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Review

The Efficacy and Modes of Accelerating Orthodontic Tooth Movement

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Abstract

Orthodontic treatment, while highly advantageous for correcting dental misalignments and enhancing oral health, typically demands a substantial time commitment. To reduce treatment duration and improve various aspects of the orthodontic process, accelerated methods for tooth movement have been explored. These methods aim to offer benefits such as decreased discomfort, enhanced patient compliance, and overall treatment efficiency. This study undertakes a review of existing literature, aiming to comprehensively assess the current evidence on accelerated orthodontic tooth movement. The review encompasses various acceleration techniques, including high-frequency vibration, micro-osteoperforations, Photobiomodulation, corticotomy-assisted orthodontics, and advancements in appliance technology. While some interventions demonstrate accelerated tooth movement and enhanced patient comfort, the field calls for further research, particularly in the form of large-scale clinical trials, to establish long-term efficacy, safety, and applicability across diverse orthodontic cases. This review offers valuable insights into the evolving landscape of orthodontics, emphasizing the need for evidence-based approaches and ongoing innovation to optimize patient outcomes and experiences in orthodontic care.

Keywords: *Orthodontics, accelerated tooth movement, efficacy, treatment*

Introduction

Orthodontic tooth movement is the controlled displacement of teeth to achieve proper alignment and improve the overall function and aesthetics of the oral cavity. Orthodontic tooth movement aims to reposition teeth within the dental arch, which are misaligned due to multiple factors such as genetics, dental development issues, and environmental influences (1). Usually, orthodontic tooth movement is either conventional or physiological. Conventional orthodontic tooth movement induces bone resorption on the side where pressure is built, with contrary bone deposition on the other side promoting the complete movement of the tooth in one direction. This tooth movement is primarily caused by a combination of mechanical forces and biological cascades of bone resorption and deposition. On the other hand, physiological tooth movement refers to slight tipping or minimal changes in the position of the tooth during the tooth eruption phase (2).

Orthodontic tooth movement is ideally considered during the treatment and management of occlusion-related issues such as crowding, spacing between teeth, and misalignment. Additionally, tooth movements are also beneficial for the correction of bite irregularities such as overbite, underbite, crossbite, and open bite. Furthermore, orthodontists prefer tooth movement as a way of making space for the treatment of functional issues such as temporomandibular joint disorders, and speech or chewing difficulties. Aesthetic concerns like smile aesthetics and facial harmony can also be improved through orthodontic tooth movement (3). While orthodontic treatment is highly beneficial in correcting dental misalignments and improving oral health, the complete treatment plan typically requires a significant time commitment. The duration varies based on the complexity of the case and the chosen orthodontic method. Some patients may find the extended treatment period to be a drawback, especially if they were hoping for a quicker resolution (4). Also, due to the prolonged time duration of the treatment, other issues such as discomfort, oral hygiene challenges, and dietary restrictions continue, which can be stressful for the patient (5).

To solve this issue, shortening orthodontic treatment duration by accelerating tooth movement has been explored since the 1890s (6). Accelerated methods for orthodontic tooth movement seek to reduce this treatment time, offering potential benefits such as decreased discomfort, improved patient compliance, and enhanced overall treatment efficiency (7). Also, accelerated tooth movement is most beneficial for adults since they have passed their growth spurt and their tissue metabolism is much slower than the younger patients. They are also more susceptible to periodontal issues, so accelerated treatment is the best course of action for them (8). Generally, the rate of orthodontic tooth movement is estimated through the surrounding root response and tissue remodeling. Similar molecular mechanisms are also responsible for the regulation of cell proliferation and apoptosis in alveolar bone as well as periodontal ligaments (9). Various surgical and non-surgical techniques are used to accelerate tooth movement for orthodontic treatment, which alter or enhance the cell activity of osteoclasts, osteocytes, and osteoblasts (8).

The current study aims to conduct a comprehensive review of the efficacy and modes of accelerating orthodontic tooth movement, recognizing the growing interest in reducing treatment duration and improving patient experience. The rationale behind this study lies in addressing the evolving landscape of orthodontics, where patients and practitioners alike seek innovative approaches to enhance treatment efficiency while maintaining safety and efficacy. By reviewing the existing literature, this study seeks to consolidate and critically evaluate the current evidence surrounding accelerated orthodontic tooth movement. The review will delve into various acceleration techniques, including high-frequency vibration, micro-osteoperforations, photobiomodulation, corticotomy-assisted orthodontics, and advancements in appliance technology. Through a rigorous examination of these methods, the study aims to provide a nuanced understanding of their effectiveness, potential drawbacks, and implications for orthodontic

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practice. Ultimately, this research contributes to the ongoing discourse in orthodontics, informing clinicians, researchers, and patients about the state of knowledge regarding accelerated tooth movement and guiding future directions for improving orthodontic treatment modalities.

