammatory, immunosuppressive medication or steroids, and medications that slow down bone metabolism, e.g.: Bisphosphonates and NSAIDs.[6]

1.6 Surgical steps of PAOO

The figure 2 enlists steps in PAOO technique.

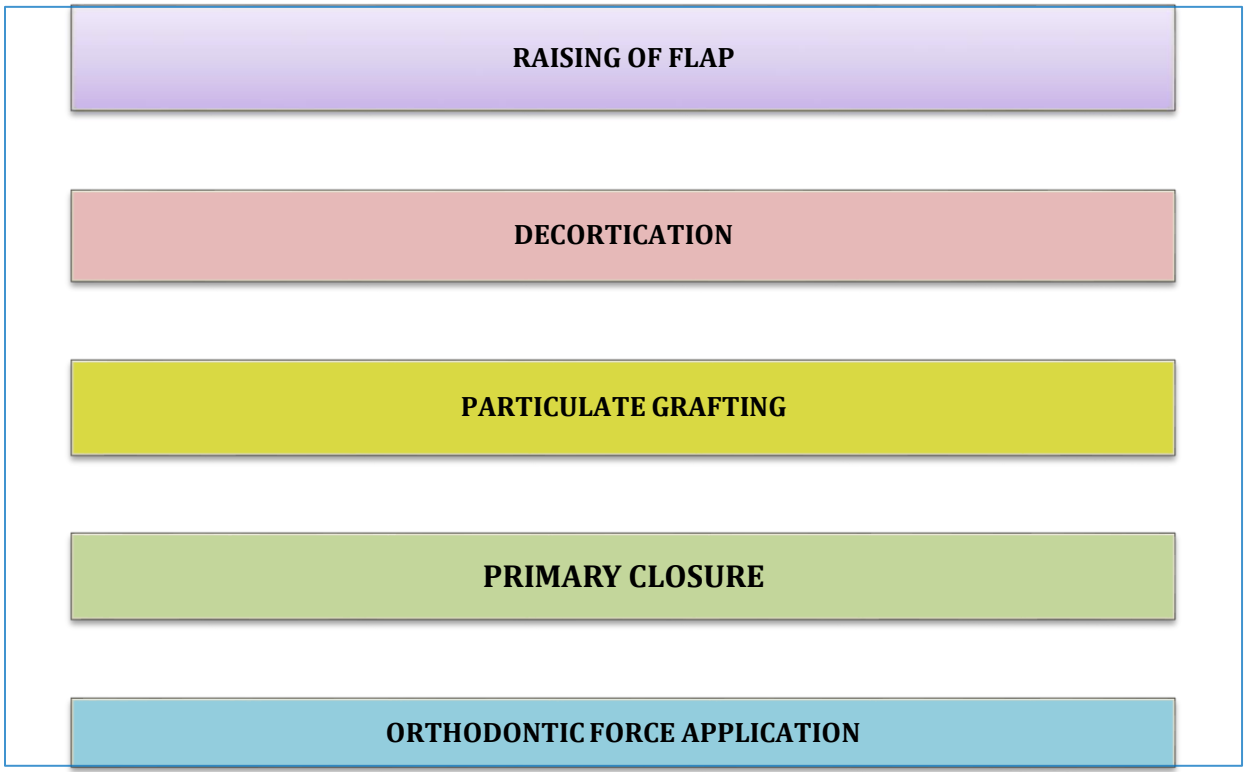

Figure 2: Steps in PAOO technique

1.6.1 PAOO using classic Corticotomy

Before opting for the periodontal surgical technique and beginning with the procedure, a complete medical review of the patient is elicited to rule out any systemic and local factors that may interfere with the surgery. A meticulous phase I therapy involving scaling and root planning is carried out, followed by oral hygiene reinforcement. Once the local factors have been controlled, the patient is recalled for the periodontal surgery. A detailed clinical and radiographic assessment is carried out to evaluate the periodontal status of the patient. Before the surgical procedures the brackets are bonded onto the tooth surfaces.

