What every dentist and patient should know about accelerated orthodontic tooth movement

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Within the last few decades, an increasing number of adults have sought orthodontic therapy. One disadvantage of pursuing orthodontic treatment in adulthood is the lengthened time span required to complete tooth movement. The purpose of this article is to review the biologic mechanisms of accelerated tooth movement as well as the literature on nonsurgical and surgical techniques that may reduce the duration of orthodontic treatment.

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The number of adult patients seeking orthodontic treatment has increased in recent years, and adult patients are currently estimated to constitute 20%-25% of orthodontic patients.[1] This trend is likely to continue as adult patients are increasingly concerned about esthetics.

Comprehensive adult orthodontic treatment usually lasts 18-30 months.[1] Bone maturation, decreased mineral turnover, and patients' poor compliance with instructions for wearing orthodontic appliances can extend the length of treatment. This additional treatment time can be daunting to patients. In addition, lengthy orthodontic treatment time can predispose patients to caries, gingival recession, and root resorption. Therefore, methods for accelerated tooth movement are being investigated with renewed focus in an effort to reduce treatment time. The aim of this article is to review the concepts behind the biologic mechanisms of orthodontic tooth movement and to discuss the efficacy and efficiency of techniques currently employed to shorten the duration of therapy.

Biology of tooth movement

Orthodontics uses mechanical forces to move teeth, which are secured in alveolar bone, into the desired position. Work published by Albin Oppenheim in 1930, directly associating orthodontic tooth movement and bone remodeling, laid the groundwork for research to follow.[2] The classic theory of tooth movement (the pressure-tension model) suggests that movement is characterized by alteration of blood flow due to biomechanical pressures, production and release of chemical factors, and activation of osteoblasts and osteoclasts.[3] As the tooth is moved in one direction, an equal and opposite force is created, applying additional forces to the tissue within the tooth socket. The blood vessels, neural cells, and periodontal ligament (PDL) are stretched on one side of the tooth and compressed on the other side. Pressure applied to the tooth creates bone resorption on the pressure side, while bone growth can be found on the opposing side of the tooth. Additionally, the PDL releases cytokines, prostaglandins, and other chemical messengers; blood flow decreases where the PDL is compressed and maintained or increased where the PDL is under tension. Cytokines assist the tooth socket redesign by stimulating the release of other biologically active agents that promote cellular differentiation and activity.[3] Osteoclasts break down surrounding bone, activating the stimulation of new bone via osteoblasts.

The balance between resorption and new bone formation must be altered if the pace of tooth movement is to increase. Currently, several methods are used to accomplish this objective. One of the most successful methods of accelerating tooth movement is planned injury of cortical bone to promote early bone resorption that results in faster tooth movement.[4] The efficacy of intentional injury for this purpose has been attributed to a demineralization-remineralization process known as the *regional acceleratory phenomenon* (RAP).[5]

Regional acceleratory phenomenon

In 1981, Frost observed that surgical wounding of the bone could stimulate bone turnover and decrease bone density of the surgical site.[6] The occurrence of temporary osteopenia (less bone density within the same bone volume) facilitated rapid tooth movement, as the teeth moved in a more elastic and less rigid environment.[5] The RAP begins within a few days of the surgical procedure and attains its maximum effect at 1-2 months. In addition, the RAP is most influential where the noxious insult has occurred.[7] Areas that are proximal to surgical sites have been found to be relatively unaltered by the RAP response.[8] The RAP concept is critical because alveolar mineralization plays a fundamental role in tooth movement. Indeed, when there is greater mineralization of alveolar bone, tooth movement becomes more difficult.[9] Consequently, as there is a transition in bone density surrounding the tooth, there will be an increase in tooth movement.

Nonsurgical approaches to accelerated tooth movement

Drugs

Several research studies have focused on the effects of different drugs on the rate of tooth movement. Bartzela et al reported that administration of bisphosphonates had a strong inhibitory effect on the rate of orthodontic tooth movement; eicosanoids resulted in increased tooth movement, and their inhibition led to a decline in tooth movement.[10] From this investigation, it was also concluded that the administration of nonsteroidal anti-inflammatory drugs (NSAIDs) abated tooth movement, but non-NSAID medications, such as acetaminophen, had no effect. Corticosteroid hormones, parathyroid hormone, thyroxine, and vitamin D_3 all increased tooth movement, whereas estrogens and dietary calcium seemed to reduce it.[10] More research is needed to investigate the safety of drug therapy in orthodontic tooth movement, as all drug therapies may present some unwanted side effects.

Mechanical stimulation

Low-level laser therapy

Saito & Shimizu investigated the effects of low-power laser irradiation (often called *low-level laser therapy* [LLLT]) on bone regeneration in the midpalatal suture during maxillary expansion in rats.[11] Their findings indicated accelerated bone regeneration during rapid palatal expansion and promotion of synthesis of collagen. Cruz et al studied the effect of LLLT on orthodontic tooth movement in human subjects and reported that irradiated canine teeth were retracted 34% faster than control canines over a period of 2 months.[12] Kim et al reported that immediately after application of LLLT, using a gallium-aluminum-arsenide laser at a wavelength of 808 nm and an output power of 96 mw, levels of fibronectin and type I collagen increased and remained elevated until the end of the experiment.[13] They concluded that application of LLLT expedited the turnover of connective tissue during tooth movement.

