Chapter

Current Methods for Acceleration of Orthodontic Tooth Movement

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Abstract

The awareness of the society and, accordingly, the number of patients who need orthodontic treatment has increased gradually. Nowadays, the importance of the concept of time has focused the attention of researchers on the completion of orthodontic treatments in a shorter time. Heavy forces applied to shorten the treatment period in orthodontic treatments cause many undesirable conditions, such as root resorption, crushing of periodontal fibers, and formation of hyalinization tissue. Therefore, researchers are working on methods that will accelerate orthodontic tooth movement and shorten the treatment time. In this section, applications that accelerate orthodontic tooth movement will be discussed.

Keywords: tooth movement, piezocision, propel, vibration, corticotomy

1. Introduction

As a result of the awareness of the society and the increasing interest in esthetic appearance, the number of patients who want to receive orthodontic treatment, especially in adults, is increasing [1]. However, one of the biggest problems in orthodontic treatments is the length of the treatment period [2]. Increased caries risk [3, 4], external root resorption risk, [5, 6] and decreased patient cooperation [7] in long-term orthodontic treatments lower its success. For some patients, the long duration of orthodontic treatment may be the only reason for their refusal [8]. The fact that the concept of time has gained importance for both patients and physicians has led researchers to work on completing orthodontic treatment in a shorter time [9].

The methods used to accelerate tooth movement in orthodontic treatment are examined under three main titles as pharmacological and biological applications, mechanical-physical applications and surgical applications [10].

2. The methods used to accelerate tooth movement in orthodontic treatment

2.1 Pharmacological and biological applications

2.1.1 Prostaglandins

Prostaglandins, especially prostaglandin E2 (PGE2), are one of the most effective regulators of bone metabolism [11]. Since prostaglandins play a role in both bone destruction and bone formation, researchers have conducted many studies on the role of prostaglandins during tooth movement [11–14].

Yamasaki et al., in their clinical study, injected prostaglandin E1 (PGE1) submucosal into the distal canine tooth during canine distalization and reported that tooth movement occurred twice as fast. They stated that it is an effective and safe method that can be used to accelerate tooth movement without causing any side effects other than mild pain in patients [15].

Leiker et al., in an animal study examining the effects of PGE2 dose and the number of applications on orthodontic tooth movement, reported that there was no significant difference between a single dose and multiple applications; however, high doses and multiple injections may cause an increase in root resorption [12].

2.1.2 Corticosteroids

Also called steroids are a group of substances used as anti-inflammatory drugs for a wide range of conditions; its name was derived from an internal hormone produced by the adrenal cortex. Cortisone is the most famous type of this group that is used in the treatment of many inflammatory and autoimmune diseases such as rheumatoid arthritis, skin diseases, ulcerative colitis, adrenal insufficiency and asthma [16]. The effects of corticosteroid on the bone turnover were demonstrated in different studies, but the mechanism by which corticosteroids suppress the bone formation and increase bone resorption is still not really understood [17].

Ashcraft et al., in a study that included 16 New Zealand rabbits, in which they examined the effect of corticosteroids on tooth movement speed, stated that the speed of tooth movement was four times higher in the experimental group in which they gave cortisone acetate compared to the control group. In addition, in the histopathological examination of the bone sections they took, it was stated that the areas of bone resorption were higher in the experimental group than in the control group [18].

Ong et al. reported that there was no significant change in orthodontic tooth movement speed, but root resorption was less in their study on rabbits to which they applied prednisolone, a corticosteroid derivative [19].

2.1.3 Parathyroid hormone

The main task of the parathyroid hormone is to maintain the calcium balance in the body together with the hormones calcitonin and 1,25 dihydroxycholecalciferol. Parathyroid hormone accelerates bone remodeling by stimulating osteoclasts and osteoblasts [20].

Gianelly injected parathyroid hormone (PTH) locally into the distal mucosa of the upper left incisors of six rats and investigated its effect on tooth motility. As a result, he reported that the amount of tooth movement was higher in the PTH applied group [21].

Goldie and King reported in their study that in the group fed with a calcium-deficient diet, parathyroid hormone secretion increased and resulted in a decrease in bone density, resulting in increased tooth movement speed and less root resorption [22].

2.1.4 1,25-Hydroxyvitamin D

Another factor that is important in orthodontic tooth movement is 1,25 dihydroxycholecalciferol (1,25-DHCC), the active form of vitamin D, and is involved in calcium hemostasis. 1,25-DHCC stimulates bone deposition and inhibits PTH release.

While it does not affect bone resorption at physiological doses, low doses stimulate the release of receptor activator nuclear kappa B ligand (RANKL) from osteoblasts, changing the receptor activator nuclear kappa B (RANK)/RANKL ratio and causing differentiation of osteoclasts. Thus, it takes part in the osteoclastic activity. It has also been shown to play a role in osteoblastic cell differentiation and bone mineralization in a dose-dependent manner in addition to its bone resorption function [14].

Collins and Sinclair examined the effects of injection of the active form of vitamin D on tooth movement in their study and reported that there was a 60% increase in tooth movement speed compared to the control group [23].

Takano-Yamamoto et al., in their study on rats, applied force to the maxillary first molar and additionally injected 1,25-dihydroxycholecalciferol locally every three days [24]. As a result, they reported that local injection of 1,25-dihydroxycholecalciferol with mechanical forces accelerated tooth movement, and the pause in tooth movement determined in the control group was not observed in the experimental group.

Kale et al., in their study evaluating the effects of locally applied 1,25-dihydroxycholecalciferol and PGE2 on orthodontic tooth movement using histological parameters, reported that both applications increased the speed of tooth movement, but the effects of the applications on the amount of tooth movement were similar [14].