Raising of periodontal flap

The main aim of raising a flap is to provide access to the underlying alveolar bone. In the case of PAOO, the flap elevation will give accessibility to perform Corticotomy and to preserve the gingival form for proper esthetic appearance. After sufficient Local anesthesia is administered, Crevicular incisions are given along buccal and lingual surface of the tooth to include two to three teeth beyond the area of treatment. The flap elevation is achieved beyond the apices of the teeth, if possible. Extra care is to be taken to avoid perforating the flaps or causing damage to any neurovascular bundles and muscle attachments.

Decortication

This step involves the removal of the cortical portion of the alveolar bone. The main motive of the decortication is to initiate the Regional Acceleratory Phenomenon (RAP) response. Care should be taken not to create movable bone segments. Following the flap elevation, decortications of bone are performed adjacent to the malpositioned teeth using low-speed No.1 or No.2 round diamond burs under the copious amount of saline irrigation. In the Canine region, straight diamond burs are used.

During PAOO, decortication is done at clinical sites without entering the cancellous bone, thus avoiding any damage to underlying structures, such as the maxillary sinus and the mandibular canal. The corticotomies are carried out labially and lingually (palatally). A vertical groove is planted in the inter radicular space, at a midpoint between root prominences along the alveolar bone. This groove is extended from a site 2 to 3 mm below the crest of the bone till two mm beyond the apices of the roots and about 1.5 - 2mm in depth. The vertical corticotomies are connected by a semicircular-shaped corticotomy in the apical region. Solitary perforations could be placed in the alveolar bone over the radicular surface of the alveolar bone is sufficiently thick. Cortical perforations are made in selective areas to improve blood supply to the graft material.

Particulate Grafting

Various materials are used for grafting after decortication such as deproteinized bovine bone, autogenous bone (Maxillary tuberosity, Mandibular symphysis, Angle of the mandible, Ramus of mandible and Exostosis), decalcified freeze-dried bone allograft or a combination there of. The graft material is retained in the decorticated bone. Resorbable grafting materials are mixed with an antibiotic solution or blood, are usually applied directly over the activated bone. Precaution should be taken not to overfill bone graft as it might obstruct flap placement.

Closure of flap

The Adequate graft material is placed so that there is no difficulty in the primary closure of the flap. The Flap is most commonly closed using non- resorbable interrupted 3-0 sutures without creating excessive tension. The patient is recalled for suture removal after one to two weeks. After the closure of the flap Orthodontic archwire is secured back into the brackets.

Orthodontic force application

A week prior to a surgical aspect of PAOO, the placement of orthodontic brackets and activation of archwires is done. In the case of management of complex mucogingival procedures along with PAOO, it would be easier to manipulate the flap and suturing if the placement of brackets and wires is delayed. In the post repositioning of the flap, immediate heavy Orthodontic forces are required. Under all circumstances, orthodontic therapy should not be delayed more than two weeks after surgery.

Advantages of classical Corticotomy

Accelerated tooth movement will shorten orthodontic treatment time. The chances of root resorption are reduced due to decreased resistance of cortical bone. The bone support is more due to the addition of bone graft, alveolar grafting also benefits the patient by repairing bony dehiscence and fenestration. Classical Corticotomy improves periodontal support to the teeth. This technique minimizes the need for extra-oral appliances like headgear. The history of relapse reported is very low.[7]

Disadvantages of classical Corticotomy

The procedure will incur the additional extra-surgical cost and post-surgical crestal bone loss and gingival recession may occur.

1.6.2 Piezocision Technique

It was introduced in 2007 by Vercellotti and Podesta.[8] The use of Piezosurgery in conjunction with conventional flap elevations is to create an environment conducive to rapid tooth movement. Dibart et al[9] introduced a procedure known as Piezocision. It is a minimally invasive procedure combining microincisions, minimal piezoelectric osseous cuts to the buccal cortex only, followed by bone and soft tissue grafting concomitant with a tunnel approach.

