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Methods of Accelerated Orthodontic Tooth Movement - A Review Article

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ABSTRACT

Orthodontic treatment is widely used to correct malocclusion and improve both functional and aesthetic aspects of dentofacial structures. However, the prolonged duration of conventional orthodontic therapy often leads to decreased patient compliance, increased risk of dental complications, and higher treatment costs. In recent years, significant attention has been directed toward methods that can accelerate orthodontic tooth movement (AOTM) while maintaining safety and treatment effectiveness. This review article aims to explore the various contemporary techniques developed to enhance the rate of orthodontic tooth movement and to analyze their mechanisms, clinical applications, advantages, and limitations.

Accelerated orthodontic tooth movement is primarily based on biological, surgical, and physical stimulation approaches that influence bone remodeling and periodontal ligament response. The theoretical framework of these techniques is largely explained through the Regional Acceleratory Phenomenon (RAP), which enhances bone turnover and reduces bone density temporarily, allowing teeth to move more rapidly within the alveolar bone. Surgical techniques such as corticotomy, piezocision, and micro-osteoperforation stimulate localized bone remodeling. Non-surgical approaches include mechanical vibration, photobiomodulation (low-level laser therapy), pharmacological agents, and customized orthodontic appliances designed to optimize force delivery.

Surgical methods like corticotomy-assisted orthodontics involve selective alveolar bone decortication to stimulate RAP, significantly reducing treatment time. Minimally invasive techniques such as piezocision and micro-osteoperforation provide similar biological stimulation with reduced surgical trauma and faster recovery. Physical stimulation methods, including low-level laser therapy, electrical stimulation, and vibrational devices, aim to accelerate bone metabolism and enhance cellular activity within periodontal tissues. Additionally, pharmacological interventions involving prostaglandins, vitamin D, and parathyroid hormone have been investigated for their role in stimulating osteoclastic activity and bone remodeling.

The significance of accelerated orthodontic tooth movement lies in its potential to transform orthodontic practice by improving patient satisfaction, reducing treatment duration, and minimizing the risks associated with prolonged appliance therapy, such as root resorption, enamel decalcification, and periodontal issues. Despite these promising benefits, several limitations remain. Surgical procedures may involve higher costs, postoperative discomfort, and require specialized clinical expertise. Non-surgical techniques, although less invasive, often show variable outcomes and may require repeated applications or specialized devices.

In conclusion, multiple approaches for accelerating orthodontic tooth movement have been developed, each with distinct mechanisms, benefits, and limitations. Surgical methods currently provide the most predictable results, while emerging non-invasive techniques continue to evolve with advancements in biomedical technology. Future research should focus on standardized clinical protocols, long-term safety evaluations, and the integration of biological and technological innovations to achieve faster, safer, and more efficient orthodontic treatments.

Keywords: Accelerated Orthodontics, Corticotomy, Piezocision, Micro-osteoperforation, Orthodontic Tooth Movement.

INTRODUCTION

Orthodontic treatment plays a crucial role in correcting malocclusion, improving dental aesthetics, and enhancing oral function. Traditional orthodontic therapy relies on the application of controlled mechanical forces to move teeth through the alveolar bone. Although effective, conventional orthodontic treatment often requires a long duration, typically ranging from 18 to 24 months or even longer in complex cases. The extended treatment time can lead to several challenges, including reduced patient compliance, increased risk of dental caries, gingival inflammation, root resorption, and enamel decalcification.

As a result, both clinicians and patients have shown increasing interest in methods that can safely accelerate orthodontic tooth movement.

Orthodontic tooth movement is a biological process that involves remodeling of the periodontal ligament and surrounding alveolar bone in response to applied orthodontic forces. When force is applied to a tooth, compression occurs on one side of the periodontal ligament while tension develops on the opposite side. This process stimulates osteoclastic activity on the pressure side, leading to bone resorption, and osteoblastic activity on the tension side, resulting in bone formation. The balance between these biological responses determines the rate at which teeth move during orthodontic treatment.

