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Evolving Trends in Orthodontics: Clear Aligner Therapy, Bio-mechanical Principles, and Custom Attachments

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Abstract: Orthodontic treatment has evolved significantly in recent years, with a growing emphasis on meeting patients' aesthetic demands. Using a series of custom-made plastic aligners, clear aligner therapy has gained popularity for treating mild to moderate malocclusions. This article traces the history of clear aligners, from their initial concept in the 1940s to the advent of computer-aided design (CAD) and 3D printing in the 1990s, exemplified by Align Technology's Invisalign system. While clear aligners offer advantages but have limitations, including their suitability for complex cases, patient compliance requirements, and cost considerations. The bio mechanical principles underlying clear aligner therapy are explored, focusing on two mechanisms: shape moulding, where aligners gradually adjust tooth positions, and using auxiliary elements to improve forecast accuracy. Custom attachments have emerged as a promising innovation to optimize tooth movements, approaching the precision achieved with traditional fixed appliances.

Keywords: Esthetic demands, History of clear aligners, Bio mechanical principles, Auxiliary elements, Custom attachments

Introduction: An orthodontic method involving a sequence of clear plastic removable devices (known as "aligners") that gradually shift teeth from their initial position to a desired final state. In recent times, there have been notable advancements in the field of orthodontics, and these have coincided with a marked uptick in patients' expectations related to aesthetics. Many individuals now seek a more active role in shaping or defining treatment parameters and objectives in collaboration with their orthodontists. This desire is primarily rooted in orthodontic appliances' impact on their overall appearance. Over the last two decades, clear aligners have gained growing popularity as an alternative to fixed appliances in treating mild to moderate malocclusions. This is mainly because Clear Aligner Therapy (CAT) is susceptible to swift technological advancements that influence the materials used, the design of the appliances, and their manufacturing processes.

History: The concept of utilizing an aligner for the purpose of straightening teeth was initially proposed in the 1940s by Kesling when he devised a dental appliance for refining the concluding stages of orthodontic therapy as described by Kesling in 1946. It was in the 1990s that the use of CAD and 3D printing for making aligners gained popularity. In 1997, Align Technology introduced Invisalign, using CAD/CAM tech to create custom transparent plastic aligners. These aligners, made from thermoplastics, are ideal due to their transparency meeting the aesthetic requirement. They work best for mild to moderate orthodontic issues involving horizontal, vertical, or rotational tooth adjustments within a specific range.

Clear aligners have gained popularity as a viable substitute for conventional metal braces in orthodontic therapy, they do have some limitations to their effectiveness. Here are some of the most significant limitations of aligners:

a) Complex cases: They may not be optimal for more intricate situations like severe malocclusions or skeletal disparities. Invisalign achieved an mean accuracy rate of 41% in terms of tooth realignment.
b) Compliance: Due to the necessity of a high level of compliance for this system to function optimally, the Invisalign System is presently advised exclusively for adults. However, adolescents with fully erupted permanent teeth (excluding third molars) may also qualify for this method, provided they have undergone a compliance assessment.
c) Limited control over the position and rotation of the teeth.
d) Cost

Biomechanical principle: To ensure CAT's efficacy, a comprehensive grasp of the underlying bio-mechanical principles of aligners becomes imperative. Orthodontic procedures employing aligners adhere to a methodical regimen, incorporating a series of consecutive aligners or trays. These aligners facilitate a gradual modification of tooth positions through incremental

adjustments depending upon the amount and complexity of tooth movement are driven by two primary mechanisms:

Shape moulding: Since its introduction in the 1940s, clear-aligner treatment has remained the primary modality for applying forces in orthodontics. This approach is inherently force-driven, necessitating a deep understanding of biomechanical principles to orchestrate the precise movement of teeth.

Aligners are crafted to exert controlled forces upon the dentition, although their shapes may not mirror those of the individual teeth. Instead, aligners mould the trajectory of tooth movement to align with their specific contours. This procedure integrates pre-existing discrepancies (activation) between the aligner's form and the teeth structure, generating intricate three-dimensional (3D) force systems that span across the complete contact areas.

Within this system are regions of close contact and minimal pressure (relief) between the aligner and the tooth surfaces. A comprehensive treatment regimen comprises of series of aligners, each featuring progressively modified shapes, which guide the transition to the desired tooth positions from the commencing anatomical configuration.

Auxillary elements: Auxiliary components are essential in enhancing the reliability of making tooth adjustments within force-driven system. This system relies on bio-mechanical principles to facilitate tooth movement. Aligners are crafted to exert targeted forces on the teeth. The careful positioning of these supplemental elements within aligners or on the tooth's surface can optimize the delivery of force. They are trategically employed to apply forces precisely to specific regions of the tooth's surface.

Auxiliary components are essential aspects in achieving crucial orthodontic movements by enhancing the definition of the contact area, creating localized disparities at specific points, and ensuring precise control of loads in terms of both intensity and direction.

