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ATTACHMENTS IN CLEAR ALIGNER THERAPY – A REVIEW

R.Parameshkumar [1], Janani ravi [2], Dilip Srinivasan [3], K.Ravi [4]
[1] Post graduate student, Orthodontics, SRM dental college, Bharathi salai, Chennai.
[2] Senior lecturer, Orthodontics, SRM dental college, Bharathi salai, Chennai.
[3,4]Professor, Orthodontics, SRM dental college, Bharathi salai, Chennai.

Abstract
Clear aligners are transparent, removable orthodontic appliances designed to straighten teeth discreetly and comfortably. They offer an aesthetic alternative to traditional braces, using a series of custom-made trays to gradually move teeth into alignment. Attachments play a critical role in enhancing the effectiveness and biomechanics of clear aligner therapy (CAT), enabling controlled and predictable tooth movements which would otherwise be challenging with aligners alone. These small, tooth-colored composite additions improve aligner retention and serve as force transducers to facilitate complex movements such as rotation, extrusion, and root torque. Different shapes and types including optimized designs tailored through digital planning allow for individualized treatment strategies. While attachments improve clinical outcomes, they may compromise aesthetics and require careful bonding and maintenance. This article will discuss about all the attachments types that we commonly use with aligner treatment that which help in achieving the orthodontic tooth movement.

INTRODUCTION

Clear aligners are removable clear plastic trays or molds predominanty made up of polyurethanes and polyethylene terephthalate that are customized to fit an individual's teeth to straighten them to a perfect smile. Aligners have to be worn over a treatment period with each stage gently applying pressure to move the teeth, a step at a time to its desired position. The history of clear aligners may be traced back to 1945, when Dr H D Kesling first proposed a clear vacuum formed tooth positioning appliance for minor tooth movement. (1) Design for the thermoforming system began in April 1997 by two MBA students from Stanford university, Zia Chishti and Kelsey Wirth, who with the aid of a computer specialist, found Align technology in a garage in Palo alto, California. (2) Clear aligner technology has evolved over the last 15 years, with these appliances continually being modified to increase the range of tooth movements that they can achieve. Compared to other removable appliances, some tooth movements such as extrusion, rotation and root control were difficult to control using aligners, which has led some companies to introduce buttons made of composite resins known as "attachments". Attachments are placed on tooth surfaces as retentive elements to improve the efficiency of the aligners in achieving tooth movements that would be difficult to achieve using the aligners alone. (3) Dental attachments are small geometries made of tooth-coloured material and attached to the teeth, as part of clear aligner therapy. They facilitate tooth movement in clear aligner treatment. Attachments serve as a handle on which the aligners apply force to bring about the desired teeth movements. They are made from composite resin, a tooth-coloured material that can be bonded to the tooth. Attachments are force transducers that seem to improve the biomechanics of invisible aligners. Essentially, these are a protrusion of composite material polymerized onto tooth surface, applied in order to improve aligner retention and to obtain orthodontic movements previously considered critical to achieve. (4) Attachments mostly increase the effectiveness of orthodontic treatment with clear aligners, improving anterior root torque, rotation, and mesio-distal movement. They provide an active surface on which the aligner can exert force to bring about complex tooth movements. Thus, these tiny tooth handles enhance the efficiency of aligners and increase the predictability of teeth movement. Aligner attachments serve as an important auxiliary device for many clear aligners to transfer the forces from the aligner to the tooth. Aligner attachments have different shape varying based on the biomechanical needs of a case. Bond failure or patient neglect can cause attachment loss from the tooth surface. Attachment loss can induce significant clinical problem that may prolong treatment time,

increase the number of revisits, and the prognosis of the treatment. [5] This article will provide a insight into different attachment types and designs and how they are used in achieving different orthodontic tooth movements.

