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ADVANCES IN BONE REMODELING AND CLEAR ALIGNERS IN ORTHODONTICS

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ABSTRACT

The use of clear aligners in orthodontics represents a significant advancement in dental treatment, allowing effective tooth movement with a less invasive approach compared to traditional fixed appliances. Clear aligners not only facilitate the alignment of teeth but also promote changes in the supporting alveolar bone. The success of these movements relies on the surrounding bone's response to mechanical stress during treatment, involving processes of bone resorption and deposition. Research has demonstrated that advancements in digital technology, such as 3D modeling and artificial intelligence, enhance the planning of tooth movements, making bone remodeling more predictable. Sophisticated algorithms simulate aligner forces on the alveolar bone, optimizing each treatment phase. However, limitations persist in complex cases where specific movements, like extrusion and rotation, require precise force control. Recent studies by Guo et al. (2023) and Abogabal et al. (2023) evaluated the effects of clear aligners on alveolar bone dimensions during orthodontic treatment, finding a greater occurrence of bone defects after treatment. They highlighted the differences in bone height changes between aligners and fixed appliances, indicating that clear aligners might have less impact on bone height. Innovative approaches such as low-intensity pulsed ultrasound (LIPUS) and high-frequency vibration (HFV) have also been investigated for their potential to enhance treatment outcomes. Research indicates that daily vibration may reduce the time required for dental correction while increasing levels of cytokines and markers for bone remodeling. Overall, the integration of digital tools and innovative techniques in orthodontics is crucial for improving treatment efficacy, addressing challenges in complex cases, and ultimately enhancing patient experience and satisfaction.

Keywords: Clear Aligners. Bone Remodeling. Orthodontics. Digital Technology. Innovative Techniques.

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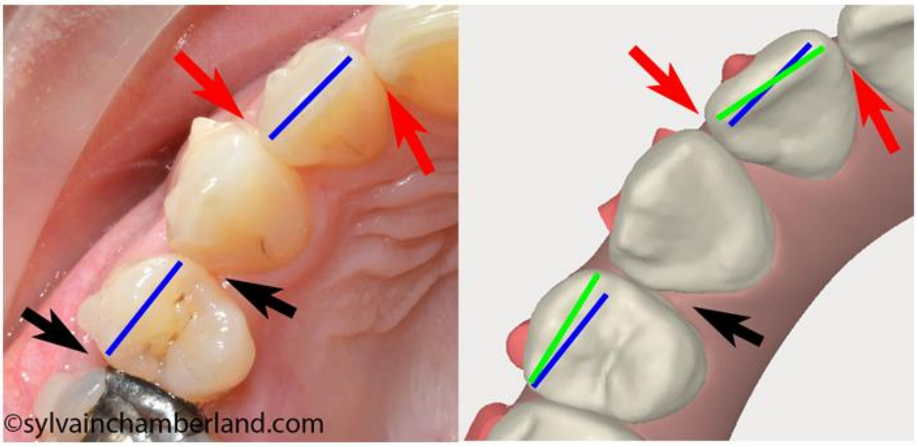
INTRODUCTION

The technology of bone remodeling induced by clear aligners represents a significant advancement in modern orthodontics, enabling effective dental movements through a less invasive approach. Clear aligners provide an aesthetic alternative to fixed appliances, promoting not only the alignment of teeth but also changes in the supporting alveolar bone. The success of these movements depends on the response of the surrounding bone to the mechanical stress applied during treatment, involving processes of resorption and deposition of new bone tissue. When an aligner exerts force on a tooth, it activates specialized cells, such as osteoclasts and osteoblasts, which are responsible for remodeling the bone around the tooth root. This process occurs in a controlled and gradual manner: osteoclasts remove bone in the direction of the tooth movement, while osteoblasts form new bone in the opposite direction, ensuring the stability of the tooth in its new position.

Advances in digital technology, such as 3D modeling and artificial intelligence, have allowed for more precise planning of dental movements, making bone remodeling more predictable and controlled. Sophisticated algorithms enable the simulation of the forces of the aligners on the alveolar bone, adjusting each phase of treatment to optimize the bone response. Despite the overall effectiveness of aligners, their use in bone remodeling in more complex cases still faces limitations. Movements such as extrusion and rotation of rounded teeth require more specific forces, which can be challenging to control. However, with the ongoing development of more flexible and durable materials, as well as customization techniques, it is expected that aligners will cater to a broader range of orthodontic needs in the future.

Figure 1: Orthodontic tooth movement with Invisalign® aligners.



Source: Chamberland (2024).

In this context, the research by Guo et al. (2023) evaluated the dimensions of the alveolar bone and its relation to dental movements—retraction, intrusion, and torque—during orthodontic treatment with fixed appliances and clear aligners. Using cone beam computed tomography (CBCT) on 32 patients before and after treatment, the researchers measured the volume of dehiscences and fenestrations in the anterior maxillary region, as well as the thickness and height of the alveolar bone and the degree of dental movement. The results showed a higher occurrence of bone defects on the labial side after treatment, with the incidence of fenestrations being higher for both groups (23.96% in the aligner group and 26.18% in the fixed appliance group) compared to dehiscences (5.21%). Additionally, in the intrusion of anterior teeth, the fixed appliance group exhibited a reduction in labial bone height and an increase in palatine bone height, while in the aligner group, retraction did not significantly alter labial bone height, although it did reduce palatine bone height. It was found that intrusion and retraction of anterior teeth can cause resorption of the alveolar bone in treatments with fixed appliances due to cervical compression, offering a three-dimensional approach to evaluating dental movements using CBCT.