2.1.5 Osteocalcin

Osteocalcin is a non-collagenous matrix protein that is abundant in bone tissue and functions as a negative regulator of mineral apposition and bone formation due to its high-binding strength with calcium and hydroxyapatite [25].

Hashimoto et al. injected local osteocalcin to the maxillary first molars of rats, while applying mesial motion with a spiral spring, and evaluated tooth movement histologically for a period of 10 days [26]. In their results, they determined that local application of osteocalcin accelerated tooth movement and explained this with the increase of osteoclast on the pressure side in the early period.

2.1.6 Nitric oxide

Nitric oxide is synthesized from arginine by the enzyme nitric oxide synthase. It is a short-lived molecule that plays a key role in the regulation of some functions of the nervous, defense, respiratory, circulatory, and reproductive systems [27]. Nitric oxide is also important in bone turnover and the regulation of pulpal blood flow [28].

Shirazi et al. injected L-arginine G-nitro-L-arginine methyl ester into experimental animals in their study. As a result, they reported increased bone remodeling and osteoclastic activity [28].

Akin et al., in their study, reported a significant increase in multinucleated osteoclasts, howship lacunae, vascularization and orthodontic tooth movement as a result of nitric oxide injection in rats [29].

2.1.7 Platelet rich plasma (PRP) and platelet rich fibrin (PRF)

Recently, there have been studies investigating the effect of PRP and PRF on orthodontic tooth movement speed. Studies have reported that these applications can accelerate orthodontic tooth movement [30–34].

In the last two decades, after a better understanding of the role of platelets in wound healing, the idea of using these cells for treatment has been proposed. The new autogenous product called PRP has been widely used in orthopedics, plastic surgery, and dentistry [35]. PRP is the plasma fraction obtained by centrifuging whole blood and containing a higher concentration of platelets than whole blood. It contains a high amount of platelets, growth factors, and coagulation factors in PRP [36].

After tooth extraction, resorptive remodeling of the alveolar bone usually occurs. This event is beneficial in accelerating tooth movement in patients with moderate crowding and undergoing fixed orthodontic treatment [37, 38].

In the literature, there are studies on the use of various bioactive grafts to increase the orthodontic tooth movement speed [39]. In orthodontic treatment, a sufficient amount of alveolar bone is required for successful orthodontic tooth movement during the closure of the extraction space. However, the application of different graft materials can promote bone formation. It has been reported that PRF has positive effects on bone healing, socket protection and acceleration of tooth movement [34].

In studies, it has been observed that PRP, which is applied at a high level, inhibits the division of bone cells and reduces bone density, and it is therefore thought that orthodontic tooth movement can be accelerated with this application [40, 41, 31]. Güleç et al., as a result of their experimental studies in which medium- and high-level PRP was injected into the mesial side of the first molar teeth of rats, showed that high-level PRP accelerated tooth movement by temporarily activating osteoclastic activity and that medium-level PRP applied at high level [31]. They reported that it accelerated tooth movement, although less than PRP. Rashid et al. reported in their study on dogs that local PRP injection can accelerate tooth movement without clinical and microscopic side effects [32].

Liou reported in their research on humans that submucosal PRP injection can increase the speed of tooth movement without surgical application and alveolar bone loss. In his clinical study, he reported that local submucosal PRP injection was 1.7 times faster in maxillary and mandibular leveling and this acceleration was PRP dose-dependent [30]. This PRP ratio (platelet count in PRP/platelet count in the blood) is <12.5. He stated that the ideal number of PRP platelets to be used to accelerate tooth movement should be 9.5–12.5 times the normal. On the other hand, PRP injection during en-masse retraction reduced alveolar bone loss by 71–77% on the pressure side, which is also dose-dependent. The optimal dose of PRP for optimal clinical performance is 11.0–12.5-folds, with submucosal injection of PRP accelerating orthodontic tooth movement and at the same time protecting the alveolar bone on the pressure side of orthodontic tooth movement. A single dose of PRP injection is effective for 5–6 months. It has been reported that the most effective period of PRP injection in accelerating tooth movement is the second half of the 4th month after the injection.

Tehranchi et al. in their study on humans, in eight patients who needed bilateral first premolar extraction, L-PRF was placed in the extraction socket on one side following a tooth extraction, and the opposite side constituted the control group. As a result of the study, tooth movement was found to be faster on the side where L-PRF was inserted into the extraction socket compared to the control side [34].

Nemtoi et al. reported that PRF placed in the extraction socket accelerates bone regeneration and tooth movement compared to the control side, and anterior and posterior teeth move faster toward the extraction cavity [33].

2.2 Physical/mechanical stimulation methods

2.2.1 Resonance vibration

In order to accelerate tooth movement, resonance or ultrasonic vibration applications are made. The application of vibration to accelerate tooth movement was first tried by Krishtab et al. [42]. Later, Ohmae et al. argued that ultrasonic vibration increases the speed of tooth movement, but they reported that ultrasonic vibration has a detrimental effect on the dental pulp [43].

Nishimura et al. showed in their study on rats that resonance vibration increases the speed of tooth movement and does not cause periodontal damage. They reported that the resonance vibration method was effective with the activation of RANK-RANKL in periodontal tissues [44].

In their study, Kau et al. had 14 patients undergoing fixed orthodontic treatment use a new commercial product, Acceledent™ (OrthoAccel Technologies, Inc., Bellaire, TX, USA) (**Figure 1**) for 20 minutes a day, in accordance with the manufacturer's recommendations [45]. They reported that there was an increase in tooth movement speed compared to the control group, which did not apply any acceleration method.

2.2.2 Direct electric current and electromagnetic stimulation

In animal studies investigating the effect of direct electric current on tooth movement, it has been reported that direct current is applied to the anode in the pressure regions and the cathode in the voltage regions, changing the bioelectric potential of the direct current and accelerating tooth movement. However, it has been reported that electrical current may have side effects such as ionic reactions causing damage to tissues and displacement of bone tissue with connective tissue [46].