The procedure includes the following, after administration of adequate local anesthesia, using a number 15 surgical blade vertical incisions are made interproximally along the attached gingiva below the interdental papilla. The procedure for piezocision for incisions and any grafting required are exclusively carried out along the buccal surface. Ultrasonic instrumentation is used to perform corticotomy cuts through the gingival micro-incisions and to a depth of three mm. A tunnel preparation is done using an elevator inserted between the gingival incisions to form sufficient space for receiving the graft, wherever needed. After these steps are done, primary closure is achieved.

Advantages of piezocision

The surgical time is shorter as compared to conventional for complete surgery on both the maxilla and mandible. The technique is minimally invasive. No periodontal complications such as bone loss and partial loss of interdental papilla might occur during the raising of a flap. The postoperative morbidity is less and concomitant soft and/or hard tissue augmentation with high patient acceptance.

Disadvantages and limitations of Piezocision

The cortical incisions may present a risk of root damage, especially in areas of close root proximity as there is no mucoperiosteal flap elevation. It is essential to maintain the gingival incisions at least two mm away from the gingival margin to avoid the formation of the gingival cleft. The technique might result in postoperative scar formation.

1.6.3. Modified corticotomy technique

Germec et al[10] in 2006, introduced "Modified Corticotomy," technique. They showed a conservative technique that shortened the treatment time during lower incisor retraction. In this modification of the technique, corticotomy is done only on the buccal side without lingual cuts. This technique is backed up by reasoning of the surgically induced transient osteopenia; the Regional Acceletory Phenomenon. The use of the Modified Corticotomy technique to obtain a specific clinical objective indicates knowledge of RAP and respect for a discrete surgical technique.

Advantages: The Surgical time is shorter as compared to classical technique and less technique sensitive.

Disadvantages: It does not offer the benefits of bone grafting**,** which would enhance periodontal support in desired areas.

1.6.4 Laser Corticotomy

The Orthodontic forces with the laser-assisted corticotomy procedures result in significantly greater tooth movements than orthodontic forces alone. The laser can also be used to perform flapless corticotomy. Seifi in 2012 found that flapless corticotomy accomplished by Er:Cr: YSGG laser-accelerated tooth movement in rats.[11] In 2014, a study done by Salman and Ali concluded that corticotomy by Er: YAG Laser achieved accelerated canine retraction in 15 patients.[12]

The procedure for laser-assisted Corticotomy is as follows, after administration of sufficient anesthesia, small perforations are made in the buccal gingiva at an equal distance from the involved teeth. This can be done using fiber tip with laser device set at 100 MJ, 10 Hz, 2 W. Each of the perforations is 1 to 2 mm wide and 1.5-2 mm away from each other. To perform alveolar cortical perforations of 3 mm depth, the settings can be changed to 200 MJ, 12 Hz, 3 W,[13] after measuring with a periodontal probe. The gingival and cortical perforations are carried out under water-air spray cooling using noncontact mode holding the fiber tip 1-2 mm away from the gingiva and the alveolar bone.

Advantages: This technique has the advantage of a bloodless field of surgery as compared to conventional and less possibility of infection. The trauma is less during a surgical procedure. Post-operative swelling, scars, and pain are minimal.

Disadvantages: High cost due to the use of lasers compared to conventional method.

1.7 Complications and side effects of PAOO

The chances of interdental bone loss and loss of attached gingiva are increased. Periodontal defects were observed in cases with short interdental distance. Subcutaneous hematomas of the face and the neck have been reported after intensive Corticotomy.[13]

2.0 Mechanical or Physical Mode of Accelerating Orthodontontic Tooth Movement

The application of high-frequency low-magnitude forces (vibration) to teeth undergoing orthodontic therapy is one of the methods proposed to accelerate tooth movement. The studies conducted have hypothesized that the bone is a direct target for orthodontic forces, and hence optimizes mechanical stimulation.[14] This mechanism aids in accelerating the rate of tooth movement. This form of mechanical stimulation under certain conditions could be effective; however, the postulation of tooth movement due to the direct response of bone cells to mechanical stimulation is improper. During orthodontic movement, the application of high-

frequency low magnitude forces is researched to stimulate a pathway that aids in acceleration of tooth movement.[15]