Another study, conducted by Abogabal et al. (2023), aimed to assess the impact of clear aligners on the buccal alveolar bone after orthodontic treatment. The study involved 14 patients (male and female) aged between 15 and 25 years, with mild to moderate malocclusion, who were randomly selected and divided into two groups: the Aligners group and the Fixed group. Both groups underwent orthodontic treatment with sequentially exchanged sets of aligners and wires. The participants were recruited from the outpatient orthodontic clinic of the Faculty of Dentistry at Al-Azhar University, Assiut branch. Each subject was evaluated for eligibility based on specific inclusion and exclusion criteria, and all participants provided informed consent for the study. The evaluation was performed using CBCT examinations. The results indicated that both aligners and fixed appliances had a non-significant effect on bone thickness; however, there was a significant difference in bone height between the two groups. Notably, the reduction in bone height in the Aligners group was less than that observed in the Fixed group, while no significant difference was found regarding bone thickness.

The study by Bahammam and El-Bialy (2022) investigated the potential effects of low-intensity pulsed ultrasound (LIPUS) on the thickness and height of the buccal bone plate after maxillary arch expansion using clear aligners. The researchers analyzed

CBCT images obtained before and immediately after a 3 mm maxillary arch expansion on each side in 28 adult patients (18 in the LIPUS group and 10 in the control group), with a mean age of 36.2 ± 13.2 years. The LIPUS group followed a protocol of exchanging aligners every 4 to 5 days, while the control group exchanged their aligners every 7 to 10 days. Measurements of bone thickness at 3 mm and 6 mm from the buccal alveolar crest, as well as heights of buccal alveolar bone, were obtained in standardized sagittal sections. Statistical analyses were performed using paired t-tests and Wilcoxon tests, considering a p-value < 0.05 as statistically significant. The results indicated a significant increase in bone height for both groups; however, there was no statistically significant difference in bone thickness or height between the LIPUS and control groups. Thus, the study concluded that the use of LIPUS, combined with an accelerated aligner tray exchange protocol, did not impact the integrity of the alveolar bone compared to the control group.

The research conducted by Shipley, Farouk, and El-Bialy (2019) aimed to evaluate the effects of high-frequency vibration (HFV) on dental movement during the treatment phase and on post-treatment bone density at the beginning of retention, using cone beam computed tomography (CBCT). Thirty patients with initial Class I skeletal relationships and mild to moderate crowding (3–5 mm) were treated to completion with clear aligners, with or without HFV (control group). Patients were instructed to change their aligners as soon as they became loose. The researchers assessed the changes in bone density associated with orthodontic treatment using i-CAT CBCT and InVivo Anatomage® software to quantify density in Hounsfield units (HU) in ten different regions. The mean aligner exchange time was significantly shorter in the HFV group (5.2 days) compared to the control group (8.7 days). The results showed a significant increase in HU values from baseline (T1) to the beginning of retention (T2) in both arches (P = 0.0001) and (P = 0.008) for the HFV group, while no significant change was observed in the control group. Additionally, comparisons between the groups indicated a significant difference in bone density between the two groups. The study concluded that the addition of high-frequency vibration to clear aligners facilitated faster aligner exchanges, resulting in shorter treatment times and a significant increase in bone density at the beginning of retention compared to the control group.

Finally, the research conducted by Alansari et al. (2018) investigated the impact of brief daily high-frequency vibration application on the efficiency of treatment with clear aligners, hypothesizing that it could improve dental movement by stimulating cytokines and bone remodeling factors in the periodontal ligament (PDL) without causing additional pain or discomfort. Sixty subjects were recruited and divided into five groups, each changing clear aligners at different time intervals, with or without the application of daily vibration for 5 minutes. After the fourth aligner, intraoral scans and digital simulation images from ClinCheck were superimposed to measure the anterior-posterior movement of a lower anterior tooth. The researchers assessed cytokine levels in the crevicular gingival fluid (GCF) at the end of the second aligner and measured pain levels using a numeric scale on days 1 and 3 after each aligner change. The results indicated that treatment with brief daily vibration significantly reduced the intervals between aligner exchanges and led to dental movement that approached the predictions of ClinCheck. This effect was associated with elevated levels of cytokines and markers of bone remodeling in the GCF, along with reduced pain and discomfort. The study concluded that treatment with daily vibration resulted in a clinically significant reduction in the time required to correct dental crowding and the need for a more rigorous approach to the use of vibrations for better efficacy in treatments with clear aligners.

The reviewed studies demonstrate that the technology of clear aligners has a significant impact on bone remodeling, although challenges and limitations remain in its application in complex cases. The use of digital technologies and innovative methods, such as high-frequency vibrations and ultrasound, can enhance outcomes, promoting more effective and comfortable treatments. It is essential that clinical practices continue to evolve, incorporating these advances to improve patient experience and the effectiveness of orthodontic treatment.

The text outlines significant advancements in orthodontic treatment through the use of clear aligners, emphasizing their role in effective dental movement and bone remodeling. It highlights the less invasive nature of clear aligners compared to traditional braces and underscores the importance of understanding the biological responses of surrounding alveolar bone during treatment. The research reviewed demonstrates how factors such as mechanical stress, digital technology, and innovative methods like low-intensity pulsed ultrasound (LIPUS) and high-frequency vibration (HFV) can enhance treatment outcomes.

The findings from various studies indicate that while clear aligners are generally effective, challenges remain, particularly in more complex cases requiring precise movements. Importantly, the integration of digital planning and advanced technologies can optimize bone response and improve the predictability of outcomes. As orthodontic practices evolve, incorporating these innovations will be crucial in providing more effective and comfortable treatments, ultimately enhancing patient experiences and treatment success rates. The ongoing research in this field promises to address existing limitations and broaden the applicability of clear aligners, solidifying their role in modern orthodontics.

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