Custom attachments: Andrews (1979) introduced the concept of the definitive fixed appliance system, which centred on using designated brackets for each tooth to guide them into their ideal positions. This was achieved through the application of a rectangular bracket slot, facilitating two primary types of tooth movements achievable with fixed appliances, which are as follows:

A. bodily movement, where the crown and root move together in harmony
B. tipping movements, characterized by the crown's displacement while the root tip remains stationary

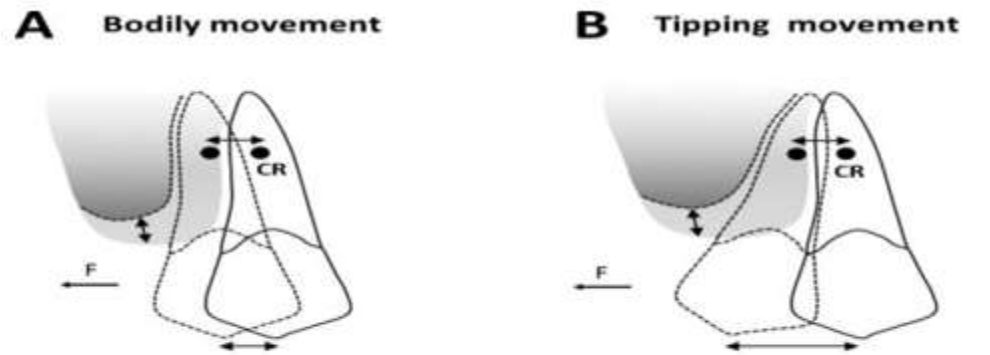

Fig 1- Bodily (A) and tipping (B) tooth movement in the displacement of the tooth crown, centre of resistance (CR), and the alveolar bone resorption. The dotted line represents the tooth after movement. F indicates orthodontic force.

Achieving orthodontic tooth movement through CAT clear aligner treatment is a more intricate process compared to fixed appliances. This complexity can be attributed to several factors, including:

I. The lack of defined locations for the application of force.

II. Differences in tooth structure and the characteristics of aligner materials.

III. Inconsistencies in the alignment between the aligner and the dentition.

IV. Movement or shifting occurring between the shapes in contact.

V. Multiple factors related to biomechanics.

To enhance predictability and improve duration of time, a practical solution involves incorporating a dependable and personalized adjunts to clear aligners. Incorporating this enhancement can minimize the need for numerous adjustments.

In recent times, aligners have advanced by incorporating attachments to generate moments of force (MoF) and couple (MoC), bringing them closer to the idea proposed by Andrew of pre-configured attachments designed for individual teeth.

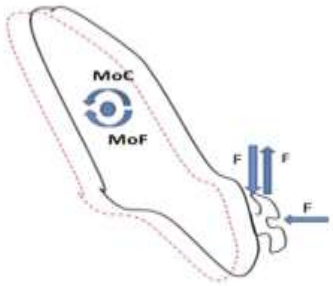

Fig 2- Diagram depicting the notion of bodily movement. The opposing rotational effects of moments of force (MoF) and couple (MoC) cancel each other out.

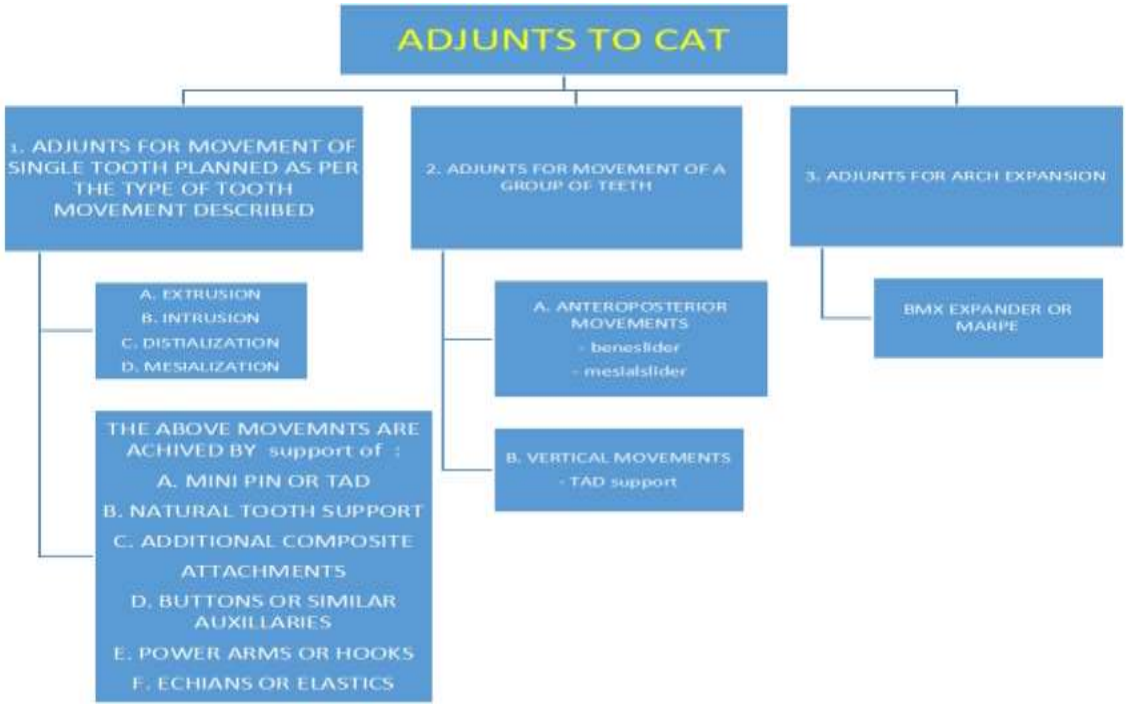

Fig 3 - Different types of Adjuncts to CAT

Conclusion: This paper assesses the reasons behind the increasing preference and forecasts for Clear Aligner Therapy (CAT) over traditional orthodontic methods. The factors influencing the success of any aligner system can be attributed not only to the orthodontist's profound grasp of the biomechanics of aligners but also on the clinician's expertise, appropriate patient selection, and the patient's compliance to the treatment plan.

Furthermore, we shift our focus to recent developments in orthodontic technology. During this period, various aligner devices have undergone significant enhancements, incorporating additional components designed to improve the precision and efficacy of controlling the movement of teeth and the efficacy of clear aligner treatment, bringing it closer to achieving the desired tooth movements and treatment objectives.

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