In recent years, advances in orthodontic research have led to the development of several techniques aimed at accelerating tooth movement by enhancing the biological processes involved in bone remodeling. These approaches can generally be classified into three main categories: surgical methods, physical or mechanical stimulation techniques, and pharmacological interventions. Surgical methods, such as corticotomy-assisted orthodontics, piezocision, and micro-osteoperforation, aim to stimulate the regional acceleratory phenomenon (RAP), a localized increase in bone turnover that facilitates faster tooth movement. Physical stimulation techniques, including low-level laser therapy, vibrational devices, and electrical stimulation, are designed to enhance cellular activity within the periodontal ligament and surrounding bone. Pharmacological agents such as prostaglandins, vitamin D metabolites, and parathyroid hormone have also been explored for their potential to stimulate osteoclastic activity and accelerate bone remodeling.

The growing demand for shorter orthodontic treatment times has further encouraged the exploration of minimally invasive and patient-friendly techniques that can achieve effective results without compromising safety or treatment outcomes. Advances in biomedical technology and clinical research have provided orthodontists with a variety of innovative tools and strategies to facilitate accelerated orthodontic tooth movement.

Therefore, the purpose of this review article is to examine the different methods used to accelerate orthodontic tooth movement, analyze their underlying biological mechanisms, evaluate their clinical effectiveness, and discuss their advantages, limitations, and future prospects in modern orthodontic practice.

ACCELERATED ORTHODONTIC TOOTH MOVEMENT (AOTM

The theoretical framework of accelerated orthodontic tooth movement (AOTM) is based on the biological principles of bone remodeling and the response of periodontal tissues to mechanical forces. Orthodontic tooth movement occurs through a complex interaction between the periodontal ligament (PDL), alveolar bone, and cellular mediators that regulate bone resorption and formation. When orthodontic forces are applied to a tooth, mechanical stress triggers biochemical and cellular responses within the periodontal ligament, initiating the process of bone remodeling that allows the tooth to move within the alveolar socket.

One of the central theories explaining accelerated orthodontic tooth movement is the Regional Acceleratory Phenomenon (RAP). RAP is a localized biological response of bone to surgical or mechanical injury, characterized by temporary increases in bone turnover, decreased bone density, and enhanced healing activity. This phenomenon leads to faster remodeling of the alveolar bone, thereby facilitating quicker tooth movement. Surgical procedures such as corticotomy, piezocision, and micro-osteoperforation are specifically designed to stimulate RAP in the alveolar bone surrounding the teeth.

Another important theoretical concept underlying orthodontic tooth movement is the pressure–tension theory. According to this theory, the application of orthodontic force produces areas of compression (pressure) and tension within the periodontal ligament. In the pressure zone, osteoclasts are activated, leading to bone resorption, while in the tension zone, osteoblasts promote bone deposition. The coordinated activity of these cells allows the tooth to gradually move through the alveolar bone. Accelerated orthodontic techniques aim to enhance this natural remodeling process by increasing cellular activity and metabolic processes within the periodontal tissues.

The bone-bending theory also contributes to the understanding of orthodontic tooth movement. This theory suggests that orthodontic forces cause slight deformation or bending of the alveolar bone, which in turn stimulates cellular responses and bone remodeling. Techniques that apply micro-vibrations or mechanical stimulation take advantage of this principle by promoting bone flexibility and increasing cellular signaling within the periodontal ligament.

In addition to mechanical and surgical theories, biochemical and molecular mechanisms play a significant role in accelerated tooth movement. Orthodontic force stimulates the release of various inflammatory mediators and signaling molecules, including cytokines, prostaglandins, interleukins, and growth factors. These molecules regulate the activity of osteoclasts and osteoblasts, which are responsible for bone resorption and formation. Pharmacological approaches that introduce substances such as prostaglandins, vitamin D metabolites, and parathyroid hormone aim to enhance these biochemical pathways and accelerate the rate of bone remodeling.

Furthermore, advances in biomedical technology have introduced physical stimulation theories, including the use of low-level laser therapy, electrical stimulation, and vibrational devices. These methods are believed to enhance cellular metabolism, increase blood circulation in periodontal tissues, and stimulate osteoblastic and osteoclastic activity, ultimately contributing to faster orthodontic tooth movement.

Overall, the theoretical framework of accelerated orthodontic tooth movement integrates biological, mechanical, and biochemical principles of bone remodeling. Understanding these underlying mechanisms is essential for developing effective clinical techniques that can safely reduce orthodontic treatment time while maintaining the stability and health of dental and periodontal structures.