Doshi-Mehta & Bhad-Patil investigated the effects of LLLT on canine distalization in a split-mouth design.[14] A semiconductor gallium-aluminum-arsenide diode laser emitted infrared radiation with a wavelength of 808 ± 10 nm for 10 seconds. This radiation was applied to the buccal and palatal surfaces of the canine tooth, which was distalized after first premolar extractions. They reported that the canine tooth on the side treated with LLLT was distalized 29% faster than the canine on the control side in the maxillary arch.[14]

Vibration device

AcceleDent Optima (OrthoAccel) is the latest generation of a US Food and Drug Administration–cleared, Class II medical device that delivers pulsatile forces to the teeth and is claimed to accelerate tooth movement. In 2008, Nishimura et al measured the effects of vibration forces on tooth movement in rats.[15] Vibration at a frequency of 60 Hz was applied to molar teeth undergoing "standard orthodontics" to achieve buccal movement. At the end of the 21-day experiment, Nishimura et al reported that increased tooth movement and diminished root resorption could be achieved within the vibration group when compared to the static-force group.[15]

Kau et al used an AcceleDent prototype in 14 patients and reported 3.0 mm per month of tooth movement in the maxillary arch and 2.1 mm per month in the mandibular arch.[16] In another clinical study, Bowman used AcceleDent during initial leveling and aligning of the teeth of 30 adult subjects with Class II malocclusion who were undergoing nonextraction orthodontic treatment.[17] He observed a 30% reduction in treatment time compared to 2 control groups. Based on 5 years' clinical experience, Orton-Gibbs & Kim stated that "…successful incorporation of AcceleDent into an orthodontic practice could significantly reduce treatment time…"[18]

The data supporting the use of AcceleDent and its effectiveness in orthodontic tooth movement are based mainly on clinical case reports. Further studies and well-designed randomized controlled trials are needed to better understand the true effects of pulsatile forces on the rate of orthodontic tooth movement.

Surgical approaches to accelerated tooth movement

It has long been known that surgical wounding of bone increases bone turnover and decreases bone density surrounding the surgical site.[6] As Köle proposed in 1959, interdental corticotomies could be used to reposition the tooth orthodontically.[9] Several surgical techniques to increase efficiency of tooth movement and decrease treatment time—including corticotomy, periodontal surgery, distraction osteogenesis, piezocision, and micro-osteoperforation—are being investigated.

Corticotomy-assisted orthodontics

Corticotomy-assisted orthodontic treatment is an adjunct procedure for the orthodontic treatment of adult patients.[19] In this approach, the practitioner selectively performs alveolar decortication in linear formation and marks the tooth intended to move. Corticotomy induces a transient inflammatory response that results in increased bone turnover, which is followed by a faster rate of tooth movement and reduced treatment time.[19]

Vercellotti & Podesta reported a significant 60%-70% reduction of orthodontic treatment time after corticotomies were performed with a piezosurgical microsaw.[20] However, due to the small size of the device and precision of the technique, a buccal periodontal flap was still required, yielding little reduction in surgical time or postoperative discomfort.

To examine differential orthodontic tooth movement in mature male foxhounds, Sanjideh et al investigated the combined effect of performing corticotomies simultaneously with tooth extractions as well as the effect of performing a second corticotomy after 4 weeks.[21] The researchers found that the rate of tooth movement in the corticotomy/appliance group was greater until day 22 and then progressively declined. When tooth movement reached peak velocity, the rate of tooth movement was 85% faster than the movement in the control group (orthodontic appliances without corticotomy). Furthermore, the group that received a second corticotomy showed greater tooth movement than did the group with a single corticotomy. Sanjideh et al concluded that alveolar corticotomy significantly enhanced tooth movement when orthodontic forces were applied.[21] However, a follow-up surgery was not found to add significant improvements to the tooth movement achieved from the initial surgery.

In a recent systematic review, Hassan et al concluded that corticotomy is a safe and effective method for accelerated orthodontic tooth movement.[22] They also reported that corticotomy-assisted orthodontic treatment "...accelerates space closure, traction of palatally impacted canines, and resolves crowding of incisors by 2-2.5 fold when compared to conventional orthodontic tooth movement."

