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Modern Approaches to Accelerating Orthodontic Tooth Movement in Impaired Eruption: A Literature Review

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Abstract: Delayed tooth eruption represents one of the most complex clinical challenges in orthodontics, as it significantly complicates treatment planning, increases treatment duration, and raises the risk of complications. In patients with impacted teeth, pathological changes in the periodontium are often observed, including dental arch displacement, root resorption of adjacent teeth, as well as pronounced aesthetic and psychological problems, especially during adolescence. In this regard, optimizing and accelerating orthodontic tooth movement in cases of impaired eruption is of great importance for both clinical practice and scientific research. When selecting treatment methods, the key criteria remain safety, biological compatibility, and proven effectiveness. The most effective approach is considered to be an individualized strategy that takes into account the morphological characteristics of bone tissue, type of impaction, patient age, comorbidities, and interdisciplinary collaboration between specialists. Thus, modern orthodontics is focused not only on eliminating mechanical obstacles to tooth eruption but also on actively stimulating the physiological processes of tooth movement in order to achieve faster, more stable, and aesthetically acceptable outcomes. To analyze scientific literature data on the effectiveness of modern methods for accelerating orthodontic tooth movement in cases of delayed tooth eruption. A systematic review of scientific publications was conducted using the Web of Science, PubMed, and Google Scholar databases over the past 15 years. The selection of sources was based on their relevance and scientific significance. Modern technologies aimed at accelerating orthodontic tooth movement in cases of eruption disturbances can significantly reduce treatment time and decrease the risk of complications. The best clinical outcomes are achieved through the combined use of surgical, pharmacological, and biostimulatory methods, including laser therapy, photobiomodulation, and vibration-based techniques, within a personalized treatment approach.

Keywords: Orthodontic Tooth Movement, Delayed Eruption, Tooth Impaction, Surgical Methods, Pharmacological Stimulation, Laser Therapy, Photobiomodulation, Vibration Technologies, Malocclusion

Introduction

In recent years, the issue of accelerating orthodontic tooth movement has attracted increasing attention from researchers and clinicians, which is associated with the active introduction of both surgical and non-surgical methods for optimizing treatment in routine practice [1–2]. Acceleration of tooth movement is an important demand among patients with malocclusions, as reducing treatment duration decreases the risk of complications, including periodontal inflammatory diseases, enamel demineralization, carious lesions, and root resorption [3].

Prolonged use of orthodontic appliances, especially esthetic or fixed systems, often leads to reduced patient motivation for treatment. In some cases, particularly among adults, this results in refusal of necessary therapy even in the presence of clear clinical indications [4].

Orthodontic tooth movement is based on the biological response of the periodontal ligament and alveolar bone to applied mechanical force [5]. In response to force application, bone tissue undergoes remodeling processes, including bone formation on the tension side and resorption on the pressure side. This process is conventionally divided into three sequential phases: an initial phase characterized by rapid tooth displacement immediately after force application; a lag phase during which movement is minimal or temporarily absent; and a post-lag phase accompanied by gradual or accelerated increases in movement rate.

Cellular responses, inflammatory mediators, cytokines, and signaling molecular pathways play a key regulatory role in these processes by modulating tissue responses and facilitating bone remodeling mechanisms [6].

In response to orthodontic force, immunological mechanisms are activated in periodontal tissues. This process involves various biologically active molecules, including chemokines, growth factors, and pro-inflammatory cytokines such as interleukin-1β (IL-1β), interleukin-6 (IL-6), interleukin-8 (IL-8), tumor necrosis factor-alpha (TNF-α), interferon-gamma (IFN-γ), and prostaglandin E2 (PGE2) [7–8]. These mediators play a key role in the development of a local inflammatory response and subsequent bone remodeling.