AOTM MODELS AND METHODOLOGIES

The development of accelerated orthodontic tooth movement (AOTM) techniques has led to the proposal of several clinical models and methodologies designed to reduce orthodontic treatment duration while maintaining treatment safety and effectiveness. These methodologies are primarily categorized into surgical approaches, minimally invasive techniques, physical stimulation methods, and pharmacological interventions. Each approach focuses on enhancing the biological processes of bone remodeling and periodontal ligament response to orthodontic forces.

1. Surgical Models

Surgical methods are among the most effective techniques proposed to accelerate orthodontic tooth movement. These approaches are based on the stimulation of the Regional Acceleratory Phenomenon (RAP), which temporarily increases bone turnover and reduces bone density in the targeted region.

- **Corticotomy-Assisted Orthodontics:**
  This method involves selective decortication of the alveolar bone surrounding the teeth. Small cuts are made in the cortical bone to stimulate RAP, leading to increased bone remodeling and faster tooth movement. Corticotomy is often combined with bone grafting to improve periodontal support and treatment stability.

- **Piezocision Technique:**
  Piezocision is a minimally invasive surgical procedure in which small gingival incisions are made using piezoelectric instruments. These micro-incisions stimulate bone remodeling without extensive flap surgery, reducing postoperative discomfort while still accelerating tooth movement.

- **Micro-Osteoperforation (MOP):**
  In this method, small perforations are created in the alveolar bone using specialized instruments. These perforations stimulate localized inflammation and increased osteoclastic activity, which enhances bone resorption and facilitates faster tooth movement.

2. Minimally Invasive Mechanical Models

These models aim to stimulate bone remodeling through controlled mechanical stimulation without the need for surgical procedures.

- **Vibrational Devices:**
  High-frequency, low-amplitude vibrational forces are applied to the teeth using specialized orthodontic devices. These vibrations are believed to enhance cellular activity in the periodontal ligament and promote faster bone remodeling.

- **Customized Orthodontic Appliances:**
  Advanced orthodontic systems, such as self-ligating brackets and customized aligners, are designed to optimize the distribution of orthodontic forces, thereby improving treatment efficiency and potentially reducing treatment time.

3. Physical Stimulation Techniques

Physical stimulation methods aim to accelerate orthodontic tooth movement by enhancing cellular metabolism and biological responses in periodontal tissues.

- **Low-Level Laser Therapy (LLLT):**
- This technique uses low-intensity laser light to stimulate mitochondrial activity and cellular metabolism in periodontal tissues. LLLT is believed to increase osteoblastic and osteoclastic activity, thereby accelerating bone remodeling.
- **Electrical Stimulation:**
  Controlled electrical currents can stimulate cellular processes involved in bone formation and resorption, potentially enhancing orthodontic tooth movement.
- **Photobiomodulation:**
  Similar to laser therapy, photobiomodulation uses specific wavelengths of light to stimulate biological processes within the periodontal ligament and alveolar bone.

4. Pharmacological Models

Pharmacological approaches involve the use of biochemical agents that influence bone metabolism and inflammatory responses associated with orthodontic tooth movement.

- **Prostaglandins:**
  Local injections of prostaglandins can stimulate osteoclastic activity, leading to increased bone resorption and faster tooth movement.
- **Vitamin D Metabolites:**
  Vitamin D enhances calcium metabolism and bone remodeling, potentially accelerating orthodontic tooth movement.
- **Parathyroid Hormone (PTH):**
  Intermittent administration of PTH has been shown to increase bone turnover, which may facilitate faster orthodontic tooth movement.

5. Integrated Multimodal Approaches

Recent research has proposed combining multiple techniques, such as surgical stimulation with physical therapies, to achieve more effective acceleration of orthodontic treatment. For example, combining micro-osteoperforation with low-level laser therapy may enhance both biological and cellular responses, leading to improved treatment outcomes.

In summary, the proposed models and methodologies for accelerated orthodontic tooth movement aim to optimize biological responses and enhance bone remodeling processes. While surgical methods generally demonstrate greater effectiveness in reducing treatment time, non-invasive and minimally invasive approaches are gaining popularity due to their improved patient comfort and lower risk of complications. Further clinical research is required to establish standardized protocols and determine the long-term safety and effectiveness of these methodologies.