Attachments in aligners

Attachements may be classified into two categories

1. Conventional attachments
2.Optimized attachments

1.Conventional attachments

Conventional attachments are passive attachments that increase the engagement of the aligner into the tooth. They act as a handle for the aligners to move teeth. They can be placed by the clinician while deigning and includes standard shapes, which can be decided based on the type of tooth movement desired.There are three types of conventional attachments:

1.Ellipsoid attachments
2.Rectangular attachments
3.Bevelled attachments

1.Ellipsoid attachments: Used for retention or anchorage when the tooth surface area is limited, for example for peg-shape lateral incisors or the lingual surface of a lingually inclined mandibular second molar. (Fig 1)

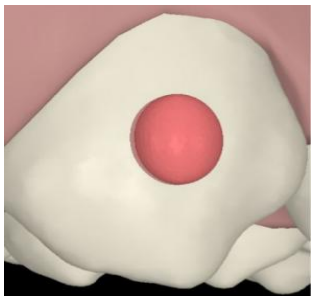

Fig 1: Ellipsoid attachments

2. Rectangular attachments: These are passive attachments that can be vertical or horizontal. By default, they are placed in the middle of the tooth crown, but can be moved to any desired position to facilitate the mechanics that have been planned for the case. They are two types of rectangular attachments

a. Horizontal rectangular: Horizontal rectangular attachments can be used for root control, especially for labial root torque on the molars. These can also be used in short crowns in order to increase the retention of the aligners, which is part of the standard Align's protocols for patients that are still growing in interventions such as mandibular advancement or first protocols (similar to this, but optimized). In unilateral crossbites, horizontal rectangular attachments are used in the side without the crossbite in order to provide anchorage to correct the unilateral posterior crossbite on the contralateral side. (Fig 2)

Fig 2: Horizontal rectangular attachments

b. Vertical rectangular: These are used for root control when the software cannot place optimized root control attachments, such as mandibular incisors in cases involving the extraction of one lower incisor. (Fig 3)

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Fig 3: Vertical rectangular attachments

3. Bevelled attachments: They are two types of bevelled attachments. (Fig 4)

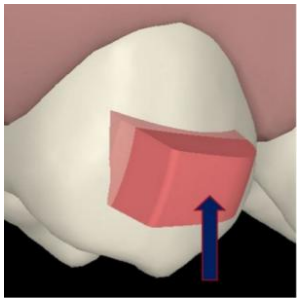

Fig 4: Bevelled attachments

a. Horizontal attachments: Horizontal attachments can be bevelled to the occlusal (HBO) or to gingival (HBG) to help with intrusion or extrusion movements:
-For extrusive tooth movements on posterior molars, a horizontal attachment bevelled to gingival can be used.
-For intrusion, use the horizontal attachment bevelled on the occlusal on the teeth adjacent to the one that has to be intruded.
b. Vertical attachments: Vertical attachments can be bevelled to mesial (VBM) or to distal (VBD): for rotation movements when the software has not placed optimised rotation attachments, for example when correcting first molar rotation. The bevelled surface is the active one, as the bevel provides a flat surface for the aligner to push against to achieve the desired tooth movement.
2. Optimized Attachments
Designed to provide optimal force to achieve a more predictable movement, Tailor-made for each tooth's width, long axis and contour, positioned precisely to deliver the forces while simultaneously eliminating interferences All these characteristics are defined by the ClinCheck software and do not permit changes by the practitioner.
Optimized attachments provide SmartForces applied to the teeth. They provide the amount of force necessary to create the ideal movement of the tooth. In addition:
They are automatically placed by the software when it detects certain thresholds of tooth movement. They are designed to control the point of application of the force, the direction of the force and the amount of force applied.
Currently available optimized attachments include:
1. Optimized Rotation Attachment: These are placed for rotation of canines and premolars greater than 5 degrees:
- Placed when more than 5 degrees of rotation is needed.
- The predictable rotation is between 30 and 45 degrees.