Darendeliler et al. suggested that the static magnetic field accelerates tooth movement by shortening the pause period in which orthodontic tooth movement is not seen. It has been reported that the electromagnetic field affects the level of a group of enzymes responsible for the regulation of intracellular metabolism by changing the sodium-calcium exchange rate in the cell membrane, thereby increasing cellular proliferation [47]. By affecting the cellular activity in the periodontal space, it accelerates both osteoclastic and osteoblastic activities, and thus, the movement takes place in a shorter time in force-applied teeth. It has been reported that due to the stabilization of the rate of resorption due to increased bone formation, mobility in the teeth decreases and pain is not observed in teeth exposed to chewing forces [48, 49]. In a study on the side effects of this method, it was reported that minor changes in blood chemistry may occur with a decrease in serum calcium level [47].

2.2.3 Low-level laser irradiation therapy

One of the techniques developed to accelerate tooth movement is low-dose laser application. Laser is a light source obtained by stimulating and amplifying radiation [50].

Figure 1.
Acceledent™.

Laser application: It has been stated that it stimulates the proliferation of osteoclasts, osteoblasts, and fibroblasts and thus accelerates tooth movement by affecting bone remodeling [51]. Low-dose laser application activates the cytochrome C oxidase enzyme in electron transfer, causing an increase in adenosine triphosphate (ATP) in the cell, thus accelerating the tooth movement [52]. It has been reported that low-dose laser application accelerates tooth movement through RANK-RANKL, M-CSF, and the receptor of this factor [53].

In an animal study in which the effect of low-dose laser application on tooth movement speed was examined for the first time, 10 g orthodontic force was applied to the molar teeth of experimental animals for 12 days in three parts of the teeth (buccal, palatal, mesial) for a total of 9 minutes a day, 35.3 W/cm2 (54 Joule) Gallium aluminum arsenide (GaAlAr) diode laser with a wavelength of 830 nanometers (nm) was applied. As a result of histomorphometric and histological analyzes, it was reported that there was an increase in bone remodeling and a 1.3-fold acceleration in tooth movement with laser application [54].

Cruz et al. conducted the first clinical study on the effect of low-dose laser application on tooth movement and applied only mechanical activation on one side of the arch and laser with mechanical activation on the other side in 11 patients who were planned to undergo canine distalization [55]. After each force activation, GaAlAr semiconductor diode laser was applied at a power of 780 nm and a dose of 5 J/cm2 for 10 seconds. They showed that they could accelerate tooth movement by 34% when they applied four times a month over the mucosa from the buccal and palatal of the canine tooth to the cervical, middle and apical third of the root. They also found a significant reduction in patient discomfort and pain sensation.

Seifi et al. and Yamaguchi et al. reported that laser application did not cause any change in tooth movement speed [13, 56].

There have also been several studies showing contrasting results with low-level laser therapy. Therefore, more studies are needed to distinguish the optimum wavelength, optimum energy, and optimum duration.

3. Surgical methods

3.1 Corticotomy and osteotomy

Corticotomy and osteotomy are surgical techniques that have been used clinically for many years. Osteotomy a is surgical cut in the bone, including the cortical and trabecular bone [57, 58]. Corticotomy is incisions, cut and perforation procedures performed only in the cortical bone, not involving the medullary bone [51].

Corticotomy-assisted orthodontic tooth movement was first described by LC Bryan in 1893 [59]. However, corticotomy performed by Henrich Köle in 1959 to accelerate orthodontic tooth movement is an evolution in this regard [60]. Köle thought that the main resistance to tooth movement was the cortical bone and that tooth movement could be accelerated by disrupting the integrity and continuity of the cortical bone. Köle created “bone blocks” by making interradicular vertical corticotomy incisions on the buccal and palatal surface and subapical horizontal osteotomy incisions connecting these incisions in the buccopalatinal direction. He made the incisions only in the cortical bone without causing any damage to the cancellous bone. He reported that when high orthopedic forces are applied with adjustable screw appliances, major active tooth movement can be completed within 6–12 weeks [60].

The changes that occur in the bone after corticotomy was first described by Herald Frost as the Regional Acceleratory Phenomena (RAP) [61]. Based on this phenomenon, increasing the rate of tooth movement is not due to the decreasing bone resistance only but also the effects of the healing process on the rapidity of bone cell activation.

The most widely accepted technique today was put forward by Wilcko et al. [62, 63]. According to the results of their studies, they stated that tooth movement resulted from demineralization and remineralization in reversible osteopenia occurring in the alveolar bone during wound healing, in line with RAP, rather than bone block movement.

The Wilcko brothers introduced the technique called "accelerated osteogenic orthodontics"(AOO), in which they combined selective alveolar decortication, alveolar augmentation, and orthodontic tooth movement, later called "periodontally accelerated osteogenic orthodontics"(PAOO) or "Wilckodontics." The basic principle in this technique is to create a layer of bone of 1.5 mm or less on the root surface in the direction of intended tooth movement. Similar to techniques in which bone block is created, the flap is raised and vertical corticotomies are performed. Alternatively, horizontal corticotomies that do not descend into the medullary bone are performed under the roots of the teeth to be moved. Thus, it was stated that the vitality of the teeth was preserved. In order to accelerate healing, a bone graft was applied and RAP was modified. (**Figure 2**) As a result of the study, no periodontal problems, root resorption, luxation, and changes in alveolar bone height were found, and the duration of orthodontic treatment was reduced by 1/3 or 1/4 [62, 63].