Methods

Commencing on December 4th, 2023, this research was instigated following a meticulous examination of existing literature. Diverse databases, such as PubMed, Web of Science, and Cochrane, were utilized in the comprehensive literature review. The search strategy involved employing various combinations of medical terminology, and manual searches on Google Scholar were conducted to identify relevant research terms. The primary emphasis of this literature review encompassed crucial elements, notably the methods of accelerating tooth movement such as mechanical methods, pharmacological strategies, and customized orthodontic appliances, and their efficacy concerning long-term patient outcomes. It is imperative to underscore that the selection of articles for inclusion in this study adhered to multiple criteria, ensuring a thorough and robust review process.

Discussion

Several methods and technologies have been explored to enhance the efficiency of orthodontic tooth movement. These interventions can be broadly divided into three categories: mechanical methods, pharmacological approaches, and innovative orthodontic appliances. Although these technologies have been explored by researchers for a long time, many of them are still under critical scrutiny for their efficacy and potential risks.

Mechanical methods

High-frequency Vibration (HFV)

HFV is a technique employed in orthodontics to accelerate the movement of teeth during treatment. As illustrated in (**Figure 1)**, this method involves the use of devices that deliver vibrational forces to the teeth and surrounding bone structures (10). The rationale behind high-frequency vibration lies in its potential to enhance bone remodeling, which, in turn, facilitates the repositioning of teeth. Devices such as AcceleDent and Propel use high-frequency vibrations to stimulate bone remodeling, potentially accelerating tooth movement. HFV devices typically consist of a mouthpiece that patients can use daily for a specified duration. The vibrational forces generated by these devices are transmitted through the teeth and surrounding tissues. The biological response to these vibrations involves an increase in cellular activity, particularly in the bone remodeling process (11). The mechanical signals generated by HFV may stimulate osteoblasts and osteoclasts, the cells responsible for bone formation and resorption, respectively. This heightened bone turnover is believed to create a more conducive environment for accelerated tooth movement (12). Several studies have shown promising results from the induction of HFV in orthodontic tooth movement. The initial study conducted on HFV devices in 2010 suggested that the use of these vibrations improved and accelerated the rate of tooth movement after using this device. Moreover, patient compliance was recorded to be 67%, considering the high acceptance and compliance rate (13). Another study that estimated the PDL response to HFV supported the evidence of an increase in PDL activity after the induction of HFV (14).

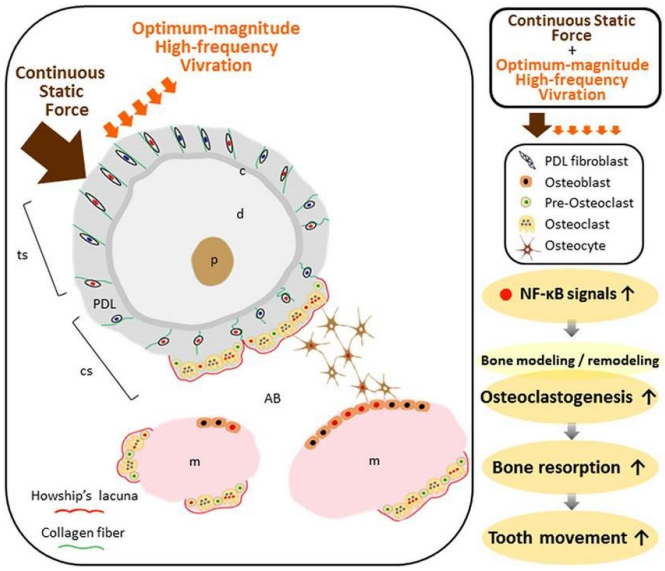

Figure 1: High frequency vibration for accelerated orthodontic tooth movement (43)

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Despite these positive findings, several clinical trials and systematic reviews reported that no significant difference was observed in the tooth movement between the groups that received vibrations and those that did not (11). Due to the mixed reports from the evidence, further studies and clinical trials of high quality are recommended for HFV (10, 15).

Micro-osteo perforations (MOPs)

This technique involves the creation of small perforations or micro-fractures in the cortical bone that surrounds the teeth. The underlying principle of MOPs is to induce a controlled inflammatory response in the bone, which, in turn, enhances the rate of tooth movement by stimulating localized bone remodeling (16). Micro-perforations trigger the osteoclasts and osteoblasts, heightening bone turnover, which in turn creates a dynamic environment for tooth movement in the desired direction. This procedure was deemed highly effective since it showed an increased rate of tooth movement along with a rise in inflammatory markers within the periodontal tissues (17). The rate of tooth movement increased by more than 2-fold in most of the studies (17, 18). Additionally, the procedure was considered minimally invasive, and negligible pain and discomfort were reported by all the patients (19). Furthermore, the procedure was also found to be technically simple, as well as time and cost-effective (17).