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● If one needs to be replaced for a conventional one, it will be a vertical rectangular attachment bevelled too mesial or distal. (Fig 5)

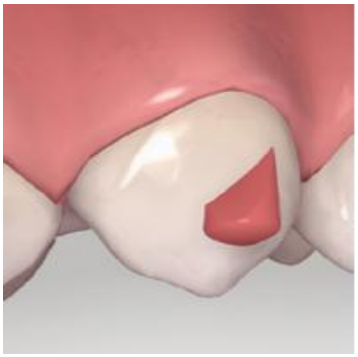

Fig 5: Rotation attachments

2. Optimized Extrusion Attachment: Designed for extrusion of incisors, canines and premolars, these attachments are bonded in the middle of the crown:
● They are placed when the extrusion is more than 0.5 mm and have a wedge shape
● When they are placed on lower premolars, they are used as an anchorage for the anterior intrusion of the incisors and they have a different shape
● They can also be activated to provide an extrusion force on the premolars during the anterior intrusion
● When extrusion of the four upper incisors is greater than 0.5 mm the four teeth will act as a single unit and attachments will be required to correct the open bite (Fig 6)

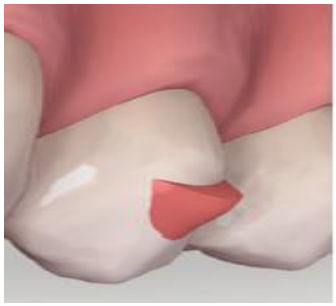

Fig 6: Extrusion attachments

3. Optimized root control attachment: These are designed for upper central upper incisors and lower canines, where they will control root movement, for tipping management and 'en masse' translation
● They have two active surfaces and are placed when there is a translation of the tooth centre of resistance greater than 0.75 mm (Fig 7)

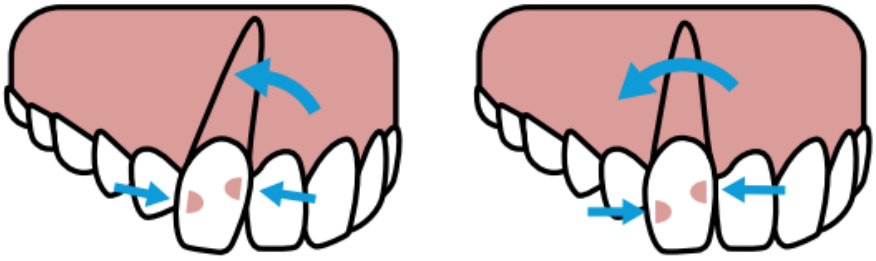

Fig 7: The figure on the right shows how optimized root control attachments create a couple of forces to improve root tipping

4.Optimized Attachments for Lateral Incisors:
a. Multiplane Attachment:

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● Placed when the lateral incisors need intrusion or extrusion while simultaneously requiring rotation, torque or tipping movements.
● They have an active surface on the attachment and a lingual pressure point. (Fig 8)

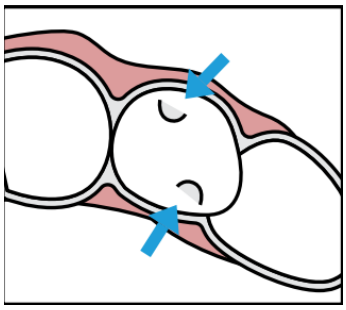

Fig 8: Combination of attachments and lingual pressure points help creating an excellent force system.

b.

