Hızlandırılmış Ortodontik Diş Hareketi: Genel Bir Bakış

Acceleration of Orthodontic Tooth Movement: An Overview

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Abstract

The purpose of orthodontic treatment is to enhance patients' life quality by improving their dentofacial functions and aesthetics. Minimal histological damage and pain, rapid tooth movement, short treatment duration, and stability of results are the major criteria for successful treatment. In recent years, the demand for orthodontic treatment has been increasing gradually. Prolonged duration of orthodontic treatment affects the psychological motivation of the patients and leads to several undesirable situations, such as caries, gingival recession, and root resorption. Thus, in recent years, related research has investigated the acceleration of orthodontic tooth movement. However, despite the various laboratory and clinical interventions designed to achieve faster tooth movement, uncertainties and unanswered questions about these techniques persist and warrant further investigation. Several surgical techniques as well as physical and chemical applications have been reported by previous studies to accelerate orthodontic tooth movement, most of which have been conducted on animals, with debatable applicability on humans. However, as tooth movement is a multifactorial phenomenon, further research is needed in the future. In this review, we describe the orthodontic tooth movement acceleration methods reported thus far.

Keywords: acceleration; orthodontic tooth movement

Öz

Ortodontik tedavinin amacı; bireyin dentofasiyal fonksiyonlarını ve estetiğini geliştirerek yaşam kalitesini artırmaktır. Başarılı bir tedavinin kriterleri; en az histolojik hasar ve ağrı, hızlı diş hareketi, kısa tedavi süresi ve stabil sonuçlardır. Son yıllarda ortodontik tedavi talebi giderek artmaktadır. Ortodontik tedavi sürelerinin uzun olması, hem hastaların psikolojik motivasyonlarını etkilemekte, hem de çürük, dişeti çekilmesi ve kök rezorpsiyonu gibi birçok istenmeyen duruma yol açmaktadır. Bu sebeple son yıllarda araştırıcılar ortodontik diş hareketinin hızlandırılması üzerine çalışmalar yapmaktadır. Ancak daha hızlı diş hareketi elde etmek için laboratuvar ve klinik olarak birçok girişimde bulunulmasına rağmen, bu tekniklerle ilgili belirsizlikler ve cevaplanmamış sorular halen mevcuttur. Literatürde ortodontik diş hareketini hızlandırmak amacıyla çoğu henüz hayvanlar üzerinde denenmiş ve insanlar üzerinde uygulanabilirliği kuşkulu olan cerrahi teknikler, fiziksel ve kimyasal uygulamalar bildirilmiştir. Ancak diş hareketi multifaktöriyel bir olgu olduğu için konu hakkında gelecekte daha fazla araştırma yapılması gerekmektedir. Bu derlemede literatürde şu anda var olan ortodontik diş hareketi hızlandırma yöntemlerinden bahsedilecektir.

Anahtar Sözcükler: hızlandırma; ortodontik diş hareketi

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INTRODUCTION

The purpose of orthodontic treatment is to increase the individuals' quality of life by improving their dentofacial functions and aesthetics. However, the estimated length of treatment using conventional orthodontics is 2–2.5 years. Prolonged treatment involves disadvantages, such as psychosocial effects on the patients, caries, gingival recession, and root resorption. Acceleration of orthodontic tooth movement (OTM) shortens the treatment duration and minimizes these adverse effects. Consequently, researchers have examined whether it is possible to move a tooth faster than achieved by using conventional methods. Orthodontic archwires and brackets have been used as alternatives. These biomechanical systems have certain limitations; therefore, new methods need to be developed to accelerate OTM.

Applications for accelerating OTM can generally be classified into the following three groups:

- Chemical applications
- Mechanical–physical applications
- Techniques using the advantage of "regional acceleration phenomena" (RAP) based on the biological response of the tissues

CHEMICAL APPLICATIONS

Prostaglandins

Prostaglandins (PGs) are a type of inflammatory mediator. PGs increase the osteoclastic activity and stimulate osteoblastic cell proliferation. Studies evaluating PGs' effects on OTM acceleration and root resorption have mostly been conducted on animals. In these studies, PGs have reportedly increased OTM speed 1.5–3 times on average without causing significant root resorption (1,2). New research is warranted for determining the application dose and frequency of PGs and the possible adverse effects of local application.

Vitamin D3

1,25 dihydroxychloecalciferol (1,25DHCC), one of the agents acting in OTM, is a biologically active form of vitamin D3. In addition to increasing the osteoclastic activity, it also provides osteoblastic cell differentiation. Vitamin D3 has been shown to accelerate OTM significantly in an animal study with no obvious adverse effects (3). However, to our knowledge, no study has investigated the effect of vitamin D3 injection on human OTM, necessitating further research.