The advantages of the technique are shortening the treatment period compared to conventional treatments, moving the teeth more, reducing hyalinization and root resorption due to the decrease in the pressure in the periodontal ligament, treating bone defects by grafting, and decreasing the recurrence rate by deteriorating tissue memory with corticotomies. The invasive surgical procedure, additional costs, risk

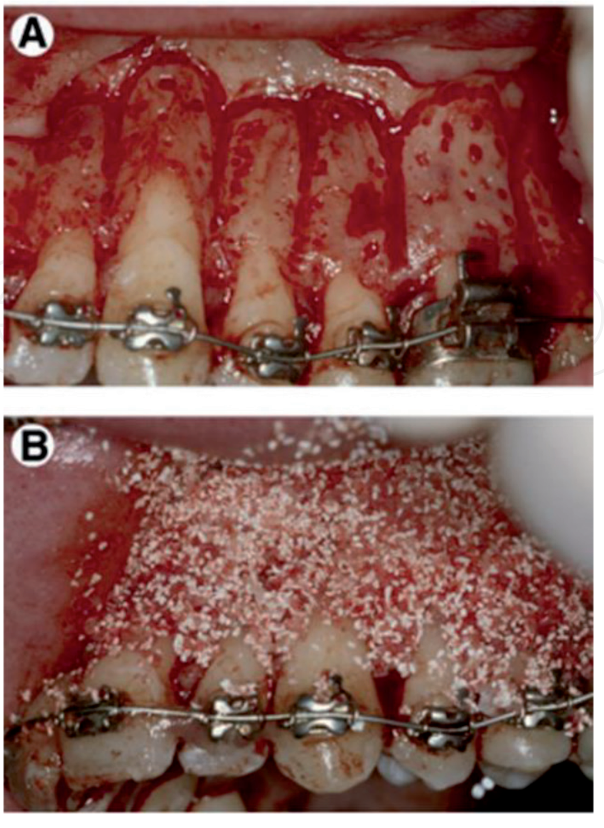

Figure 2.
Treatment of a 23 year-old male patient. A, Before treatment, anterior view. B, After treatment, total AOO treatment time 6 months 2 weeks,anterior view. Corticotomy and bone grafting (Wilcko 2009).

of bone loss, and complications such as pain, edema and infection due to surgery are also disadvantages of the technique [62, 63].

The "rapid orthodontic treatment" technique developed by Chung is based on corticotomy and serial movement of the dentoalveolar segments with orthopedic forces [64]. The method is similar to the accelerated osteogenic orthodontic technique, but the difference of this technique is that the dentoalveolar segment is also moved along with the teeth [65].

3.1.1 Distracting the periodontal ligament

Liou and Huang, in their study, defined the technique as "distraction of the periodontal ligament," which is based on the formation of new bone due to the tension of the healing bone, by reducing bone resistance in principle similar to distraction osteogenesis. The aim of this technique is to distalize in a short time, to prevent loss of anchorage in posterior teeth and resorption of canine teeth. In cases where they applied fixed treatment with first premolar extraction in this technique, the interseptal bone distal to the canine after extraction was vertically weakened with a drill [66]. Following the surgical procedures, a special tooth-supported intraoral distractors were placed and activated 0.5–1 mm per day. With this technique, the canines were moved 6.5 mm toward the extraction space in three weeks. It has been reported that this technique can accelerate tooth movement without causing serious root resorption, ankylosis and root fracture [51]. However, some conflicting results have been reported regarding the vitality of distalized canine teeth. Liou and Huang reported that 9 out of 26 teeth responded positively to the vitality test, while 7 out of 20 teeth responded positively to the vitality test after the sixth month of retraction, in the study by Sukurica et al. [66, 67]. Therefore, there are still uncertainties regarding this technique.

3.1.2 Dentoalveolar distraction

Dentoalveolar distraction differs from periodontal ligament distraction in that the tooth is moved together with the surrounding bone. Kişnişçi et al. presented this technique in order to shorten the duration of orthodontic treatment. In this technique, following the extraction of the first premolar tooth, the alveolar segment around the canine was mobilized and an intraoral distractor was placed and 0.8 mm of tooth movement per day was performed. Canine distalization was completed in 8–14 days. Researchers stated that there was no loss of anchorage, root resorption, ankylosis and discoloration in the first molar teeth [68, 69].

3.1.3 Micro-osteoperforation (MOP)

The method of creating holes in the alveolar bone to increase osteoclastic activity in order to accelerate orthodontic tooth movement is called "alveosynthesis." For this purpose, a disposable device called propel was designed by "propel orthodontics." It has been reported that microosteoperforations (MOPs) applied during canine distalization cause a significant increase in the amount of cytokines that increase osteoclast differentiation and number. It has been found that MOPs increase tooth movement 2–3 times compared to the control group during canine distalization. It was stated to be a comfortable and reliable method [70].

3.1.4 Piezocision

Corticotomy, which is one of the methods applied to accelerate orthodontic tooth movement, is an effective method, but it is a highly invasive method. Because it requires wide flap removal and bone surgery, which can cause discomfort and complications after surgery [71]. Vercellotti and Podesta, in their study, recommended the use of a piezosurgical blade in order to create safer and more precise corticotomies without causing osteonecrotic damage after flap removal in order to reduce surgical trauma and accelerate tooth movement [72]. Kim et al. applied the corticization method, which is a method that causes surgical damage to the bone without lifting the flap. They argued that this method increased the effect of BHF and accelerated tooth movement. However, due to the difficulty of accessing the periodontium and the surgical procedures, temporary dizziness was observed in the patients [73]. Most recently, Dibart et al. introduced the "piezoincision" technique, which is a new and minimally invasive method and performed without flap lifting [74].