Optimized Support Attachment:
● Placed on lateral incisors when 1 mm or more of intrusion is planned on adjacent canine or central incisors, similar to the example given for posterior intrusion, but with characteristics adapted to lateral teeth clinical crowns.
● The aim of these attachments is to prevent tracking problems on the lateral incisors during the vertical correction of the central incisors and the canines. (Fig 9)

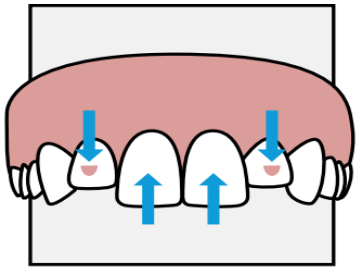

Fig 9: Attachments are designed for support instead of movement

5. Optimized attachments on molars:
These are automatically placed by the software for anchorage purpose and to assist the molars to move in different planes of space. (Fig 10)

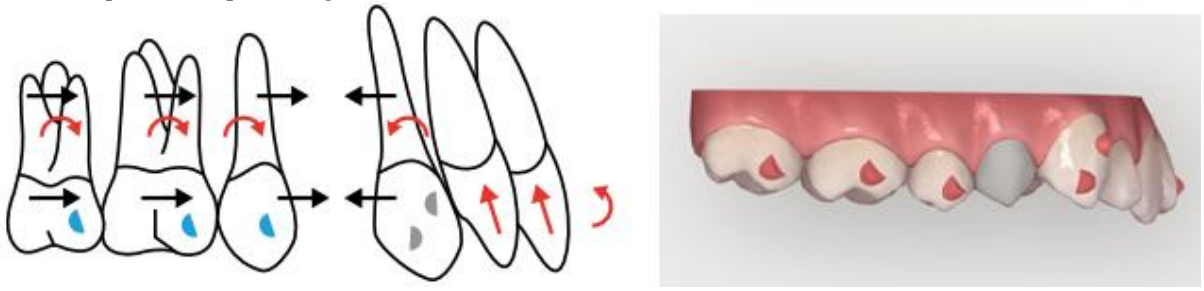

Fig 10: Attachments for molars are relatively new and provide improved root movement.

a. Multiplane Attachments for Molars:
● Optimized multiplane attachments are designed for molars that require rotation correction and a vertical correction of intrusion or extrusion at the same time.

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● For extrusion + rotation, equal to or more than 0.5mm extrusion and 5 degrees of rotation about the long axis of the tooth.
● For extrusion/intrusion, between 0.5 mm intrusion/extrusion and more than 5 degrees of rotation about the long axis of the tooth. (Fig 11)
● For intrusion, equal to or less than 0.5mm intrusion and 5 degrees of rotation about the long axis of the tooth (Fig 12)

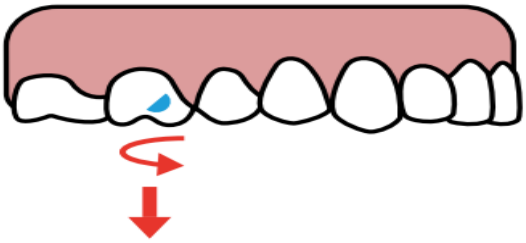

Fig 11: Mesiobuccal rotation combined with extrusion

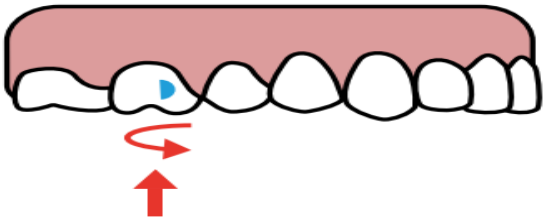

Fig 12: Mesiobuccal rotation combined with intrusion

b. Optimized Extrusion Attachments for Molars:
These help with the extrusion of the molars, for extrusion + rotation, more than 0.5mm extrusion and less than 5 degrees of rotation about the long axis of the tooth. (Fig 13)

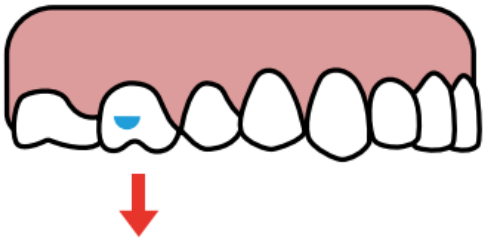

Fig:13 Molar extrusion.