Corticosteroids

Corticosteroids are steroid hormones synthesized in the adrenal cortex. Acute corticosteroid application has been shown to reduce bone turnover and increase root resorption in rats. Chronically administered corticosteroids have been reported to slow OTM (4). However, animal studies show contradictory results because of the lack of standardized protocols, such as the differences in the animals used in the related studies as well as the dosage and duration of drug administration.

Parathyroid Hormone

Parathyroid hormone (PTH) is a major hormone that regulates bone remodeling and calcium homeostasis. Soma et al. suggested that systemic continuous or local slow-release administration of PTH was applicable for orthodontic therapy, while systemic intermittent injection of PTH did not increase the OTM rate (5). By contrast, another study demonstrated that systemic intermittent PTH administration might help accelerate OTM (6). Local PTH application appears more advantageous than systemic application because it requires lower application doses, the movement at the same speed for each tooth during treatment is not desired (anchor teeth), and it has fewer adverse effects.

Leukotrienes

Leukotrienes are an arachidonic acid metabolite and formed by the metabolism of arachidonic acid with the lipoxygenase enzyme. These OTM mediators stimulate bone resorption. Leukotrienes reportedly accelerate OTM while leukotriene inhibitor drugs cause delay (7). Leukotrienes may have potential future clinical applications for enhancing OTM.

Osteocalcin

Osteocalcin is the most commonly found noncollagenous matrix protein in the bone. It is released from differential osteoblasts and helps maintain the alveolar bone matrix throughout bone remodeling (8). Histological findings indicate that osteocalcin increases the number of osteoclasts. OTM was accelerated by the effect of osteocalcin due to the enhancement of osteoclastogenesis on the pressure side (9). The effec-

tiveness of osteocalcin in mediating OTM acceleration needs further study.

Nitric Oxide

Nitric oxide (NO) is an important cellular messenger that plays a role in several physiological and pathological events in mammals (10). High NO doses reduce osteoclastic activity while low doses increase osteoclastogenesis and osteoclastic activity (11). NO has been shown to accelerate OTM with a marked increase in vascularization (10). However, further detailed studies are needed before initiating the clinical application of NO.

Relaxin

Relaxin is a hormone in the structure of the periodontal ligament (PDL). Relaxin increases collagenization on the pressure side and decreases it on the tension side (12). Relaxin application in rats has been observed to accelerate the early stages of OTM (13). By contrast, in another study, relaxin did not accelerate OTM, decreased the PDL organization level and mechanical resistance, and increased tooth mobility (14). Current evidence regarding the effect of relaxin on OTM acceleration is contradictory; therefore, the precise effect is unclear.

MECHANICAL–PHYSICAL APPLICATIONS

Electromagnetic Field

Electromagnetic field increases the level of a group of enzymes responsible for the regulation of intracellular metabolism, therefore, cellular proliferation by altering the rate of sodium-calcium exchange in the cell membrane. Histological studies have shown that alveolar bone remodeling increases not only the bone cell activity in the magnetic field, but also the formation of new bone in the stress zone (15). Both static and vibratory fields have been shown to accelerate OTM in animal studies (16,17). However, the available data are insufficient to fully examine the effects of electromagnetic field on the OTM rate.

Gene Therapy

Gene therapy (GT) was first suggested for curing a disease by replacing the defective gene with a healthy one in the 1990s (18). Transferring the RANKL gene to PDL has been shown to accelerate OTM without causing any systemic effect. Moreover, local OPG gene transfer reportedly inhibits OTM significantly (19–21). GT may be a new therapeutic method for accelerating or slowing OTM when administered locally. However, further work is needed to determine the reliability and effectiveness of this technique.

Laser Application

The effects of low-level lasers (LLL) on bone cellular activity, bone structures, bone healing, fibroblast activity, and inflammation process have already been investigated (22). Some studies have shown that LLL application does not accelerate or slow OTM (23,24) while other studies suggest just the opposite (25–27). The difference in the results can be explained by the wavelength, dose, location, and frequency of the laser. Laser is a noninvasive, painless, and practical procedure with no adverse effects. However, further studies are required for optimal application of lasers.

Electric current

Histological studies have shown that electric current leads to an increase in the number of osteoblasts owing to increased cellular activity in PDL (28). However, electric currents may involve certain complications, such as ionic reactions causing damage to the tissues and displacement of the bone connective tissue (29). Kim et al. suggested that the exogenous electric current from the electric device might accelerate OTM by one third (30). The current evidence about this is inadequate. Due to the reliability issue of this method, it does not seem applicable in humans at present.