As a result of a histological study, it has been shown that decortication with piezoincision has an effect similar to the BHF effect. In this study, it was shown histologically that transient osteopenia occurred and osteoclastic activity was stimulated in as little as one day. In addition, it has been determined that piezoincision application creates deeper demineralization areas and accordingly tooth movement is twice as fast [75] (**Figure 3**).

It has been reported that, depending on the difficulty of tooth movement and the bone morphology of the patient, the piezoincision procedure can be repeated 5–6 months later in order to reactivate the RAP [76].

Aksakalli et al., in their study investigating the effect of piezoincision during canine distalization, reported that tooth movement speed increased, anchorage control was better in posterior teeth, and there was no transversal narrowing in the upper jaw. They also stated that periodontal health was not adversely affected [77]. It has been reported that the possibility of bacterial endocarditis should be considered in high-risk patients, since bacteremia may occur temporarily in patients with piezoincision [78].

The most important feature of piezoelectric surgery devices is that when they come into contact with soft tissue, the tissue can absorb vibrations and disperse them by converting them to a slight heat. In this case, the device cannot make the incision. When the physician realizes that the vibrations have stopped, he realizes that he is in contact with the soft tissue and stops the procedure. Even when you continue to force it in the same position, no rupture occurs in the vessels or nerves. In the worst case, the damage will usually be reversible. Due to this feature, it is possible to make precise incisions without damaging tissues such as nerves, vessels, and membranes [79]. One of the important advantages of the device is the cavitation phenomenon created by ultrasonic frequency. The cooling solution applied during the procedure takes the form of an aerosol and washes the treated area, clogs small vessels, and removes tissue residues and blood. In this way, it both reduces bleeding

Figure 3.
RAP with piezocision. (Dibart 2015).

and provides a good viewing angle [80]. It is possible to make more precise incisions since macro-vibrations do not occur as in conventional techniques [81]. In addition, it is more comfortable for the patient as it produces less vibration and noise [82].

The vibrations created by the device and the shock waves that occur in the liquid environment act as a disinfectant and reduce the bacteria [83]. In another study, it was stated that the application of piezoincision may cause transient bacteremia and therefore the risk of bacterial endocarditis should be considered [78]. As a result of the examinations made on the bone fragments exposed during the surgical procedure, it was determined that the cells were alive and necrosis did not occur in the bone tissue [84]. It is more advantageous than conventional techniques in terms of wound healing and new bone formation, thanks to the reduction of the risk of necrosis and the ability to make precise incisions with micro-vibrations [72].

4. Conclusions

In the literature, there are many invasive and non-invasive methods that accelerate orthodontic tooth movement. More extensive studies should be done on this subject.

Conflict of interest

The authors declare no conflict of interest.

Acronyms and abbreviations

PGE2	prostaglandin E2
PGE1	prostaglandin E1
PTH	parathyroid hormone
1,25-DHCC	1,25 dihydroxycholecalciferol
RANK	receptor activator nuclear kappa B
RANKL	receptor activator nuclear kappa B ligand
PRP	platelet-rich Plasma
PRF	platelet-rich Fibrin
ATP	Adenosine triphosphate
GaAlAr	gallium aluminum arsenide
RAP	Regional acceleratory phenomena
MOP	micro-osteoperforation
AOO	accelerated osteogenic orthodontics
PAOO	periodontally accelerated osteogenic orthodontics

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References

[1] Cano J, Campo J, Bonilla E, Colmenero C. Corticotomy-assisted orthodontics. Journal of Clinical and Experimental Dentistry. 2012;**4**:54

[2] Fisher MA, Wenger RM, Hans MG. Pretreatment characteristics associated with orthodontic treatment duration. American Journal of Orthodontics and Dentofacial Orthopedics. 2010;**137**:178-186

[3] Geiger AM, Gorelick L, Gwinnett AJ, Benson BJ. Reducing white spot lesions in orthodontic populations with fluoride rinsing. American Journal of Orthodontics and Dentofacial Orthopedics. 1992;**101**:403-407

[4] Bishara SE, Ostby AW. White spot lesions: formation, prevention, and treatment. In: Seminars in Orthodontics. US: Elsevier, WB Saunders; 2008. Vol. 14 pp. s 174-s 182

[5] Segal G, Schiffman P, Tuncay O. Meta analysis of the treatment-related factors of external apical root resorption. Orthodontics & Craniofacial Research. 2004;**7**:71-78

[6] Pandis N, Nasika M, Polychronopoulou A, Eliades T. External apical root resorption in patients treated with conventional and self-ligating brackets. American Journal of Orthodontics and Dentofacial Orthopedics. 2008;**134**:646-651

[7] Royko A, Denes Z, Razouk G. The relationship between the length of orthodontic treatment and patient compliance. Fogorvosi Szemle. 1999;**92**:79-86

[8] Lv T, Kang N, Wang C, Han X, Chen Y, Bai D. Biologic response of rapid tooth movement with periodontal ligament distraction. American Journal of Orthodontics and Dentofacial Orthopedics. 2009;**136**:401-411

[9] Genc G. The Effect of Application of Low Level Laser Therapy(LLLT) on Orthodontic Tooth Movement. Ankara: Hacettepe University; 2010

[10] Ren A, Lv T, Kang N, Zhao B, Chen Y, Bai D. Rapid orthodontic tooth movement aided by alveolar surgery in beagles. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(2):160. e1-. 160.e10.