6. Optimized support attachments:
These provide support for predictable dental arch expansion. (Fig 14)

Fig 14: Optimized support attachments are commonly used in first treatments.

Biomechanism of attachments in aligners Anterior extrusionCorrection of open bite based solely on anterior extrusion is to be viewed with caution because of possible negative effects such as root resorption, periodontal deterioration, instability, and unfavorable esthetics. along with these clinical restrictions, aligner extrusion poses mechanical limitations in anterior teeth in which buccal and lingual crown surfaces converge towards the incisal edge facilitating aligner dislodgement and rendering this type of tooth movement virtually impossible without the use of supplementary composite attachments. Gingivally oriented, inclined plane configuration provides a force system that improves predictability of this type of movement. [6] The importance of attachment design can be illustrated with a graphic simplication of a

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complex interaction of vectors. The resultant force acting on the incisor is derived from the two red arrows that represent buccal and lingual forces present during aligner-based extrusion. Reducing the angle formed by the active surface of the attachment and the buccal surface of the tooth will result in a stronger resultant force. Clinicians must be wary of excessive reduction of this angle, which along with excessive force may produce diffculty of aligner-attachment engagement with the ensuing localized plastic deformation. (Fig 15)

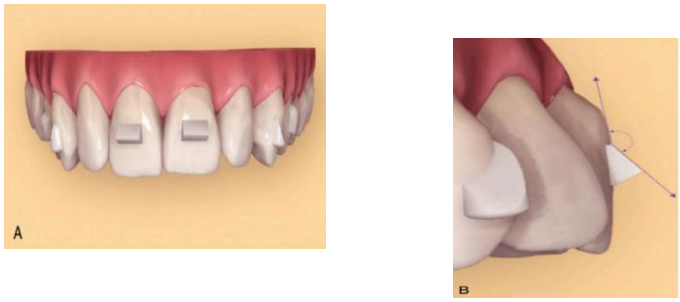

Fig 15:

A) Optimized extrusion Attachments on central incisors.

(B) Gingivally oriented inclined plane with optimal active surface angulation.

Posterior intrusion

Recent studies suggest that the presence of interocclusal plastic during aligner treatment may produce a bite-block effect that potentiates bite closure and posterior intrusion capabilities.[6] This improves treatment outlook, especially in cases in which anterior extrusion is not desirable and intrusion of posterior teeth, with the clockwise mandibular rotation, are to be considered as part of the strategy for bite closure. Intrusive forces acting in the posterior region will tend to dislodge the aligner in the occlusal direction. Even with light posterior intrusive forces, an opposite, reactive force should be expected in the anterior arch that will tend to vertically dislodge the aligner. Gingivally positioned rectangular horizontal or occlusally attachments beveled towards the incisal edge should provide the necessary aligner stability for optimal treatment progress. (Fig 16)

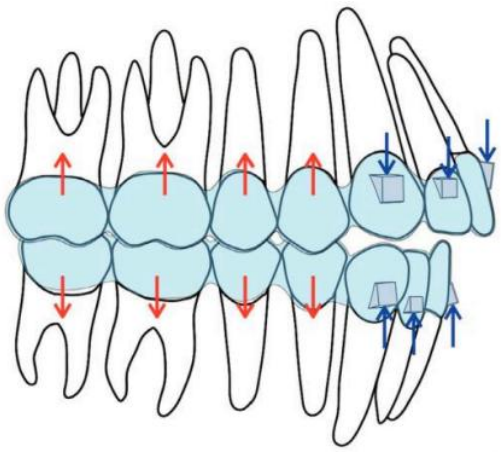

Fig 16: Intrusion in the posterior segment (red arrows) produces reactive forces that will tend to dislodge the aligner anteriorly (blue arrows) Adequate attachment selection on anterior teeth will counter act this undesired occurrence.

