

Review Article

Biomechanical innovations in correcting severe malocclusions

Madhawi Faisal Alshammri^{1*}, Amjad Awadh Alazmi², Khalid Waleed Tarabzouni³,
Latifa Hamad Alshayea², Naif Khalid Almalik⁴

¹Department of Dental Administration, Prince Sultan Military Medical City, Riyadh, Saudi Arabia

²Department of Dental, Prince Sultan Military Medical City, Riyadh, Saudi Arabia

³Department of Dental, Armed Forces Hospital, Dhahran, Saudi Arabia

⁴Department of Dental, Alnakheel Medical Center, Riyadh, Saudi Arabia

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*Correspondence:

Dr. Madhawi Faisal Alshammri,

E-mail: am768796@gmail.com

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ABSTRACT

The correction of severe malocclusions presents significant challenges in orthodontics due to the complexity and precision required for effective treatment. Recent biomechanical innovations have transformed the landscape of orthodontic care, offering more precise, efficient, and patient-friendly solutions. Advancements in orthodontic bracket systems, including the development of self-ligating brackets and heat-activated arch wires, have enhanced the control and comfort of tooth movements, reduced treatment times and improving patient outcomes. Temporary anchorage devices (TADs) have provided stable anchorage points, enabling complex tooth movements that were previously difficult to achieve. TADs have proven particularly effective in managing open bites and class II malocclusions, offering non-surgical alternatives for severe cases. The integration of digital technology in orthodontics, such as 3D imaging and computer-aided design/manufacturing (CAD/CAM), has further revolutionized treatment planning and execution. These technologies facilitate accurate diagnostics and the creation of customized orthodontic appliances, ensuring precise and predictable treatment outcomes. Clear aligner therapy, initially limited to simple cases, has advanced through the use of improved thermoplastic materials and digital customization, allowing for the treatment of more complex malocclusions. Innovative force application techniques, including the use of attachments and elastics, have expanded the capabilities of aligners, making them a versatile and effective alternative to traditional braces. Collectively, these biomechanical innovations have significantly improved the management of severe malocclusions, enhancing treatment efficiency, precision, and patient comfort. The ongoing development of these technologies promises to further advance the field of orthodontics, providing more effective and aesthetically pleasing solutions for patients with complex dental alignment issues.

Keywords: Orthodontics, Malocclusion, Biomechanical, Temporary anchorage devices

INTRODUCTION

Malocclusions, or misalignments of the teeth and jaws, are common dental problems that can significantly impact oral health and aesthetics. Severe malocclusions, in particular, pose substantial challenges for orthodontic treatment due to their complexity and the need for precise biomechanical interventions. Over the years, advancements in orthodontic techniques and technologies

have revolutionized the management of severe malocclusions, offering more effective and efficient treatment options.

Historically, orthodontic treatment primarily relied on fixed appliances, such as braces, which use brackets and arch wires to apply continuous pressure on the teeth, gradually moving them into the desired position. Despite their effectiveness, traditional braces often required

extended treatment durations and were associated with discomfort and aesthetic concerns for patients. However, the development of advanced bracket systems and arch wires has significantly improved treatment outcomes by enhancing the control and precision of tooth movements.¹ One of the most notable innovations in the correction of severe malocclusions is the use of TADs. These small, screw-like implants are temporarily placed in the bone to provide stable anchorage points for orthodontic forces. TADs enable orthodontists to achieve complex tooth movements that would be difficult or impossible with conventional methods alone. By minimizing the unwanted movement of anchor teeth, TADs have expanded the scope of orthodontic treatment, particularly in cases involving severe malocclusions.²

The advent of clear aligner therapy has revolutionized the field of orthodontics. Clear aligners, such as those offered by Invisalign, provide a nearly invisible and removable alternative to traditional braces. These aligners are custom-made for each patient and gradually shift teeth into place through a series of incremental adjustments. While clear aligners were initially limited to mild to moderate cases, recent advancements in aligner materials and treatment planning software have extended their applicability to more complex malocclusions.³ Moreover, the integration of digital technology into orthodontic practice has further enhanced the management of severe malocclusions. Digital imaging, 3D scanning, and CAD/CAM allow for highly accurate diagnostics and treatment planning. These technologies facilitate the creation of precise models of the patient's dentition, enabling orthodontists to simulate and optimize treatment outcomes before initiating therapy.⁴ The field of orthodontics has seen significant biomechanical innovations that have transformed the treatment of severe malocclusions. Advances in bracket systems, the use of TADs, the development of clear aligners, and the incorporation of digital technologies have collectively improved the efficiency, effectiveness, and patient experience of orthodontic care. This review will explore these innovations in detail, highlighting their impact on contemporary orthodontic practice.

