October University for Modern Sciences and Arts University
MSA Dental Journal

https://msadj.journals.ekb.eg/ PRINT ISSN: 2812 - 4944 VOL. 2, Issue 4, 82-88 October, 2023

Acceleration In Orthodontics: An overview

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ARTICLE INFO.

Keywords:
Acceleration, Orthodontics, Corticotomy, LLLT, Chemical agents

Abstract

The duration of orthodontic treatment is of great importance to both the patient and the orthodontist. This is one of the factors that affects the compliance of the patient, and his satisfaction. Moreover, different problems accompany the long treatment duration from caries, white spot lesions, and periodontal problems. For any orthodontist, shorter treatment time correlates with fewer visits, saving chair time duration. Thus, the acceleration of orthodontic treatment has been researched widely and extensively to achieve better results in less time.

Different methods of acceleration have been investigated that differ in their invasiveness such as corticotomy, corticision, piezocision, low-level laser therapy, and other chemical agents. The goal is to have a non-invasive, simple method with minimum side effects that can increase the velocity of treatment. All the ways provided aim to accelerate the process of bone remodeling that includes bone resorption and bone deposition. This is a review of most of these techniques and how efficient they are.

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1. Introduction

Orthodontic treatment aims to provide better aesthetics to the patients and improve functional activity and health of the oral cavity. Patient satisfaction is considered one of the main outcomes that orthodontic treatment tries to accomplish through adopting new techniques and developing new ways to achieve a fast efficient treatment. The conventional treatment usually has its hazards originating from long treatment period, causing caries development, periodontal problems, and root resorption. Hence, acceleration of tooth movement is a demand from the clinicians and the patients were coined to reduce the risks of long-term treatments. The main concept of acceleration is speeding up the sequel of the biological inflammatory process which is a response to the orthodontic forces applied to the teeth and tissues without comprising the result of treatment to be as efficient as the conventional ones, maybe more but with accelerated duration. This review aims to shed some light on the

various methods used in this area, and reveal their efficacy in accelerating tooth movement.

2. Review of literature:

2.1 Invasive Surgical Approach:

2.1.1 Corticotomy:

In an attempt to decrease the resistance to tooth movement, a new technique "Corticotomy" arose in 1959 by Köle based on the belief that cortical plates of bone are the major source of this hindrance. The procedure is identified through three main steps: A full thickness flap, multiple vertical buccal and lingual interdental cuts through the cortical bone and barely though the medullary bone, and subapical horizontal osteotomy cuts connecting the vertical cuts. It was theorized that bone blocks move not the teeth. [1] In 2001, this theory was challenged by Wilcko et al. proposing "bone matrix transportation" theory which includes Frost's concept of regional accelerating phenomenon (RAP). This approach is done by selective decortication and referred to by "accelerated osteogenic orthodontics" (AOO). This technique was modified by adding a bone graft in the site where the tooth will move, and called periodontally accelerated osteogenic orthodontics (PAOO). Osteopenia usually follows the surgery allowing RAP in a transient and reversible fashion that ends when RAP terminates. [2,31] **Figure 1**

Figure 1. Corticotomy Surgery [3]

2.2 Minimally-Invasive Surgical Approach:

2.2.1 Corticision:

Corticision is an advanced technique from corticotomy, where the main difference is that no gingival flap is made in the corticision. This technique was suggested in 2009 by Kim et al. The flapless way makes this technique less invasive, that is why it is considered more conservative than corticotomy. The word 'corticision' means making incisions in the cortical bone. A reinforced scalpel and mallet make a five mm vertical cut from the papillary gingiva reaching two thirds of the root length. Unlike corticotomy, this technique does not allow placing grafts. A study made on animals showed that this procedure activates the catabolic remodeling in the tooth movement direction. The effect reached its peak in the second month and then dropped in the third. [4]

2.2.2 Piezocision:

Although the two techniques mentioned previously have reduced the time needed for treatment, they are still aggressive techniques. Therefore, Dibart et al developed the "Piezocision" technique. This technique is done by making an incision in the interdental gingival area on the facial side only, using the vibrating piezoelectric knife to make an injury in the bone then making a tunnel beneath the gingiva for putting off a slurry bone graft if needed. It is a less invasive technique that requires no flap.[5] **Figure 2**