Reports suggesting that tooth movement rates in human subjects are accelerated by corticotomies have been based primarily on clinical case studies.[23-25] Well-designed randomized control trials are warranted. Overall, corticotomies appear to be effective in accelerating tooth movement; however, these procedures are invasive and cause significant postoperative discomfort to patients, so patients and practitioners are reluctant to use this approach.[26]

Periodontally accelerated osteogenic orthodontics

Periodontally accelerated osteogenic orthodontics (also known as *Wilckodontics*) is claimed to enhance bone remodeling, accelerate tooth movement, and reduce the duration of treatment.[27] Wilcko & Wilcko stated that corticotomy provides an increase in tooth movement when the RAP and osseous tissue augmentation are coupled.[27] Therefore, if the osseous tissue is thinned adequately in the direction of the desired movement of the teeth, a premolar extraction space can be closed in approximately 6-8 weeks with lighter forces and 3-4 weeks with stronger orthopedic forces.[28]

Mathews & Kokich argued that periodontally accelerated osteogenic orthodontics requires additional bone surgery and periosteal flaps to support bone graft elements.[26] The supplementary releasing of the periosteum has the potential to increase the postoperative discomfort of the patient.

Distraction osteogenesis

Osteotomy, first described by Codivilla in 1905, was refined by Ilizarov in 1988.[29,30] In the Ilizarov technique, bony segments are completely resected and placed in ideal healing conditions to promote the development of normal architecture. In 2000, Liou et al proposed the use of distraction osteogenesis as an orthodontic tooth movement accelerator.[31] In their technique, cortical bone was separated, in 0.5- to 1.0-mm increments, from the teeth to be moved, and a bone distractor was screwed to both sides of the alveolar bone to move the bony segment. The first week after activation of the device was the latency period; after that, the distractor could be activated 1.0 mm/d.[31]

In 2008, Lee et al investigated the rate of tooth movement in corticotomy and distraction osteogenesis groups and reported that tooth movement was faster in the distraction osteogenesis group, although the difference was not statistically significant.[32] In 3 separate human trials with limited numbers of patients, Işeri et al, Kumar et al, and Kharkar & Kotrashetti performed distraction osteogenesis to accelerate canine retraction in extraction cases.[33-35] Işeri et al reported 50% faster movement; full canine retraction was achieved in 8-14 days.[33] Kumar et al reported that canine retraction was completed in 20 days, and Kharkar & Kotrashetti noted completion in 12 days.[34,35] None of these investigators reported the occurrence of pulpal damage caused by stretching of the blood vessels; gingival damage; or root resorption.

Reportedly, distraction osteogenesis could lead to long-term side effects such as molar extrusion, anchorage loss, mesial tipping of the canine due to resistance of the interseptal bone, and pulpal damage.[33] These problems have not been fully investigated and need to be examined further.

Piezocision

Piezocision is a minimally invasive technique that, unlike corticotomy, does not require surgical flaps. A piezoelectric knife is used instead of a bur; it is claimed that the vibrations of the knife could accelerate tooth movement.[4] Although piezocision is a less aggressive method than corticotomy, the underlying biologic response is believed to be the same (RAP).[4]

In a study in dogs, Kim et al reported a 3.26-fold increase in orthodontic tooth movement in the maxilla and a 2.45-fold increase in orthodontic tooth movement in the mandible when flapless piezocision, or cortical perforation through the soft tissues, was performed.[36] Dibart et al reported that piezocision increased the rate of tooth movement in rats to more than twice that in the control group (tooth movement alone).[4] After 28 days, 0.6 mm of tooth movement was achieved in the piezocision group compared to 0.25 mm in the control group.

Unfortunately, there is a lack of human trials investigating the effect of piezocision on orthodontic tooth movement; therefore, these results should be interpreted cautiously.

Flapless micro-osteoperforation of the cortical bone

Another less invasive alternative designed to accelerate tooth movement is micro-osteoperforation of cortical bone. In the micro-osteoperforation procedure, limited and shallow perforations of the buccal cortical plates are performed. Teixeira et al investigated cytokine expression and tooth movement after creating shallow perforations of approximately 0.25 mm in diameter and 0.25 mm in depth in adult Sprague-Dawley rats.[37] This study described how minor trauma to the cortical plate induced a physiologic response in the experimental group, leading to increased bone activity. The authors also found that the rate of tooth movement was significantly greater in the experimental group than in the control group. Teixeira et al concluded that limited, shallow perforations of the buccal cortical plate can accelerate bone remodeling and lead to an increased rate of tooth movement.[37] A major advantage of this less invasive method to improve the rate of tooth movement is that it requires no elevation of a periodontal flap.

In 2013, Alikhani et al reported that small perforations in the bone surrounding the tooth would allow it to be moved at an increased pace.[38] In a recent study performed to investigate the effects of both flapless micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats, Tsai et al observed no differences between these 2 minimally invasive, flapless procedures.[39] They reported that both flapless surgical techniques increased osteoclastic activity and bone remodeling, which showed increased tooth movement over a short period of time in rats.

Conclusion

In an attempt to reduce treatment time and maintain efficacy of orthodontic therapy in adults, surgical and nonsurgical approaches to accelerating orthodontic tooth movement are continually evolving. Although the concept of accelerated tooth movement is a positive development in orthodontic therapy, the available techniques have been shown to have varied effects on tooth movement. Therefore, clinicians should thoroughly consider all options when introducing any accelerated tooth movement method.

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