2.1 Low level laser therapy

In the past decade, there has been an increased application of low-level laser therapy (LLLT) on the rate of tooth movement. In LLLT, light-emitting diodes or low-level lasers are utilized to alter cellular function. There is controversy regarding the use of LLLT in medicine but literature also shows the demonstrable effect of LLLT over a specified set of wavelengths.[16] LLLT may decrease pain associated with inflammation by dose-dependent lowering levels of PGE2, IL-1, and TNF-α, decreasing the influx of inflammatory cells such as neutrophils, oxidative stress, and edema.[17] The accelerated tooth movement inducted by physical stimuli includes a sequence of events that consists of physiological and pathological reactions of the periodontium.[18] The proliferative effect of LLLT helps increase the number of osteoblasts for accelerating orthodontic tooth movement, while the anti-inflammatory effect of LLLT delays the tooth movement.

2.2 Electric current Vibration

Various studies have been carried out on animal models that have experimentally tested the effect of electrical current on tooth movement.[19-22] The results have shown that electrical current aids in accelerated tooth movement. This can be owed to the direct currents or electrical currents which are piezoelectrically generated and thus accelerate the orthodontic tooth movement. The procedure is carried out by placing an electric appliance that delivers direct electric current which generates bio-electric potential. This results in local responses and accelerated bone remodeling. The electric current vibration procedure is conducted by some researchers on living animals and is effective in accelerated tooth movement.[23]

2.3 Cyclic vibration

This method involves placing light alternating forces on the teeth through mechanical radiations. The cyclic vibrations are rendered by transferring the signals from the force sensor and the accelerometer to the vibration controller. The amplified signal transferred to the vibrator causes excitation. The vibration applied by the control signal through the power amplifier controlled by the output signal from the accelerometer maintains acceleration at one meter per square second (m/s2). A vibration imposed system includes a vibration controller, charge amplifier, vibrator, force sensor, and accelerometer. Using an adhesive, the top of the vibrator is fixed on the tooth. The vibration tests are conducted for five minutes with a display of resonance curves as frequency-force relationships on the monitor of the vibration. Various researches have been conducted as clinical trials on humans using oral vibration devices such as AccledentTM, AcceleDent®, and electric toothbrushes.[24] It is concluded that cyclic vibrations are effective in aiding the rate of tooth movement.

The well-known use of the vibrating devices has been investigated by Miles and Fisher, 19 Miles et al.,[25] Woodhouse,[26] DiBiase et al.,[27] and Miles et al.[28] but concluded that using vibration is not a significant means for accelerating OTM.

3.0 Chemical Mode of Accelerating Orthodontontic Tooth Movement

The main feature in accelerating the rate of tooth movement is bone resorption. The resorption of the bone that results from osteoclast activation is crucial for controlling the rate of tooth movement. Any modality that accelerates the rate of resorption of bone accelerates the rate of tooth movement. This could be achieved by the application of agents that modify the bone turnover rate and hence help in an increased rate of tooth

movement. Under this section, we shall discuss the effect of the application of osteocalcin, corticosteroids, thyroxin, parathyroid hormone (PTH), vitamin D3 and relaxin.

3.1 Osteocalcin and Corticosteroids

An in vitro study was conducted on a rat model that showed rapid movement following an administration of local injection of a bone matrix component, osteocalcin.[29] This was attributed to the attraction of numerous osteoclasts in that area. Literature indicates a study conducted to show the effects of Corticosteroid on tooth movement.[29,30] In the presence of cytokines like IL-6, it is proven to stimulate osteoclastogenesis and result in osteoporosis. Based on the dose and time of administration, the effect of corticosteroids on tooth movement varies. The mode of application as described by Kobayashi et al,[29] purified osteocalcin (0 to 10 μg) in 20 μg of phosphate-buffered saline injected into the region of root bifurcation of the molar for four days. The study by Kobayashi resulted in osteocalcin having an additive effect on the rate of orthodontic tooth movement.