To date, several main strategies for accelerating orthodontic tooth movement have been identified: biomechanical, physiomechanical, pharmacological, as well as surgically assisted and surgically modified methods. In clinical practice, a personalized approach is becoming increasingly important, taking into account occlusal characteristics, bone tissue condition, type of tooth impaction, patient age, and comorbidities. Treatment effectiveness is also strongly influenced by the level of interdisciplinary collaboration among specialists.

Particular attention is given to pharmacological agents affecting bone metabolism. These include growth hormone, parathyroid hormone, thyroxine, and vitamin D, which can enhance osteoclast activity and thereby increase bone resorption through various biochemical mechanisms. Pharmacological strategies for accelerating orthodontic tooth movement also consider local cytokine administration, prostaglandin application, activation of the RANKL system, use of parathyroid hormone, vitamin D3, and corticosteroids.

According to the review by Michelogiannakis D. et al. [9], the effect of corticosteroid therapy on the rate of orthodontic tooth movement remains controversial. Some studies report a reduction in tooth movement rate or no significant effect, while others demonstrate an increase. Additionally, corticosteroids have been shown to reduce bone density and enhance bone resorption, as well as influence the degree of root resorption. Regarding thyroxine, some studies demonstrate an increase in orthodontic tooth movement rate, whereas others report no significant differences. There is also evidence suggesting a reduction in inflammatory root resorption; however, the findings remain inconsistent [10].

The use of injectable platelet-rich fibrin (i-PRF) in orthodontic practice has demonstrated the ability to accelerate the closure of interdental spaces and reduce the overall duration of treatment. This method is considered a safe adjunctive approach that does not negatively affect anchorage stability and enhances treatment efficiency [11]. Studies also show that the combination of micro-osteoperforations with i-PRF application produces a pronounced synergistic effect, significantly accelerating tooth movement during retraction, although it may be associated with increased tooth tipping [12].

Local application of prostaglandins promotes an increase in the rate of orthodontic tooth movement by stimulating osteoclastic activity. However, at high doses, root resorption may occur as a side effect. The addition of calcium gluconate helps reduce the severity of this adverse effect. Submucosal administration of prostaglandins may cause pain, requiring local anesthesia, whereas oral forms such as misoprostol are not associated with significant pain and do not demonstrate notable root resorption [13].

According to systematic review data, the local application of vitamin D also contributes to the acceleration of orthodontic tooth movement. Surgical methods based on the regional acceleratory phenomenon (RAP), including corticotomy and its modifications, are considered an effective adjunct to orthodontic treatment, particularly in adult patients and those with periodontal disease [14].

Nitric oxide plays a role in regulating bone remodeling and contributes to bone formation on the tension side during orthodontic force application. Among surgical methods for accelerating tooth movement, corticotomy, micro-osteoperforations, and piezosurgical techniques are distinguished. Their effectiveness has been confirmed by numerous clinical observations, especially in adult patients requiring shortened treatment duration.

Although some invasive techniques have not become widely adopted due to their traumatic nature, they remain among the most predictable methods for accelerating tooth movement, particularly within interdisciplinary treatment protocols [15]. It is currently widely accepted that the primary mechanism of acceleration is the regional acceleratory phenomenon rather than bodily movement of a bone block; however, the exact cellular and molecular mechanisms remain insufficiently understood.

Modern trends are focused on minimizing the invasiveness of surgical interventions while maintaining their effectiveness. Minimally invasive corticotomy techniques are considered a promising direction, allowing acceleration of orthodontic treatment while reducing the risk of complications. Such approaches have demonstrated effectiveness in the correction of impacted teeth, including maxillary canines, without a significant increase in adverse effects [16].

Piezosurgical techniques, including piezocision, represent a localized alveolar decortication that initiates processes of demineralization and subsequent remineralization of bone tissue within the framework of the regional acceleratory phenomenon. This is accompanied by increased bone turnover and temporary reduction in mineral density, which facilitates faster tooth movement.

Clinical studies show that both single and multiple piezocision procedures can significantly accelerate orthodontic treatment compared to conventional methods. In particular, the rate of tooth retraction may increase by 1.5–2 times with piezosurgical techniques, while corticotomy may achieve a 1.5–4-fold increase [17].