The tipping movement

This is the easiest move to obtain when a force is applied against the crown.

a) Uncontrolled tipping:

A study was carried out by Baldwin et al in 2006 to describe the movement of teeth adjacent to premolar extraction spaces during space closure with aligner appliances and then fixed appliances. In this study, treatment with aligners resulted in significant tipping of the teeth adjacent to premolar extraction sites. [6] (Fig 17)

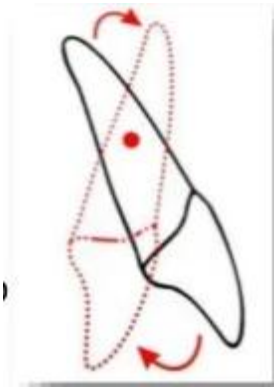

Fig 17: Uncontrolled tipping

b) Controlled tipping:

As described in the literature, tipping is predictable with thermoplastic aligners, but it remains difficult to establish comparable root control. However, there is a side effect of tooth movement with thermoplastic aligners called the 'water melon seed' effect, which refers to the unintentional intrusion of the displaced tooth triggered by an intrusive force caused by the distortion of the appliance. A study was performed by Gao & Wichelhaus in 2017 to evaluate the effect of material thickness on the forces and moments delivered by aligners to a maxillary incisor during tipping and intrusion. The calculated mean moment/force (M / F) ratio was between 8 and 9 (8.2) for tipping. [6] (Fig 18)

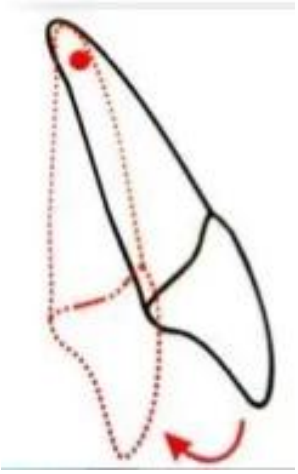

Fig 18: Controlled tipping

Torque

Torque movement with aligners can be done using Power - Ridges. They are supposed to apply a lingual or palatal force on the cervical part of the crown, which, when constrained by the plastic covering the incisal edge of the same tooth, creates a couple of forces, this couple is supposed to produce the lingual torque. Another method used in the Essix system is also effective: using Hilliard thermoplier or one layer of composite, two forces are applied simultaneously buccally and lingually of the target tooth. Controlling the torque of an upper central incisor requires the creation of effective couple of forces. [6] (Fig 19,20)

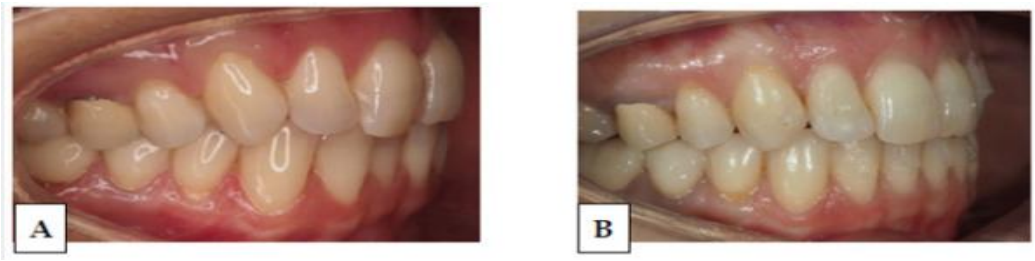

Fig 19: Comparative right lateral occlusion views before (A) and after (B) treatment showing the expression of torque in the upper incisors.