[11] Yamasaki K, Shibata Y, Fukuhara T. The effect of prostaglandins on experimental tooth movement in monkeys (Macaca fuscata). Journal of Dental Research. 1982;**61**(12):1444-1446

[12] Leiker BJ, Nanda RS, Currier GF, Howes RI, Sinha PK. The effects of exogenous prostaglandins on orthodontic tooth movement in rats. American Journal of Orthodontics and Dentofacial Orthopedics. 1995;**108**(4):380-388

[13] Seifi M, Shafeei HA, Daneshdoost S, Mir M. Effects of two types of low-level laser wave lengths (850 and 630 nm) on the orthodontic tooth movements in rabbits. Lasers in Medical Science. 2007;**22**(4):261-264

[14] Kale S, Il K, Atilla P, Asan E. Comparison of the effects of 1, 25 dihydroxycholecalciferol and prostaglandin E2 on orthodontic tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 2004;**125**(5):607-614

[15] Yamasaki K, Shibata Y, Imai S, Tani Y, Shibasaki Y, Fukuhara T. Clinical application of prostaglandin E1 (PGE1) upon orthodontic tooth movement. American Journal of Orthodontics. 1984;**85**(6):508-518

[16] Walsh LJ, Wong CA, Pringle M, Tattersfield AE. Use of oral

corticosteroids in the community and the prevention of secondary osteoporosis: A cross sectional study. British Medical Journal. 1996;**313**(7053):344-346

[17] Angeli A, Dovio A, Sartori ML, Masera RG, Ceoloni B, Prolo P, et al. Interactions between glucocorticoids and cytokines in the bone microenvironment. Annals of the New York Academy of Sciences. 2002;**966**(1):97-107

[18] Ashcraft MB, Southard KA, Tolley EA. The effect of corticosteroid-induced osteoporosis on orthodontic tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 1992;**102**(4):310-319

[19] Ong CK, Walsh LJ, Harbrow D, Taverne AA, Symons AL. Orthodontic tooth movement in the prednisolone-treated rat. The Angle Orthodontist. 2000;**70**(2):118-125

[20] Shinoda Y, Kawaguchi H, Higashikawa A, Hirata M, Miura T, Saito T, et al. Mechanisms underlying catabolic and anabolic functions of parathyroid hormone on bone by combination of culture systems of mouse cells. Journal of Cellular Biochemistry. 2010;**109**:755-763

[21] Gianelly AA. Force-induced changes in the vascularity of the periodontal ligament. American Journal of Orthodontics. 1969;**55**(1):5-11

[22] Goldie RS, King GJ. Root resorption and tooth movement in orthodontically treated, calcium-deficient, and lactating rats. American Journal of Orthodontics. 1984;**85**(5):424-430

[23] Collins MK, Sinclair PM. The local use of vitamin D to increase the rate of orthodontic tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 1988;**94**(4):278-284

[24] Takano-Yamamoto T, Kawakami M, Yamashiro T. Effect of age on the rate of tooth movement in combination with local use of 1, 25 (OH) 2D3 and mechanical force in the rat. Journal of Dental Research. 1992;**71**(8):1487-1492

[25] Tsao Y-T, Huang Y-J, Wu H-H, Liu Y-A, Liu Y-S, Lee OK. Osteocalcin mediates biomineralization during osteogenic maturation in human mesenchymal stromal cells. International Journal of Molecular Sciences. 2017;**18**(1):159. DOI: 10.3390/ijms18010159

[26] Hashimoto F, Kobayashi Y, Mataki S, Kobayashi K, Kato Y, Sakai H. Administration of osteocalcin accelerates orthodontic tooth movement induced by a closed coil spring in rats. The European Journal of Orthodontics. 2001;**23**(5):535-545

[27] Brennan P, Thomas G, Langdon J. The role of nitric oxide in oral diseases. Archives of Oral Biology. 2003;**48**(2):93-100.120

[28] Shirazi M, Nilforoushan D, Alghasi H, Dehpour A-R. The role of nitric oxide in orthodontic tooth movement in rats. The Angle Orthodontist. 2002;**72**(3):211-215

[29] Akin E, Gurton AU, Olmez H. Effects of nitric oxide in orthodontic tooth movement in rats. American Journal of Orthodontics and Dentofacial Orthopedics. 2004;**126**(5):608-614

[30] Liou EJ. The development of submucosal injection of platelet rich plasma for accelerating orthodontic tooth movement and preserving pressure side alveolar bone. APOS Trends in Orthodontics. 2016;**6**(1):5

[31] Gulec A, Bakkalbasi BÇ, Cumbul A, Uslu U, Alev B, Yarat A. Effects of local platelet-rich plasma injection on the rate of orthodontic tooth movement in a rat model: A histomorphometric study.

American Journal of Orthodontics and Dentofacial Orthopedics. 2017;**151**(1):92-104

[32] Rashid A, ElSharaby F, Nassef E, Mehanni S, Mostafa Y. Effect of platelet-rich plasma on orthodontic tooth movement in dogs. Orthodontics & Craniofacial Research. 2017;**20**(2):102-110

[33] Nemtoi A, Sirghe A, Nemtoi A, Haba D. The Effect of a Plasma With Platelet-rich Fibrin in Bone Regeneration and on Rate of Orthodontic Tooth Movement in Adolescents. Revista de Chimie. 2018;**69**(12):3727-3730

[34] Tehranchi A, Behnia H, Pourdanesh F, Behnia P, Pinto N, Younessian F. The effect of autologous leukocyte platelet rich fibrin on the rate of orthodontic tooth movement: A prospective randomized clinical trial. European Journal of Dentistry. 2018;**12**(3):350

[35] Kocyigit I, Tunali M, Ozdemir H, Kartal Y, Suer B. Clinical application of second generation trombosite concentration. Cumhuriyet Dental Journal. 2012;**15**(3):279-287

[36] Paoloni J, De Vos RJ, Hamilton B, Murrell GA, Orchard J. Platelet-rich plasma treatment for ligament and tendon injuries. Clinical Journal of Sport Medicine. 2011;**21**(1):37-45