Figure 2. A) piezocision technique (B) Penetration of cortical and medullary bone by vibrating piezoelectric knife (C) Bone graft is done by tunneling under gingiva only if needed, and (D) Placement of graft slurry by syringe (E) The mouth after piezocision technique with the addition of graft material. (F) Ten months later. [6]

Mheissen et al in 2020 conducted a systematic review and meta analysis to compare the piezocision technique with the conventional orthodontics. The outcome was in favor of piezocision but with low-quality evidence supporting it. Canine retraction rate was increased using piezocision with minimum loss of anchorage. This effect was evident in the first two months

after surgery. Interestingly, the penetration depth was assumed to be positively correlated with the amount of acceleration with a minimum of 3 mm depth. In regards to en-masse retraction, results were inconclusive and did not show any statistical difference. No consensus reached about the effect on the total treatment time. Root resorption and periodontal score were assessed but there were no statistical difference between both groups. [7]

2.2.3 Micro-osteoperforation:

Microosteoperforations (MOPs) are small holes that are made in the cortical bone using a variety of tools such as miniscrews or the PROPEL device. It is considered the least invasive among the surgical techniques for acceleration as no flap is required and it is a relatively simple technique with less complications. MOP stimulates the bone remodeling process increasing osteoclastogenesis through the elevation of different inflammatory markers. [8]

Some considerations should be in mind before starting the MOP procedures. The location, depth, and number of MOPs must be planned accurately and carefully. Another factor to be noted is the repeated applications of MOP which increased the rate of tooth movement in some studies. Anti-inflammatory drugs should not be prescribed as such drugs inhibit the inflammatory effect of MOPs, thus causing the method to be ineffective. **Figure 3**

Despite of the promising results achieved by Alikhani et al in 2013 [9], a recent systematic review and meta-analysis in 2020 found no significant difference between MOP group and control group but the results achieved were supported by low-quality evidence. There was a high-quality evidence that supported the safety of MOP in regards to pain, gingival recession, and root resorption. [10,32]

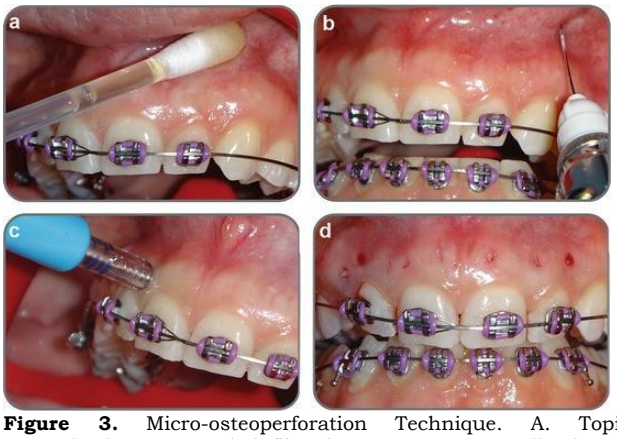

Figure 3. Micro-osteoperforation Technique. A. Topical Anaesthesia. B. Local infiltration. C. MOPs Application. D. Attached gingiva appearance after application. [11]

2.3 Physical Approach:

2.3.1 Low-Intensity Pulsed Ultrasound (LIPUS):

Ultrasound essentially is a form of mechanical energy that propagates through tissues as pressure waves and is above the range of human hearing. LIPUS technology was developed in the 1950s and was widely applied in physical therapy to treat numerous conditions such as bursitis and tendinitis. It employed a low-power ultrasound of about one MHz and later expanded into treating a plethora of other conditions including bone fractures in the 1980s and onwards. The effects of ultrasound treatment are not only a product of heat but also non-thermal effects such as mechanical stress and other undetermined effects. [12] **Figure 4**

LIPUS works by enhancing blood flow to the tooth's surrounding area. This increased blood flow provides more nutrients and oxygen to the area, aiding in the bone remodeling process. The passage for the tooth to go through is created when the bone is remodeled. This can result in significant time savings when moving teeth. The method of application of ultrasound waves in clinical trials typically involves a mouthpiece with LIPUS transducers embedded into the mouthpiece at the teeth root level, they are connected to a handheld control device and a gel is used. The frequency of the LIPUS is 1.5 MHz with a one kHz pulse repetition rate and an output intensity averaging 30 mW/cm^2. [13]