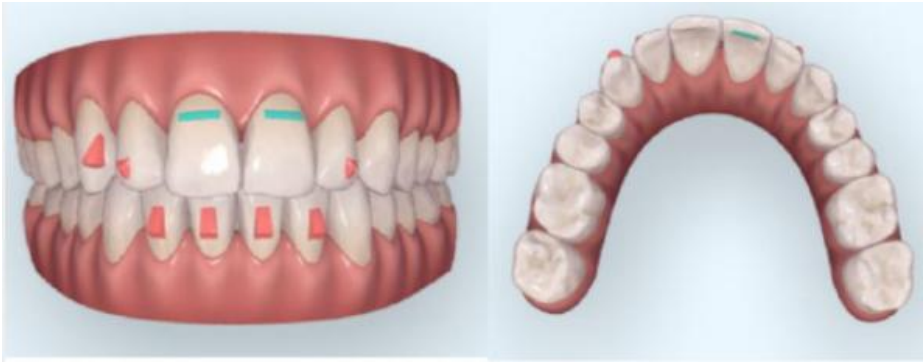

Fig 20: 3D simulation of objectified processing. The use of V and L "power-ridge" allows control root torque of the maxillary incisors to have a root lingual torque effect on 11 and 21.

Molar distalization:

A retrospective study was performed by Ravera et al [7] the results of which showed that the translational movement of the maxillary molars was achievable with the use of aligners in combination with composite attachments and class II elastics. The aligners allowed the maxillary second molars to be distalized by 2.25mm without version movement or significant vertical crown movements. Another study by Simon et al [8], focused on evaluating the effectiveness of aligners regarding incisal torque movement, premolar derotation, and molar distalization. Molar distalization marked the highest rate of accuracy, approximately 87% without the use of Class II elastics during treatment.

Power ridge

Power ridges are small indentations in clear aligners that apply gentle pressure to the teeth to move them into place. They are often used on the upper or lower incisors either on the labial or the lingual side to achieve better torque control. [9] Incorporating power ridges along with the aligner treatment in extraction cases helps eliminate roller coaster effects that occurs due to torque loss and the associated deepening of bite. These pressure areas can either be given as indentations in the 3D models prior to printing it, or by using precision tools like aligner pliers after printing the aligners [10]. There is bound to be a gap between

the aligners and the teeth because of these pressure spots and the patient should be advised of pain till they get used it (Fig 21)

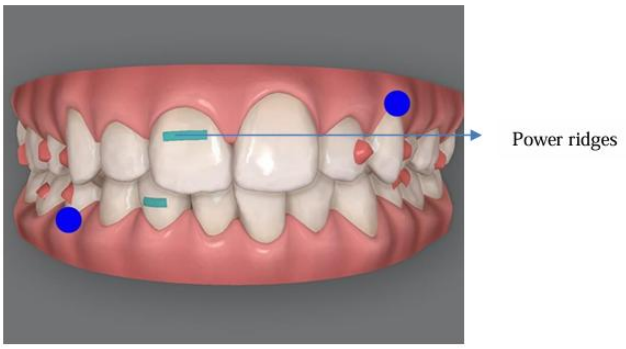

Fig 21: Power ridges

CONCLUSION

Clear aligners have evolved from a tool for treating minor Class I malocclusions to a system capable of addressing complex orthodontic cases. Initially limited to managing mild crowding with interproximal reduction, today's aligners can facilitate a wide range of precise tooth movements. Their discreet appearance, removability, and comfortable, customized fit make them especially appealing to adult and adolescent patients seeking aesthetic alternatives to braces. Additionally, clear aligners support better oral hygiene and can be used on both natural and prosthetic teeth. One of the most important advancements in clear aligner therapy is the introduction of attachments. These are small, tooth-colored composite projections bonded onto teeth that enhance aligner retention and act as force transducers. Attachments improve the biomechanics of aligners, allowing them to exert the necessary forces for movements such as rotation, extrusion, and root control. They come in various forms like conventional (e.g., ellipsoid, rectangular) and optimized (for specific functions like multiplane movement or anchorage support). Attachments are essential for achieving accurate anterior torque, mesio-distal movements, and stable posterior anchorage, making them a critical element in the effectiveness of modern clear aligner treatments.

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