Vibration

Vibrational force increases RANKL synthesis and osteoclast formation in PDL (31). Although the OTM rate increased with the vibrational force in some studies (32,33), the majority of the studies showed no clinical advantage of using the vibrational appliance (34,35).

Extracorporeal Shock Wave Therapy (ESWT)

ESWT is a treatment method for the application of high-level sound waves to the body that stimulates the expression of cytokines during OTM (36). ESWT has a regenerative ability with no obvious adverse effects in the oral cavity (37). These shock waves can be an effective therapy option for accelerating OTM. However, the required energy flow density, number of impulses, frequency, and pressure values for shock waves to create optimal biological effects are still unclear.

TECHNIQUES USING THE "RAP" ADVANTAGE BASED ON THE BIOLOGICAL RESPONSE OF THE TISSUES

Regional acceleratory phenomenon (RAP) can be defined as a local response that increases the regeneration speed of hard and soft tissues beyond the normal rates of regeneration and remodeling processes following a traumatic injury (38). Changes in the number of osteoclasts and osteoblasts in the presence of effective RAP exert osteopenic effects that are believed to mediate OTM acceleration.

Corticotomy

Surgical procedures to alleviate alveolar integrity and accelerate OTM have been tested for almost a hundred years. In 1959, Henrich Kole introduced the idea of corticotomy-assisted orthodontics. Kole believed that the greatest resistance of the cortical bone to OTM was its thickness and continuity and suggested that the formation of bony blocks would destroy the continuity of the cortical layer. Kole's procedure is based on interdental incisions on the buccal and lingual cortical bone without disturbing the integrity of the spongios portion. These incisions are combined with the horizontal osteotomies after the full thickness flaps are removed (39). This technique is highly invasive, and its routine application in dental clinics appears challenging for both the patient and the clinician.

Periodontally Accelerated Osteogenic Orthodontics (PAOO)

In 1995, Wilcko brothers suggested that the RAP could play a major role in corticotomy-assisted orthodontic treatment by observing the diminution of alveolar bone mineralization in the corticotomy area. Subsequently, Kole's idea relevant to bony blocks was replaced with the Wilcko brothers' idea of acceleration based on the RAP phenomenon. The Wilcko brothers have modified Kole's technique with alveolar augmentation. This technique, now known as "Wilckodontics," also known as "periodontally accelerated osteogenic orthodontics (PAOO)" or "alveolar osteogenic orthodontics," is a clinical procedure involving alveolar decortications with grafting of the bone combined with proper orthodontic force mechanics (40). The periodontal application creates increased turnover in the spongiosal areas of the bone, resulting in osteopenia (41). Researchers have suggested that the length of treatment with PAOO is 3–8 months (42). However, the technique is invasive and acceleration is observed only in the first 3–4 months; therefore, it cannot be used in routine clinical dental practice. In the light of the current literature, it is not yet possible for clinicians to routinely apply PAOO within their own facilities. Controlled clinical trials are needed to better understand the therapeutic and potential iatrogenic effects of the technique.

Dentoalveolar Distraction

Distraction osteogenesis was first used in the field of orthopedics at the beginning of the 1900s. Subsequently, the Russian orthopedic surgeon Gabriel Ilizarov developed the technique in the 1950s. Dentoalveolar distraction (DAD) involves the creation of monocortical perforations to the alveolar bone around the canines, followed by a movement of the teeth with the aid of distractors. In DAD, mesial, distal, and apical incisions are made to reduce the resistance between the canine and the surrounding bone. Kişnişçi et al. reported no anchorage loss in the second premolar and first molar teeth, root resorption, dental ankylosis, discoloration, or loss of vitality associated with DAD (43). This method for rapid OTM seems promising and feasible for use in clinical practice.

Periodontal (Dental) Distraction (PLD)

When a mechanical force is applied to a tooth, the periodontal ligament (PDL) is stretched (distracted) on the compression side and followed by alveolar bone formation (osteogenesis), on the tension side. The process of osteogenesis during OTM with PLD is similar to that in the distraction of midpalatal suture during rapid palatal expansion. The periodontal ligament is a "suture" between the alveolar bone and the tooth. This technique, developed by Liou and Huang (44) in 1998, is applied by using the same distraction technique as DAD, following the opening of the vertical grooves by scraping 1–1.5 mm on the mesial side of the sockets during the same visit. Researchers have revealed that the canine retracts to the first premolar socket about 6–7 mm at 3 weeks. The most important advantage of this technique is that it prevents anchorage loss in the posterior teeth. Researchers have attributed this to the completion of the canine retraction in a stalling period

wherein no OTM was observed for 2–3 weeks after the force was applied to the teeth (45,46). Both techniques (DAD–PDL) do not seem to lead to significant root resorption, ankylosis, root breakage, and anchorage loss. However, the vitalities of distalized canines remain unclear in the context of these techniques.