Figure 4. LIPUS device adapted for research. A: Handheld control device. B: Mouthpiece. C: Oral Ultrasound Gel. [14]

A case-control study in 2017 by Giri on thirty young patients undergoing orthodontic treatment on both maxillary quadrants found significant acceleration of tooth movement in the side treated with LIPUS at two-week intervals compared to the other side treated with conventional orthodontic treatment. [15] This is in agreement with what El-Bialy et al found in 2020 evaluating the efficiency of LIPUS on tooth movement rate and root resorption during canine retraction. The LIPUS group showed an accelerated rate of tooth movement by an average of 29% while suffering less root

resorption compared to the control group. [14] Most studies show more favorable results in individuals receiving LIPUS therapy compared to those who undergo conventional orthodontic treatment only.

2.3.2 Electromagnetic field:

Recently, great progress has been made in using magnets and developing Pulsed Electric Magnetic Fields (PEMFs) for the use in medicine and particularly in orthopedics. Fukada and Yasuda were pioneers in examining the effects of electric currents on bone in 1957 which aided in the discovery of the now well-known piezoelectric theory of bone remodeling. It has been suggested that PEMFs affect cellular permeability allowing an elevated flow of sodium, potassium, and calcium ions affecting intracellular cyclic guanosine and adenosine monophosphate. [16]

A clinical investigation on the efficacy of PEMFs in accelerating tooth movement was done by Patil et al. in 2022 showed that the side exposed to the PEMFs had a 31% average increase in the rate of tooth movement when compared to the other side that was treated conventionally. [17] This result is similar to previous studies that used PEMFs.

2.3.3 Low-level laser therapy (LLLT):

Low-level laser (also referred to as photobiomodulation or "cold" laser therapy) was invented in the 1960s soon after the invention of ruby and Helium-Neon lasers. In an experiment done on mice in 1967, Hungarian surgeon and physician Endre Mester discovered that exposing the mice's shaven backs to a low-power laser beam resulted in the hair growing faster compared to the non-laser group. They also performed other experiments on wounds and found that laser therapy resulted in faster wound healing and later expanded their subjects to include humans with similar results. [18]

Little is understood about the biomechanical mechanisms of low-level laser therapy (LLLT) and thus it remains controversial. A proper wavelength that has the lowest chromophore and water absorbance coefficient must be chosen to allow penetration of the laser beam into the tissues which is in the range of 600 to 1000 nm. [19] Many parameters such as wavelength, pulse structure, power density, and timing of laser application must be correctly chosen to obtain positive results and failure to do so may result in no effects or even negative results. [20]

Despite the controversy, many studies support evidence suggesting the effectiveness of LLLT regarding the acceleration of orthodontic tooth movement. In 2013, Cossetin et al found significantly greater osteoclastic activity in the initial stage of tooth movement in 70-day-old, forty-two Wistar rats that were exposed the most to LLLT compared to other groups. [21]

Hasan et al demonstrated the effectiveness of LLLT in 2017, in a randomized controlled clinical trial on 26 patients using a laser-emitting device throughout the leveling and alignment stages to apply a LLL to all maxillary incisor roots at the midline between the cervical and apical halves. The laser beam was applied for 1 minute on each tooth at different intervals across 3 months (On days 3, 7, and 14 and then every 15 days at the beginning of the second month). It was found that the laser group had a 26% less overall time of treatment compared to the control group. [19]

A 2021 retrospective study designed by Al-Dboush et al. on the impact of photobiomodulation on treatment duration finds similar results. The group exposed to the LLLT showed a 26.6% reduction in treatment time compared to the control group.[22] This result contradicts with the findings of the split-mouth randomized controlled trial published in 2017 which showed no significant differences in canine retraction rate in comparison to the control group. [33]

In a systematic review by Wilson and Jain in 2018, it was concluded that LLLT is a promising technique though research should continue to reach an optimized formula for the parameters that could give the most acceleration. Regarding the rate of tooth movement, it increased the most during the third and fourth months of application approaching an acceleration of 30%. Ga-Al-As diode laser with a wavelength of 780-904 nm was the mostly used type. [23]