KEY PARAMETERS & CLINICAL ANALYSIS

The studies from various clinical and experimental studies on accelerated orthodontic tooth movement (AOTM) indicate that several techniques can effectively reduce the duration of orthodontic treatment by enhancing the biological processes involved in bone remodeling. The analysis of these studies focuses on key parameters such as the rate of tooth movement, treatment duration, biological response of periodontal tissues, patient comfort, and potential complications.

Most clinical studies demonstrate that surgical techniques produce the most significant acceleration in tooth movement. Procedures such as corticotomy-assisted orthodontics and piezocision stimulate the regional acceleratory phenomenon (RAP), which increases bone turnover and reduces bone density in the affected area. As a result, teeth can move more rapidly through the alveolar bone. Research studies show that these surgical approaches can reduce orthodontic treatment time by 30–50% compared to conventional orthodontic therapy. Additionally, the increased metabolic activity in bone tissue allows orthodontic forces to be more effective during the early stages of treatment.

Studies evaluating micro-osteoperforation (MOP) have also shown promising results. Clinical trials indicate that MOP increases osteoclastic activity, leading to faster bone resorption on the pressure side of the periodontal ligament. Split-mouth studies, where one side of the mouth receives the experimental treatment while the other serves as a control, have demonstrated that the rate of tooth movement in the treated side is significantly higher than in the untreated side. However, the magnitude of acceleration may vary depending on the number and depth of perforations performed.

Table 1: Analysis of Methods for Accelerated Orthodontic Tooth Movement (AOTM)

Method	Type of Technique	Mechanism of Action	Advantages	Limitations / Drawbacks	Effectiveness in Accelerating Tooth Movement
Corticotomy-Assisted Orthodontics	Surgical	Stimulates Regional Acceleratory Phenomenon (RAP) leading to increased bone turnover	Significant reduction in treatment time, improved bone remodeling	Invasive procedure, postoperative discomfort, higher cost	High (30–50% faster tooth movement)
Piezocision	Minimally invasive surgical	Small cortical bone incisions stimulate RAP and bone remodeling	Less invasive than corticotomy, minimal surgical trauma, faster healing	Requires surgical expertise, limited access in some areas	High (25–40% acceleration)

Micro-Osteoperforation (MOP)	Minimally invasive surgical	Creates micro-perforations in bone to increase osteoclastic activity	Simple procedure, minimal surgical intervention, repeatable	Mild discomfort, variable clinical outcomes	Moderate to High (20–35% acceleration)
Low-Level Laser Therapy (LLLT)	Physical stimulation	Enhances cellular metabolism and increases osteoblastic and osteoclastic activity	Non-invasive, painless, improves tissue healing	Results depend on wavelength, dosage, and application frequency	Moderate (10–25% acceleration)
Vibrational Devices	Mechanical stimulation	Applies high-frequency vibration to stimulate periodontal ligament activity	Non-invasive, easy to use, improves patient comfort	Limited clinical evidence, variable effectiveness	Low to Moderate (10–20% acceleration)
Electrical Stimulation	Physical stimulation	Enhances bone remodeling through electrical signals	Potential to increase osteoblastic activity	Requires specialized equipment, limited clinical research	Moderate
Pharmacological Agents (Prostaglandins, Vitamin D, PTH)	Pharmacological	Stimulate inflammatory mediators and osteoclastic activity	Directly affects bone metabolism and remodeling	Risk of systemic side effects, dosage control issues	Moderate to High (experimental)
Customized Orthodontic Appliances (Self-ligating brackets, aligners)	Mechanical / Appliance-based	Optimizes force distribution and reduces friction	Comfortable for patients, improved treatment efficiency	Limited ability to significantly accelerate biological tooth movement	Low to Moderate

The comparative analysis indicates that surgical and minimally invasive techniques such as corticotomy, piezocision, and micro-osteoperforation generally provide the most significant acceleration in orthodontic tooth movement due to their ability to stimulate the regional acceleratory phenomenon. Physical stimulation techniques, including laser therapy and vibrational devices, offer non-invasive alternatives with moderate effectiveness and greater patient comfort. Pharmacological approaches show promising results in experimental settings but require further clinical validation due to potential safety concerns.

Non-surgical techniques such as low-level laser therapy (LLLT) and vibrational devices have produced mixed but generally positive outcomes. Several studies report enhanced cellular metabolism, increased blood circulation, and stimulation of osteoblastic and osteoclastic activities when laser therapy is applied to periodontal tissues. These biological effects can contribute to faster orthodontic tooth movement. However, the results vary widely across different studies due to differences in laser wavelength, dosage, frequency of application, and patient characteristics.