Higher levels of root resorption were observed in one of the research studies, and hence additional studies and clinical trials are recommended to highlight the complete extent of biological changes due to MOPs (20, 21).

Photobiomodulation (PBM)

PBM is an emerging technique in orthodontics that involves the use of light to stimulate biological processes and potentially accelerate tooth movement during orthodontic treatment. As shown in (**Figure 2)**, PBM utilizes low-level light, typically in the red or near-infrared spectrum, to target tissues in the oral cavity (22). The light energy is absorbed by cellular structures, particularly mitochondria, leading to increased production of adenosine triphosphate (ATP), the energy currency of cells. This heightened cellular activity is believed to promote various physiological effects, including accelerated tissue repair, reduced inflammation, and modulation of cellular functions (23).

Figure 2: Photobiomodulation for accelerated orthodontic tooth movement (44)

The existing systematic reviews present varied findings on the efficacy of Photobiomodulation therapy (PBMT) in accelerating orthodontic tooth movement (OTM). While some studies suggest a potential benefit, highlighting positive results such as increased tooth movement rates and reduced treatment durations (24), others report inconclusive or negative outcomes (25, 26). Specific standardized characteristics of laser settings and methodological designs need further validation in larger trials to establish PBMT's reliability in routine clinical practice. The analysis across studies emphasizes the importance of addressing heterogeneity, refining parameters, and conducting more rigorous research designs to enhance the consistency and predictability of laser and LED therapy in orthodontics (22). Despite some positive effects observed in tooth movement rates, the overall evidence remains inconclusive, calling for more large-sample multicenter clinical trials to determine optimal parameters and treatment efficiency in human orthodontic practices (27, 28).

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Corticotomy

Corticotomy-assisted orthodontic treatment is an innovative approach aimed at accelerating the movement of teeth during orthodontic procedures. This technique involves a surgical procedure where controlled cuts or corticotomies are made in the cortical bone that surrounds the teeth (**Figure 3**). The goal is to create localized areas of increased bone turnover, allowing for faster tooth movement (29). Corticotomy-assisted orthodontics is often used in conjunction with traditional orthodontic methods to enhance the overall efficiency of the treatment.

Figure 3: Corticotomy for accelerated orthodontic tooth movement (45)

The available literature collectively suggests that corticotomy-assisted orthodontic treatment has the potential to significantly accelerate the rate of tooth movement. Experimental evidence, particularly in canine models, indicates a doubling of tooth movement compared to orthodontic forces, with effects lasting up to 1-2 months. However, the translation of these findings to humans may be limited to 2-3 months, resulting in an expected 4-6 mm of tooth movement. Despite the observed acceleration, routine corticotomies in private practices may not be justified based on current literature, highlighting the need for controlled clinical studies to better understand the treatment and any potential iatrogenic effects (30). Nevertheless, other studies demonstrate a statistically meaningful increase in the rate of tooth movement with corticotomy techniques, and while some reported temporary acceleration, there were no apparent adverse effects on the periodontium, root resorption, or tooth vitality (31). One study specifically concludes that buccal corticotomy is a valuable adjunct technique, accelerating orthodontic tooth movement approximately two times faster than conventional orthodontics, particularly in the early stages after the surgical procedure (32). Overall, while corticotomy-assisted orthodontics shows promise in expediting tooth movement, careful consideration and further controlled clinical research are necessary to establish its broader applicability and long-term effects.

Pharmacological approaches

Local injections

Several studies have explored the administration of substances, including corticosteroids and prostaglandins, through local injection into the periodontal ligament to augment the rate of tooth movement. This approach involves the targeted delivery of these pharmacological agents to the specific area around the tooth undergoing orthodontic treatment. The rationale is to leverage the biological effects of corticosteroids or prostaglandins to modulate the local cellular responses in the periodontal ligament, potentially facilitating and accelerating the process of tooth movement (33).

In the first study, it was found that the local injection of prostaglandins (PGE2) during an orthodontic procedure did not result in a significant difference in root resorption. However, it was observed that a slightly higher incidence of root resorption in the teeth was present where PGE2 injections were administered (34). On the contrary, another study highlighted that the rate of distal canine movement was approximately 1.6 times higher on the side where PGE1 injections were administered as compared to the side where a placebo was injected. Except for minor pain, no changes in the surrounding periodontal tissues were observed (35). While the use of these substances for accelerated tooth movement has been investigated, it is essential to note that their efficacy, safety, and optimal application methods continue to be subjects of ongoing research and evaluation within the field of orthodontics.