Comparing LLLT with surgical corticotomy by El-Ashmawi et al in 2018 revealed similar results regarding the rate of canine retraction suggesting the benefits of using this non-invasive method. Moreover, it was assumed that LLLT exhibits a cumulative dose dependent effect on orthodontic tooth movement. [34]

2.4 Chemical Approach:

The chemical approach utilizes artificial methods to accelerate tooth movement. It depends on the action of certain hormones, vitamins, and drugs. One of these hormones is the parathyroid hormone (PTH), which is secreted from the parathyroid glands. It causes bone resorption thus increasing the calcium level in the blood. When the PTH is minimally elevated bone resorption takes place, while when it is intermittently increased bone deposition occurs. This is called the biphasic effect. Thus, Soma et al suggested that the continuous low slow local release is the cause of the accelerated tooth movement while the systematic intermittent injection does not affect

the tooth movement. [24,25]

Prostaglandins (PGs) are a type of inflammatory mediator which causes bone resorption through increasing the number of osteoclasts. Studies done by Yamasaki on roots revealed an increased in the rate of tooth movement with PGs. Split-mouth studies on rats by Lieker et al. showed increased root resorption with different concentrations administration of PGs. Moreover, the acceleration was not affected by the number of injections nor the concentrations of PGs. More studies should be designed to investigate the most suitable application dosage, frequency of the Prostaglandins application, and to detect any possible side effects. [26]

Vitamin D3 (1, 25-dihydroxycholecalciferol) is a biologically active form of vitamin D3 which inhibits the PTH and reverses its action causing bone deposition as it provides osteoblastic cell differentiation. It accelerates the tooth movement when injected locally as it has some osteoclastic effect. It has no obvious side effects. It also regulates the calcium, and phosphorus serum levels by increasing intestinal absorption and renal reabsorption. All studies were done on animals, so further studies should be done on humans to use it. [27]

Osteocalcin and corticosteroids are synthesized naturally and may be given as drugs that cause accelerated tooth movement. Osteocalcin is the most abundant non-collagenous matrix protein in the bone, released from differential osteoblasts, and maintains the alveolar bone matrix through the bone remodeling process. It causes rapid bone resorption as it attracts many osteoclasts. Osteocalcin along with cytokines, like IL-6, can start the processes of osteoclastogenesis on the pressure side, and osteoporosis. Despite all the advantages, it still needs further investigation to be used. [28]

Corticosteroids are steroid hormones that are synthesized in the adrenal cortex. They are dose, and cytokines expression dependent. Therefore, the rate of tooth movement varies according to the dose is given, and when it is given (before, or after the expression of the cytokines). It also has an anti-inflammatory effect which slows the rate of tooth movement. Studies done on rats showed that acute corticosteroids application decreased bone turnover, and increased root resorption while chronic corticosteroids application decreased tooth movement. However, these studies were done on animals which means that they could give different results when done on humans, especially since these animal experiments lack standardized protocols, such as the differences between the animals used in these studies, the dosage, and the duration of the drug administration. [29]

Nitric Oxide (NO) is an essential cellular messenger which is found in several physiological and pathological events. In high doses, osteoclastogenesis decreases while in low doses, it increases. It enhances the vascularization thus increasing the tooth movement. But it still needs further investigations before Clinical trials are carried on. [30]

Leukotrienes are an arachidonic acid metabolite that is caused by the reaction of arachidonic acid with the lipoxygenase enzyme. It increases the tooth movement rate as it causes bone resorption while leukotriene inhibitor drugs have an opposite effect.

Every method has its drawbacks and complications, but the safety of chemical approaches is still questionable as they have systemic effects. Most of the chemical agents used need repeated administration as they have short half-life time making them impractical. If the chemical agents are not evenly distributed, this will change the normal biomechanics of the tooth movement as the pattern of the bone resorption would be changed.

3 Conclusion

Acceleration of the tooth movement is a demand carried by the patients in our fast paced life. Different techniques are being researched but no consensus was reached so far regarding the ability to incorporate any of the techniques in daily orthodontics. More studies of high quality are needed with standardized protocols evaluating these emerging techniques.

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