Pharmacological approaches, including the use of prostaglandins, vitamin D metabolites, and parathyroid hormone, have shown the potential to accelerate tooth movement by stimulating bone remodeling and inflammatory mediators. Experimental studies demonstrate that these agents can significantly increase osteoclastic activity and reduce resistance to tooth movement. Despite these positive findings, their clinical application remains limited due to concerns regarding systemic effects, dosage control, and patient safety.

Patient-centered outcomes have also been analyzed in several studies. While surgical techniques may provide faster results, they are sometimes associated with postoperative discomfort, swelling, and higher treatment costs. In contrast, non-invasive techniques generally result in better patient acceptance and lower discomfort levels, although their effectiveness may be less consistent compared to surgical approaches.

Overall, the analysis of current study indicates that accelerated orthodontic techniques can significantly improve treatment efficiency. Surgical methods appear to provide the most predictable and substantial reduction in treatment time, while physical and pharmacological methods offer alternative options with varying degrees of effectiveness. The variability in results among different studies highlights the need for standardized clinical protocols, larger sample sizes, and long-term follow-up studies to confirm the reliability and safety of these techniques in routine orthodontic practice.

Overall, selecting an appropriate method for accelerated orthodontic treatment depends on clinical requirements, patient preference, cost considerations, and the orthodontist's expertise.

SIGNIFICANCE OF AOTM

Accelerated orthodontic tooth movement (AOTM) has gained considerable importance in modern orthodontics due to the increasing demand for shorter and more efficient orthodontic treatments. Traditional orthodontic procedures often require extended treatment periods, sometimes lasting two years or more, which may lead to patient dissatisfaction, poor compliance, and an increased risk of oral health complications. Therefore, exploring methods that can safely accelerate tooth movement has become a critical area of research and clinical interest.

One of the primary significances of this topic is its potential to reduce overall orthodontic treatment time. Shorter treatment durations benefit both patients and clinicians by improving patient cooperation, reducing the number of clinical visits, and increasing treatment efficiency. This is particularly important for adult patients who often prefer quicker treatment options due to professional, social, or personal considerations.

Another important aspect is the improvement of patient comfort and oral health outcomes. Long-term orthodontic appliance use can increase the risk of dental caries, enamel demineralization, gingival inflammation, and root resorption. By reducing treatment time through accelerated methods, the exposure of teeth and supporting tissues to these risks can be minimized, thereby improving overall oral health.

The topic is also significant because it contributes to advancements in orthodontic science and technology. Research into accelerated tooth movement has led to the development of innovative techniques such as corticotomy-assisted orthodontics, piezocision, micro-osteoperforation, laser therapy, and vibrational stimulation devices. These advancements demonstrate how interdisciplinary approaches involving biology, biomedical engineering, and clinical dentistry can enhance treatment outcomes.

Furthermore, accelerated orthodontic techniques have important implications for clinical practice and treatment planning. Orthodontists can use these methods to manage complex cases more effectively, especially in patients requiring rapid alignment of teeth before prosthodontic or surgical procedures. The integration of acceleration techniques into routine orthodontic care has the potential to transform traditional treatment strategies and improve patient satisfaction.

Finally, the significance of studying accelerated orthodontic tooth movement lies in its contribution to future research and innovation. Continued investigation into the biological mechanisms of bone remodeling, cellular responses, and advanced technologies will help develop safer, more predictable, and minimally invasive acceleration techniques. These advancements will ultimately support the goal of achieving faster orthodontic treatment without compromising the health and stability of teeth and surrounding tissues.

In summary, the study of accelerated orthodontic tooth movement is highly significant because it addresses one of the major challenges in orthodontic therapy prolonged treatment duration while promoting better patient experiences, improved clinical outcomes, and continued scientific progress in orthodontics.