Various non-invasive adjunctive methods are also being investigated for accelerating orthodontic tooth movement, including laser therapy, electrical stimulation, pulsed electromagnetic fields, and photobiomodulation [18]. Despite their potential effectiveness, the clinical application of these technologies is limited by the need for strict protocols and insufficient evidence for some methods.

According to Gujar A.N., increased mechanical vibration frequency is associated with elevated levels of prostaglandin E2 (PGE2), a finding also supported by Benjakul S. et al. [30]. Maximum tooth movement rates and PGE2 concentrations were observed in patients using vibrating electric toothbrushes at approximately 150 Hz compared to the 125 Hz group and individuals not using vibration devices.

However, research findings regarding vibration therapy remain inconsistent. Azeem M. reported that daily vibration using an electric toothbrush for 20 minutes did not significantly accelerate tooth movement and did not cause patient discomfort [19]. These findings are consistent with several studies showing no significant effect of vibration on orthodontic tooth movement, although other authors have reported positive outcomes.

Leethanakul C. demonstrated that combining light orthodontic force with vibrational stimulation (e.g., electric toothbrush use) increases interleukin-1β (IL-1β) production and may accelerate tooth movement [20]. In the study by Khera et al. (2022), a specially designed vibration device applied for 20 minutes daily at a low frequency (~30 Hz) did not produce a statistically significant acceleration of canine retraction.

Laser therapy also deserves special attention, as its effectiveness in accelerating orthodontic tooth movement remains controversial. Some studies report a significant reduction in treatment time and increased tooth movement compared to control groups without laser exposure [21].

The combination of low-level laser therapy with light orthodontic force has been shown to increase IL-1β levels in gingival crevicular fluid, which is associated with accelerated tooth movement.

Photobiomodulation (PBM) is considered a promising non-invasive and painless method with significant potential for stimulating orthodontic tooth movement. According to available data, PBM accelerates molar alignment by regulating IL-1β levels and influencing bone remodeling processes [22].

In a comparative study of photobiomodulation and micro-osteoperforations (MOP), the effectiveness of these methods in canine retraction was evaluated. After premolar extraction, a three-month healing period was allowed for bone formation. In the MOP group, three vertical perforations distal to the canine root were performed using Propel instruments. In the PBM group, a GaAlAs semiconductor diode laser was applied for 10 seconds at ten sites around the canine root. The results showed that the rate of retraction in the MOP group was approximately 1.1 times higher than in the photobiomodulation group [23].

Conclusion

Delayed tooth eruption represents a multifactorial clinical problem that requires a comprehensive and individualized treatment approach. Modern methods for accelerating orthodontic tooth movement include surgical, pharmacological, biomechanical, and biostimulatory technologies, which are used either independently or in combination.

Among the most significant surgical approaches are surgical exposure of impacted teeth, micro-osteoperforations, and the use of injectable platelet-rich fibrin (i-PRF), which promotes the activation of regenerative processes and the regional acceleratory phenomenon (RAP). Pharmacological methods, including the use of vitamin D, thyroxine, prostaglandins, and parathyroid hormone, can enhance bone remodeling; however, they require strict monitoring due to potential adverse effects.

In addition, laser therapy and photobiomodulation demonstrate a positive effect on the rate of orthodontic tooth movement through stimulation of osteoclastic activity, improvement of microcirculation, and modulation of inflammatory processes without significant tissue damage. At the same time, vibrational methods may contribute to increased cellular activity and accelerated bone metabolism, although their effectiveness remains a subject of debate.

Thus, the integration of various approaches—from conventional to high-tech—makes it possible to shorten orthodontic treatment duration in cases of delayed tooth eruption, reduce the risk of complications, and improve overall treatment effectiveness. Further research and standardization of clinical protocols are necessary for the optimal implementation of these approaches in practice.

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