REVIEW

The recent biomechanical innovations in orthodontics have significantly advanced the correction of severe malocclusions, providing more precise and effective treatment options. One major advancement is the development of sophisticated bracket systems and arch wires. These systems allow for better control over tooth movement, reducing treatment times and improving patient comfort. For instance, the introduction of self-ligating brackets, which reduce friction between the bracket and arch wire, has shown to enhance treatment efficiency and outcomes.⁵ Another significant innovation is the use of TADs. TADs offer stable anchorage points for orthodontic forces, enabling the correction of complex malocclusions that were previously challenging to treat.

They have been particularly effective in cases requiring significant tooth movements without compromising the position of other teeth.⁶ This has expanded the treatment possibilities and improved outcomes for patients with severe malocclusions. Furthermore, the integration of digital technology in orthodontics, such as 3D imaging and CAD/CAM, has revolutionized treatment planning and execution. These technologies enable precise diagnostics and allow for the simulation of treatment outcomes, ensuring more accurate and predictable results. The ability to create detailed digital models of a patient's dentition has significantly enhanced the customization and effectiveness of orthodontic appliances, contributing to better treatment outcomes for severe malocclusions.

ADVANCES IN ORTHODONTIC BRACKET SYSTEMS AND ARCHWIRES

The evolution of orthodontic bracket systems and arch wires has significantly enhanced the efficiency and effectiveness of treatments for severe malocclusions. Traditional brackets, while effective, presented limitations in terms of friction and control over tooth movement. Recent advancements have addressed these issues, providing orthodontists with more sophisticated tools to achieve precise tooth alignment.

One of the notable advancements is the development of self-ligating brackets. Unlike conventional brackets, which require elastic or metal ties to hold the arch wire in place, self-ligating brackets have a built-in mechanism to secure the wire. This design reduces friction between the bracket and arch wire, allowing for more efficient tooth movement and shorter treatment times. Studies have shown that self-ligating brackets can significantly decrease the duration of orthodontic treatment while maintaining high levels of patient comfort.⁷ Another significant innovation is the use of heat-activated and super elastic arch wires. These wires, made from nickel-titanium alloys, respond to the temperature changes in the mouth, becoming more flexible at lower temperatures and more rigid at higher temperatures. This property allows for continuous, gentle forces to be applied to the teeth, promoting more consistent and comfortable movement. Heat-activated arch wires have been particularly beneficial in the initial stages of treatment, where they help to reduce the discomfort typically associated with traditional stainless-steel wires.⁸ Furthermore, the introduction of customized bracket systems has revolutionized orthodontic treatment. These systems use advanced digital technology to create personalized brackets and arch wires tailored to the specific anatomy of each patient's teeth. Customized brackets are designed to fit the contours of individual teeth precisely, improving the accuracy of tooth movement and reducing the need for adjustments. The use of digital scanning and CAD/CAM technology in the design and manufacturing of these brackets has led to more predictable treatment outcomes and enhanced patient satisfaction.⁹

The integration of three-dimensional (3D) imaging and CAD/CAM in orthodontics has also contributed to the advancement of bracket systems and arch wires. Digital impressions taken with intraoral scanners provide highly accurate models of the patient's dentition, which can be used to design custom brackets and arch wires. This level of precision ensures that the orthodontic appliances are optimally configured to achieve the desired tooth movements, improving treatment efficiency and effectiveness. The advances in orthodontic bracket systems and arch wires have significantly improved the management of severe malocclusions. Self-ligating brackets, heat-activated and super elastic arch wires, and customized bracket systems represent key innovations that have enhanced the control, efficiency, and comfort of orthodontic treatments. These technological advancements continue to push the boundaries of what is possible in orthodontics, offering new solutions for patients with complex dental alignment issues.

THE ROLE OF TADS IN SEVERE MALOCCLUSION CORRECTION

TADs have revolutionized the field of orthodontics, particularly in the treatment of severe malocclusions. These small, screw-like implants are placed in the bone to provide stable anchorage points for applying orthodontic forces. Their ability to control and manage tooth movement with precision has made TADs an indispensable tool in modern orthodontic practice. The primary advantage of TADs is their ability to offer absolute anchorage, which is critical in complex cases where traditional anchorage methods may fall short. TADs can be strategically placed in various locations within the oral cavity, such as the alveolar bone, palate, or mandibular ramus, to provide support for the desired tooth movements. This versatility allows orthodontists to address a wide range of malocclusions effectively, including cases involving significant tooth displacement and vertical control issues.¹⁰