Corticision

The term "corticision" is a neologism that indicates "cortical bone incision." This technique was first proposed as a minimally invasive procedure that complements dentoalveolar surgery to provide accelerated OTM. In this technique, a reinforced scalpel is used as a thin chisel to separate the interproximal cortices transmucosally without reflecting a flap. Researchers have reported corticision as an accelerating method (47,48). Corticision with different force magnitudes, with or without mucoperiosteal flap, does not show any significant differences in terms of the OTM magnitude (49,50).

Piezoincision

The numerous surgical techniques used to accelerate OTM are highly invasive, and therefore unacceptable by the patient. Thus, research is ongoing to develop new methods. Dibart (2009) introduced the piezoincision technique, wherein grafting and microcutting with piezoelectric blades were combined to overcome the disadvantages of the corticotomy technique. A small vertical incision is made in the interproximal buccal area. The incision between the roots allows the piezoelectric blade to settle. At the areas requiring bone augmentation, tunneling is performed between the incisions to place the graft material. No suturing is required (51). The piezoincision has a localized and selective effect on the tooth; only the teeth to be moved are operated. Antibiotic medication is required in the previously mentioned surgical techniques.

Recently, researchers developed a novel method, "piezopuncture," which involve the creation of multiple cortical punctures through the overlying gingiva, with a piezotome. The technique has been found to evoke rapid tooth movement by accelerating the rate of alveolar bone remodeling (52).

Piezocision and piezopuncture are innovative, minimally invasive techniques for achieving rapid OTM. Although several case reports and few clinical trials have already been conducted on this subject, further studies are needed to expand the knowledge and establish recommendations for standard procedures.

Micro-osteoperforation (Alveocentesis)

The application of controlled microtrauma to the alveolar bone has been shown to increase the release of naturally released inflammatory markers during orthodontic treatment. This, in turn, accelerates the osteoclastic activity and increases the OTM rate. Teixeria et al. (2010) reported that performing superficial and limited perforations (micro-osteoperoperations [MOP]) on the buccal cortical bone portion of the maxilla of rats significantly increased the OTM rate (53). Subsequently, Alikhani et al. (54) reported that MOPs increased the rate of movement by 2.3 times compared to the unaffected tooth in humans. Creation of MOPs is similar to the placement of mini screws (55). The procedure is flapless. Perforations are made by inserting the mini screw at the desired depth between the tooth roots through both the labile and the attached mucosa. Perforations have to pass through the cortical bone to the medullary bone. MOPs differ from other OTM acceleration methods in its features, such as the application by clinicians themselves, repetition at desired intervals, and no requirement of medication after the procedure. However, further research is required to identify the application parameters (number, depth, and frequency) at which the MOPs will produce more effective results in humans.

CONCLUSION

Among all related studies, most research on chemical application has been conducted on animals, and the existing evidence does not reveal whether these are effective in accelerating OTM. Although PGs, PTH, and Vitamin D3 show positive outcomes, the evidence is not strong enough to justify the corticosteroid, osteocalcin, NO, leukotriene, and relaxin application. For chemicals, the possible systemic effects are the major safety concern during clinical application. Moreover, the majority of the chemicals have half-lives that require multiple applications, which is impractical. In addition, their long-term adverse effects are unknown.

Mechanical–physical applications also lack convincing evidence. Although LLL therapy appears unable to accelerate OTM, electric current, pulsed

electromagnetic fields, and mechanical vibrations are the developing noninvasive modalities. Due to the lack of standardized protocols, however, evidence-based conclusions cannot be made.

Limited evidence is available regarding the effectiveness of surgically accelerated orthodontics. Corticision and dentoalveolar–periodontal distraction show promising results. Although corticotomy and PAOO are very effective, they are invasive as well. Piezoincision–piezopuncture is a noninvasive method that offers various advantages in periodontal, aesthetic, and orthodontic aspects. Piezoincision–piezopuncture and micro-osteoperforation are considered the best surgical approaches because of their promising results in OTM acceleration and noninvasive nature; both techniques are flapless and safe.

Further clinical studies are warranted for identifying the best method to accelerate OTM, with due attention to the application protocols, adverse effects, and cost–benefit analysis and the inclusion of a higher number of patients and longer follow-up.

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