3.2 Parathyroid hormone (PTH)

PTH is secreted by the parathyroid glands and has a role in altering the calcium concentration of the blood and results in stimulation of bone resorption. This property is utilized for accelerating tooth movement by elevating the PTH levels which will result in resorption of bone along the direction of movement. Various studies have been conducted to prove this positive result and have successfully aided in accelerating tooth movement in animal models.[31] The use of PTH to increase the rate of tooth movement could be achieved by exogenous PTH in a dose-dependent manner, by systemic infusion, or local delivery by slow-release formulation. However, the regular elevation of PTH results in bone resorption, and intermittent short-term increase in hormone level can be anabolic to the bone. The mode of application as described by S. Soma et al (1999), included an animal study of rats where a subcutaneous infusion of vehicle or hPTH (1–84) at 1–10 μg/100 g of body weight/day. The findings of the study by Soma et al concluded that continuous administration of PTH aids in accelerating orthodontic tooth movement.

3.3 Thyroxin, Relaxin

Thyroxin is known to affect the absorption of intestinal calcium. This is indirectly related to bone turnover and the induction of osteoporosis. Research indicated that exogenous thyroxin increases the rate of tooth movement, which in turn is related to increased bone resorption.[32] Another hormone that has shown benefit to accelerate the rate of tooth movement is relaxin. It is capable of reducing the organization level of connective tissues, thus, facilitating rapid separation of adjoining bones. The mode of application as described by MassoudSeifi et al[33] on an animal model, where two 0.1 ml of 1 mg/ml prostaglandin E2 was injected submucosally intraperitoneally after installation of the orthodontic appliance. The study concluded the combination of thyroxine and prostaglandin E2, results in a synergistic effect that increases the rate of orthodontic tooth movement.

3.4 Vitamin D3

Vitamin D3, also known as 1,25-dihydroxycholecalciferol, is involved in the alteration of the rate of bone remodeling and in turn, has an effect on the rate of tooth movement. Vitamin D3 is involved in calcium and phosphate serum regulation by promotion of intestinal absorption and reabsorption in the kidneys. Further, it helps in promoting bone deposition and inhibition of PTH release. Depending on these mechanisms, it is studied that vitamin D3 has the capacity to decrease the rate of tooth movement. However, on the contrary, vitamin D3 increases the rate of tooth movement, if locally injected.[34] This could be related to the effect of vitamin D3 on increasing RANKL expression by local cells and hence activate the osteoclasts. The mode of application as described by Masayoshi Kawakami et al,[35] vitamin D was injected locally, at the concentration

of 10(-10) M, once every 3 days in the submucosal palatal area of the root bifurcation of the molar on the right side. The study concluded that local application of vitamin D enhances the reestablishment of supporting tissue, especially alveolar bone during tooth movement in rats.

Conclusion

The pathways of tooth movement, its biology, and treatment outcomes discretely include a complex process that mandates knowledge and understanding of different areas of bony physiology. The insights in various procedures to alter the bone remodeling processes results in modulating the tooth movement and hence benefits to shorten the orthodontic treatment time. The understanding of different modes could be utilized in different individuals for the optimal acceleration of tooth movement by surgical, chemical and physical, or mechanical forces. Among surgical approaches, the piezocision technique is considered one of the best for periodontal tissue response and excellent aesthetic outcome and comparatively less aggressive to the conventional technique. The surgical approach is most effective with predictable outcomes, but its application is restricted due to its invasive technique and hence less desirable by the patients. Other methods such as LLLT, vibrations are being researched in accelerating OTM with the least discomfort. The mechanical or chemical modes in conjunction with orthodontic treatment are being studied to offer an effective method to shorten treatment duration. Additional research is needed to verify claims and develop techniques and technology for accelerating tooth movement.

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