LIMITATIONS OF ACCELERATED ORTHODONTIC TOOTH MOVEMENT (AOTM)

Despite the growing interest and promising outcomes associated with accelerated orthodontic tooth movement (AOTM), several limitations and drawbacks must be considered before these techniques can be widely adopted in routine orthodontic practice. These limitations relate to clinical effectiveness, patient safety, cost, and the availability of sufficient long-term evidence. One of the primary limitations is the invasiveness of certain surgical techniques. Procedures such as corticotomy and piezocision involve surgical intervention in the alveolar bone and surrounding tissues. Although these procedures can significantly accelerate tooth movement, they may cause postoperative discomfort, swelling, and temporary pain. Additionally, surgical techniques require specialized clinical skills and careful patient selection to avoid complications such as infection or damage to periodontal tissues. Another drawback is the variability in clinical outcomes associated with many acceleration techniques. Non-invasive methods such as low-level laser therapy, vibrational devices, and electrical stimulation have shown inconsistent results across different studies. Factors such as patient age, bone density, treatment protocol, and device parameters can influence the effectiveness of these methods, making it difficult to establish standardized clinical guidelines.

Limited long-term research evidence is another major concern. Although many studies report short-term success in accelerating tooth movement, there is still a lack of comprehensive long-term clinical trials evaluating the stability of treatment results and potential side effects. Questions remain regarding the long-term impact of accelerated techniques on root resorption, periodontal health, and relapse rates after orthodontic treatment.

The cost of advanced technologies and procedures can also limit their widespread use. Techniques involving specialized equipment such as laser devices, piezoelectric surgical instruments, and customized orthodontic appliances may increase the overall cost of treatment. This can make accelerated orthodontic procedures less accessible for many patients, particularly in developing regions.

In addition, pharmacological approaches designed to stimulate bone remodeling present potential risks related to systemic side effects and dosage control. The administration of substances such as prostaglandins or parathyroid hormone requires careful monitoring to avoid adverse biological reactions, which restricts their routine clinical application.

Patient-related factors also present certain limitations. Not all patients are suitable candidates for accelerated orthodontic procedures. Individuals with systemic diseases, compromised periodontal health, or poor oral hygiene may face increased risks when undergoing surgical or pharmacological acceleration methods.

Finally, there is a lack of standardized protocols for many acceleration techniques. Differences in methodology, treatment duration, force application, and measurement criteria across studies make it difficult to directly compare results or establish universal treatment guidelines.

In conclusion, while accelerated orthodontic tooth movement offers promising benefits in reducing treatment duration, several limitations and drawbacks must be carefully addressed. Future research focusing on standardized clinical protocols, long-term safety evaluation, and cost-effective technologies will be essential for the safe and reliable integration of these techniques into routine orthodontic practice.

CONCLUSION

Accelerated orthodontic tooth movement (AOTM) has emerged as an important area of research and clinical practice aimed at reducing the prolonged duration of conventional orthodontic treatment. The increasing demand for faster and more efficient orthodontic procedures has led to the development of various techniques designed to enhance the biological processes responsible for tooth movement. These techniques primarily focus on stimulating bone remodeling and increasing the metabolic activity of periodontal tissues.

This review highlights several methods used to accelerate orthodontic tooth movement, including surgical techniques such as corticotomy, piezocision, and micro-osteoperforation, as well as non-surgical approaches like low-level laser therapy, vibrational devices, and pharmacological agents. Among these methods, surgical and minimally invasive procedures have demonstrated more predictable and significant reductions in treatment time due to their ability to stimulate the regional acceleratory phenomenon (RAP). On the other hand, non-invasive methods offer advantages in terms of patient comfort and reduced risk of surgical complications, although their effectiveness may vary depending on treatment protocols and patient-specific factors.

The analytical and clinical studies suggest that accelerated orthodontic techniques can significantly improve treatment efficiency and patient satisfaction by shortening treatment duration and reducing potential complications associated with prolonged orthodontic therapy. However, the success of these methods depends on careful case selection, proper clinical application, and consideration of individual patient factors. Despite the promising results, several challenges remain, including limited long-term clinical evidence, variability in treatment outcomes, higher costs associated with advanced technologies, and the need for standardized clinical protocols. These limitations highlight the importance of continued research to evaluate the long-term safety, effectiveness, and stability of accelerated orthodontic procedures.

In conclusion, accelerated orthodontic tooth movement represents a valuable advancement in modern orthodontics, offering the potential to significantly improve treatment efficiency while maintaining clinical safety. Future developments in biomedical technology, biological research, and minimally invasive procedures are expected to further enhance the effectiveness of these techniques, ultimately leading to faster, safer, and more patient-friendly orthodontic treatments.

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