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Systemic medications

Certain medications, such as bisphosphonates or selective serotonin reuptake inhibitors (SSRIs), have been explored for their potential to modulate bone remodeling and influence the rate of tooth movement. Bisphosphonates, commonly employed to treat conditions like osteoporosis, have exhibited effects on bone remodeling. Similarly, SSRIs, primarily used as antidepressants, have been studied for their potential to modulate bone metabolism. The rationale is based on the understanding that these medications may affect the bone remodeling process, potentially influencing the efficiency of orthodontic treatment.

Several studies have explored the impact of these medications on orthodontic tooth movement. A study suggests that Bisphosphonate therapy may prolong the duration of orthodontic treatment due to its interference with osteoclastic resorption, although potential benefits for anchorage procedures have been identified (36). Another study focused on the bisphosphonate-burdened alveolar bone, revealing that selective alveolar decortication can accelerate tooth movement in a shorter time duration (37). Regarding SSRIs, conflicting findings exist in the literature. While some studies suggest no significant effects on bone resorption and tooth movement, others report greater bone regeneration or reduced bone loss in some situations (38). However, it is crucial to note that the use of systemic medications for accelerating tooth movement is still in the investigational stage, and further research is needed to establish their safety, efficacy, and optimal application in orthodontic practice. Additionally, potential side effects and long-term consequences must be thoroughly assessed before considering the integration of systemic medications into routine orthodontic treatment protocols.

Innovative Orthodontic Appliances

Customized orthodontic appliances represent an innovative approach in orthodontics designed to potentially accelerate tooth movement while addressing individual patient needs. These appliances are tailor-made based on the patient's specific dental anatomy, providing a personalized and precise treatment strategy (39). Customization involves the use of advanced technologies such as digital impressions, computer-aided design (CAD), and three-dimensional printing. The key features of customized orthodontic appliances include individually designed brackets and archwires that consider the unique characteristics of each tooth and the overall treatment plan. By optimizing the fit and configuration of these components, customized appliances aim to reduce friction and resistance during tooth movement, potentially enhancing the efficiency of orthodontic treatment (40).

While research on the effectiveness of customized orthodontic appliances for accelerating tooth movement is still evolving, early findings suggest promising results. These appliances have the potential to offer a more tailored and efficient treatment approach, contributing to reduced treatment times and improved patient outcomes (41). However, continued research and clinical validation are essential to establish the long-term efficacy, safety, and widespread adoption of customized orthodontic appliances in routine orthodontic practice.

Smart archwires in orthodontics represent an advanced technological approach aimed at potentially accelerating tooth movement and improving the overall efficiency of orthodontic treatment. Unlike traditional archwires, smart archwires are designed with materials that can change in response to specific stimuli, such as temperature or pressure. These archwires can exhibit properties like shape memory or super elasticity, allowing them to exert continuous, controlled forces on the teeth over time (39). The ability of smart archwires to adapt to the changing conditions within the oral environment may contribute to optimized tooth movement. One of the key advantages of smart archwires is their potential to reduce the need for frequent adjustments during orthodontic treatment. Their adaptive nature allows for continuous, gentle forces on the teeth, which may contribute to a more consistent and controlled tooth movement process (42). Additionally, the use of smart materials in archwires may result in

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improved patient comfort and reduced treatment times (41).

While the concept of smart archwires holds promise for accelerating tooth movement, further research and clinical validation are necessary to establish their long-term efficacy, safety, and applicability across various orthodontic cases. Additionally, the integration of smart archwires into routine orthodontic practice would require careful consideration of patient-specific factors, treatment goals, and overall treatment plans. As the field of orthodontics continues to embrace technological advancements, smart archwires represent an exciting avenue for enhancing the precision and efficiency of tooth movement during orthodontic treatment.

Conclusion

In conclusion, the quest for accelerating tooth movement in orthodontics has spurred the exploration of various innovative approaches and technologies. From high-frequency vibration and micro-osteoperforations to Photobiomodulation and systemic medications, researchers are continuously investigating novel methods to optimize the efficiency of orthodontic treatment. While some approaches show promise, it is crucial to acknowledge the ongoing need for rigorous research, validation through large-scale clinical trials, and careful consideration of potential side effects and long-term outcomes.

Disclosure

Conflict of interest

There is no conflict of interest.

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Ethical consideration

Non applicable

Data availability

Data that support the findings of this study are embedded within the manuscript.

Author contribution

All authors contributed to conceptualizing, data drafting, collection and final writing of the manuscript.

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