[37] Yuan X, Luo S, Shen G. Experimental study on selecting optimal time of orthodontic tooth movement into extraction sites. Hua xi kou qiang yi xue za zhi= Huaxi kouqiang yixue zazhi=. West China Journal of Stomatology. 2003;**21**(4):311-313

[38] Gurbuzer B, Pikdoken L, Tunali M, Urhan M, Kucukodaci Z, Ercan F. Scintigraphic evaluation of osteoblastic activity in extraction sockets treated with platelet-rich fibrin. Journal of Oral and Maxillofacial Surgery. 2010;**68**(5):980-989

[39] M Dohan Ehrenfest D, Bielecki T, Jimbo R, Barbe G, Del Corso M, Inchingolo F, et al. Do the fibrin architecture and leukocyte content influence the growth factor release of platelet concentrates? An evidence-based answer comparing a pure platelet-rich plasma (P-PRP) gel and a leukocyte-and platelet-rich fibrin (L-PRF). Current Pharmaceutical Biotechnology. 2012;**13**(7):1145-1152

[40] Graziani F, Ivanovski S, Cei S, Ducci F, Tonetti M, Gabriele M. The in vitro effect of different PRP concentrations on osteoblasts and fibroblasts. Clinical Oral Implants Research. 2006;**17**(2):212-219

[41] Peerbooms JC, Colaris JW, Hakkert AA, Van Appeldorn M, Bruijn DJ, Den Oudsten BL, et al. No positive bone healing after using platelet rich plasma in a skeletal defect. An observational prospective cohort study. International Orthopaedics. 2012;**36**(10):2113-2119

[42] Krishtab S, Doroshenko S, Liutik G. Use of vibratory action on the teeth to accelerate orthodontic treatment. Stomatologiia. 1986;**65**(3):61-63

[43] Ohmae M, Saito S, Morohashi T, Qu H, Seki K, Kurabayashi H. Biomechanical acceleration of experimental tooth movement by ultrasonic vibration in vivo—part 1. Homo-directional application of ultrasonication to orthodontic force. Orthodontic Waves. 2001;**60**:201-212

[44] Nishimura M, Chiba M, Ohashi T, Sato M, Shimizu Y, Igarashi K, et al. Periodontal tissue activation by vibration: intermittent stimulation by resonance vibration accelerates experimental tooth movement in rats. American Journal of Orthodontics and

Dentofacial Orthopedics. 2008;**133**(4):572-583

[45] Kau CH, Nguyen JT, English J. The clinical evaluation of a novel cyclical force generating device in orthodontics. Orthodontic Practice US. 2010;**1**(1):10-15

[46] Davidovitch Z, Finkelson MD, Steigman S, Shanfeld JL, Montgomery PC, Korostoff E. Electric currents, bone remodeling, and orthodontic tooth movement: II. Increase in rate of tooth movement and periodontal cyclic nucleotide levels by combined force and electric current. American Journal of Orthodontics. 1980;**77**(1):33-47

[47] Darendeliler MA, Sinclair PM, Kusy RP. The effects of samarium-cobalt magnets and pulsed electromagnetic fields on tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 1995;**107**(6):578-588

[48] Stark TM, Sinclair PM. Effect of pulsed electromagnetic fields on orthodontic tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 1987;**91**(2):91-104

[49] Graber T. Magnets and impacted canines. In: Northcroft Memorial Lecture. British Society for the Study of Orthodontics: Manchester, UK; 1989

[50] Cernavin I, Pugatschew A, de Boer N, Tyas MJ. Laser applications in dentistry: a review of the literature. Australian Dental Journal. 1994;**39**(1):28-32

[51] Nimeri G, Kau CH, Abou-Kheir NS, Corona R. Acceleration of tooth movement during orthodontic treatment-a frontier in orthodontics. Progress in Orthodontics. 2013;**14**(1):42

[52] Eells JT, Wong-Riley MT, VerHoeve J, Henry M, Buchman EV, Kane MP, et al. Mitochondrial signal transduction in accelerated wound and retinal healing by near-infrared light therapy. Mitochondrion. 2004;**4**(5-6):559-567

[53] Fujita S, Yamaguchi M, Utsunomiya T, Yamamoto H, Kasai K. Low-energy laser stimulates tooth movement velocity via expression of RANK and RANKL. Orthodontics & Craniofacial Research. 2008;**11**(3):143-155

[54] Kawasaki K, Shimizu N. Effects of low-energy laser irradiation on bone remodeling during experimental tooth movement in rats. Lasers in Surgery and Medicine: The Official Journal of the American Society for Laser Medicine and Surgery. 2000;**26**(3):282-291

[55] Cruz DR, Kohara EK, Ribeiro MS, Wetter NU. Effects of low-intensity laser therapy on the orthodontic movement velocity of human teeth: A preliminary study. Lasers in Surgery and 118 Medicine: The Official Journal of the American Society for Laser Medicine and. Surgery. 2004;**35**(2):117-120

[56] Yamaguchi M, Fujita S, Yoshida T, Oikawa K, Utsunomiya T, Yamamoto H, et al. Low-energy laser irradiation stimulates the tooth movement velocity via expression of M-CSF and c-fms. Orthodontic Waves. 2007;**66**(4):139-148

[57] Lee W, Karapetyan G, Moats R, Yamashita D-D, Moon H-B, Ferguson D, et al. Corticotomy−/osteotomy-assisted tooth movement microCTs differ. Journal of Dental Research. 2008;**87**(9):861-867

[58] Wang L, Lee W, Lei D-l, Liu Y-p, Yamashita D-D, Yen SL-K. Tissue responses in corticotomy-and osteotomy-assisted tooth movements in rats: histology and immunostaining. American Journal of Orthodontics and Dentofacial Orthopedics. 2009;**136**(6):770. e1-770.e11