One of the significant applications of TADs is in the correction of open bites. Open bites, characterized by a lack of vertical overlap between the anterior teeth, are challenging to treat due to the need for precise vertical control. TADs enable orthodontists to intrude molars effectively, thereby reducing the vertical dimension and allowing the anterior teeth to overlap correctly. Studies have demonstrated the efficacy of TADs in achieving significant molar intrusion, which is essential for the successful correction of open bites.¹¹ Additionally, TADs have been instrumental in the management of Class II malocclusions, where there is a discrepancy in the anteroposterior relationship between the upper and lower jaws. By providing stable anchorage, TADs facilitate the distalization of molars and the retraction of anterior teeth without unwanted movements of the anchor teeth. This approach minimizes the need for extractions and allows for more conservative treatment plans. Clinical evidence supports the effectiveness of TADs in achieving desired

tooth movements in Class II malocclusion cases, resulting in improved treatment outcomes.¹² Moreover, TADs have expanded the possibilities for non-surgical correction of severe skeletal malocclusions. In cases where orthognathic surgery might have been the only viable option in the past, TADs offer an alternative by providing the necessary anchorage for significant tooth movements. This non-invasive approach can be particularly beneficial for patients seeking to avoid surgery, offering a less invasive yet effective treatment option.

The role of TADs in correcting severe malocclusions cannot be overstated. Their ability to provide stable, absolute anchorage has transformed the orthodontic landscape, enabling the successful management of complex cases with greater precision and efficiency. As the technology and techniques for TAD placement continue to evolve, their application in orthodontic practice is likely to expand further, offering even more innovative solutions for challenging malocclusions.

INNOVATIVE APPROACHES TO ALIGNERS AND FORCE APPLICATION TECHNIQUES

The landscape of orthodontic treatment has undergone significant transformation with the advent of clear aligner therapy and innovative force application techniques. Clear aligners, initially limited to simple orthodontic cases, have evolved considerably, allowing for the treatment of more complex malocclusions through advanced materials and digital technologies. One of the key innovations in clear aligner therapy is the use of advanced thermoplastic materials. These materials are designed to provide optimal flexibility and strength, ensuring consistent force application over the duration of wear. Recent advancements have led to the development of aligners that can withstand the stresses of more complex tooth movements, making them a viable alternative to traditional braces for a broader range of cases.¹³

The integration of digital technology in the design and fabrication of aligners has also been a game-changer. Modern aligners are custom-made using precise 3D digital scans of the patient's teeth, allowing for highly accurate treatment planning. CAD/CAM technologies enable the creation of a series of aligners that incrementally move the teeth into their desired positions. This level of precision ensures that each aligner is optimally configured to apply the necessary forces, resulting in more predictable and efficient treatment outcomes.¹⁴ Innovative force application techniques have been developed to enhance the effectiveness of clear aligners. Attachments, small tooth-colored shapes bonded to the teeth, are strategically placed to aid in the movement of teeth by providing additional grip for the aligners. These attachments can be customized in shape and size to address specific movement requirements, such as rotations or extrusions, which were previously challenging to achieve with aligners alone. The use of

attachments has expanded the range of movements that can be effectively managed with clear aligners, making them a versatile tool in the orthodontist's arsenal.¹⁵ Additionally, the incorporation of elastics and other auxiliary devices in conjunction with clear aligners has further improved their capability to treat complex malocclusions. Elastics can be used to apply additional forces in specific directions, aiding in the correction of bite issues such as overbites or crossbites. By combining clear aligners with these auxiliary devices, orthodontists can achieve comprehensive treatment outcomes comparable to those of traditional braces, but with the added benefits of aesthetics and patient comfort.

The innovative approaches to aligners and force application techniques have significantly enhanced the scope and effectiveness of clear aligner therapy. Advances in materials, digital design and fabrication, and auxiliary force application methods have collectively broadened the applicability of clear aligners, allowing for the successful treatment of a wide range of malocclusions. As these technologies continue to evolve, clear aligners are likely to play an increasingly prominent role in orthodontic treatment, offering patients effective and aesthetically pleasing solutions for their orthodontic needs.

CONCLUSION

Biomechanical innovations in orthodontics, including advancements in bracket systems, the use of TADs, and innovative aligner technologies, have significantly improved the management of severe malocclusions. These advancements have enhanced treatment efficiency, precision, and patient comfort, offering effective solutions for complex orthodontic cases. As these technologies continue to evolve, they will likely further expand the capabilities and outcomes of orthodontic treatment.

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