[59] Sirisha K, Srinivas M, Ravindranath D. Wilckodontics-A Novel Synergy in Time to Save Time. Journal of Clinical and Diagnostic Research: JCDR. 2014;**8**(1):322

[60] Kole H. Surgical operations on the alveolar ridge to correct occlusal abnormalities. Oral Surgery, Oral Medicine. Oral Pathology. 1959;**12**(5):515-529

[61] Frost HM. The regional acceleratory phenomenon: a review. Henry Ford Hospital Medical Journal. 1983;**31**(1):3-9 Review

[62] Wilcko WM, Wilcko T, Bouquot JE, Ferguson DJ. Rapid orthodontics with alveolar reshaping: two case reports of decrowding. The International Journal of Periodontics & Restorative Dentistry. 2001;**21**(1):9-19

[63] Wilcko MT, Wilcko WM, Pulver JJ, Bissada NF, Bouquot JE. Accelerated Osteogenic Orthodontics Technique: A 1-Stage Surgically Facilitated Rapid Orthodontic Technique With Alveolar Augmentation. Journal of Oral and Maxillofacial Surgery. 2009;**67**(10):2149-2159

[64] Chung K. Text Book of Speedy Orthodontics. Jeesung: J Seoul; 2001

[65] Chung K, Kim S, Kook Y. Speedy surgical orthodontic treatment with skeletal anchorage in adults. In: Distraction Osteogenesis of the Facial Bones. BC Decker: Hamilton, Ontario, Canada; 2006. pp. 167-186

[66] Liou EJ, Huang CS. Rapid canine retraction through distraction of the periodontal ligament. American Journal of Orthodontics and Dentofacial Orthopedics. 1998;**114**(4):372-382

[67] Sukurica Y, Karaman A, Gurel HG, Dolanmaz D. Rapid canine distalization through segmental alveolar distraction osteogenesis. The Angle Orthodontist. 2007;**77**(2):226-236

[68] Kisnisci RS, Iseri H, Tuz HH, Altug AT. Dentoalveolar distraction osteogenesis for rapid orthodontic canine retraction. Journal of Oral and Maxillofacial Surgery. 2002;**60**(4):389-394

[69] Iseri H, Kisnisci R, Bzizi N, Tuz H. Rapid canine retraction and orthodontic treatment with dentoalveolar distraction osteogenesis. American Journal of Orthodontics and Dentofacial Orthopedics. 2005;**127**(5):533-541

[70] Alikhani M, Raptis M, Zoldan B, Sangsuwon C, Lee YB, Alyami B, et al. Effect of micro-osteoperforations on the rate of tooth movement. American Journal of Orthodontics and Dentofacial Orthopedics. 2013;**144**(5):639-648

[71] Keser EI, Dibart S. Sequential piezocision: a novel approach to accelerated orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics. 2013;**144**(6):879-889

[72] Vercellotti T, Podesta A. Orthodontic microsurgery: a new surgically guided technique for dental movement. The International Journal of Periodontics & Restorative Dentistry. 2007;**27**:4

[73] Kim S-J, Park Y-G, Kang S-G. Effects of corticision on paradental remodeling in orthodontic tooth movement. The Angle Orthodontist. 2009;**79**(2):284-291

[74] Dibart S, Sebaoun J, Surmenian J. Piezocision: a minimally invasive, periodontally accelerated orthodontic tooth movement procedure. Compendium of Continuing Education in Dentistry (Jamesburg, NJ: 1995). 2009;**30**(6) 342-4, 6, 8-50

[75] Dibart S, Keser E, Nelson D. Piezocision™-assisted orthodontics: Past, present, and future. Seminars in Orthodontics. 2015; **21**(3):170-175

[76] Dibart S, Yee C, Surmenian J, Sebaoun JD, Baloul S, Goguet-Surmenian E, et al. Tissue response during Piezocision-assisted tooth movement: a histological study in rats. European Journal of Orthodontics. 2013;**36**(4):457-464

[77] Aksakalli S, Calik B, Kara B, Ezirganli S. Accelerated tooth movement with piezocision and its periodontal-transversal effects in patients with Class II malocclusion. The Angle Orthodontist. 2015;**86**(1):59-65

[78] Ileri Z, Akin M, Erdur EA, Dagi HT, Findik D. Bacteremia after piezocision. American Journal of Orthodontics and Dentofacial Orthopedics. 2014;**146**(4):430-436

[79] Schaeren S, Jaquiéry C, Heberer M, Tolnay M, Vercellotti T, Martin I. Assessment of nerve damage using a novel ultrasonic device for bone cutting. Journal of Oral and Maxillofacial Surgery. 2008;**66**:593-596

[80] Torrella F, Pitarch J, Cabanes G, Anitua E. Ultrasonic ostectomy for the surgical approach of the maxillary sinus: a technical note. The International Journal of Oral & Maxillofacial Implants. 1998;**13**:1

[81] Pavlíková G, Foltán R, Horká M, Hanzelka T, Borunská H, Šedý J. Piezosurgery in oral and maxillofacial surgery. International Journal of Oral and Maxillofacial Surgery. 2011;**40**:451-457

[82] Sohn D-S, Ahn M-R, Lee W-H, Yeo D-S, Lim S-Y. Piezoelectric osteotomy for intraoral harvesting of bone blocks. The International Journal of Periodontics & Restorative Dentistry. 2007;**27**:127

[83] Walsh LJ. Piezosurgery: an increasing role in dental hard tissue surgery. Australasian Dental Practice. 2007;**18**:52-56

[84] Robiony M, Polini F, Costa F, Zerman N, Politi M. Ultrasonic bone cutting for surgically assisted rapid maxillary expansion (SARME) under local anaesthesia. International Journal of Oral and Maxillofacial Surgery. 2007;**36**:267-269