IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 3 Ser. 6 (March. 2025), PP 46-52
www.iosrjournals.org

Comparison of adaptation of two different clear aligner attachment template materials

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Abstract:
Background*: Clear aligners are modern orthodontic devices used to straighten teeth without metal braces. Made from thermoplastic material, they fit snugly over the teeth and are removable. Attachments, small tooth-colored bumps, are placed on the teeth to help aligners apply the necessary force for effective tooth movement. These attachments are strategically positioned using attachment templates, which ensure precise placement by filling cavities in a thin plastic sheet with composite resin that is then cured. This technology allows for customized and effective orthodontic treatment.*
Materials and Methods*: Fourteen 3D printed models with attachments were created. Erkolen and Erkodur attachment templates were adapted and sectioned buccolingually along the distal molar surfaces. Microphotographs and micrometric gap width measurements of aligner fit was recorded at five levels using Scanning electron microscopy (SEM). The mean micrometric gap widths and fit changes were statistically analyzed using SPSS software using independent t test.*
Results*: No significant differences in aligner fit at different attachment levels were found. Least mean gap width was noted at the middle of the labial surface of the attachment (with average value of 7.56 µm) and the highest mean gap width at occlusal (average of 291.715µm) and gingival end of the attachment (average of 199.98 µm).*
Conclusion: *Both Erkolen and Erkodur template demonstrated lesser average gap widths between attachment and template and the results revealed no significant differences in the adaptation of two attachment templates. However, the Erkolen template is more user friendly, making it a more convenient choice in terms of ease of application. Ultimately the decision on which template to use depends on the orthodontist's preference based on the specific clinical requirements.*
Key Word*: Clear aligners; Attachment templates; Adaptation.*

Date of Submission: 13-03-2025 Date of Acceptance: 27-03-2025

I. Introduction

Over recent decades, there has been a significant shift in orthodontic treatment, particularly with the increasing demand for more aesthetically pleasing and less invasive solutions. Traditional fixed appliances, such as metal brackets and wires, have gradually been complemented by alternative options that offer both functionality and improved appearance. This change has been largely driven by the growing number of adult patients seeking orthodontic treatment, where aesthetics plays a critical role. Among these alternatives, clear aligners have emerged as a popular option due to their transparency, comfort, and convenience.[1] Unlike conventional braces, clear aligners are removable, offering patients the flexibility to maintain oral hygiene and eat without restrictions while still undergoing orthodontic treatment.

The material from which clear aligners are made plays a critical role in determining the success of the treatment. Polyurethane, the primary material used in clear aligners, is known to undergo changes as a result of exposure to the oral environment [3-5]. This factor, alongside the fit of the aligner to both the teeth and the anchorage attachments, is key to the success of achieving intended tooth movements.[2,6,7] Predicting the orthodontic forces delivered by clear aligners becomes more complex, and the duration for which these forces remain effective in the oral environment is a critical factor. Attachments play a pivotal role in delivering the planned tooth movement.

This study aims to compare the adaptability of two different clear aligner attachment template materials - Erkodur and Erkolen. To achieve this, we will employ scanning electron microscopy to analyse and assess the performance of each material in terms of their attachment capabilities and structural characteristics.

II. Material And Methods

This is an in-vitro study approved by Institute Research Committee (Ref.No.: RC/TDCH/35/2024). It was conducted in the Department of Orthodontics, Tagore dental college and hospital, Vandalur, Chennai.

This study aimed to assess the fit accuracy of clear aligner templates-Erkodur and Erkolen by examining how each template adapted to the 3D printed model. The study was based on the hypothesis that no significant difference would be found between the adaptational fit of both the aligner templates, suggesting both would achieve similar levels of conformity. The main outcome measured was the micrometric gap width— defined as the fine separation between the appliance surface and the attachments at five specific points of contact. By analysing these gaps, the study sought to understand how closely each template type adhered to its attachments, providing insight into the adaptational precision of each template.

In this study,3D printed models with attachments were generated using Maestro 3D Dental studio V6 designing software and slicing software: Chitu boxv1.9.5. These 3D models were fabricated using the STL file obtained by scanning ideal dental stone models which were available in the department. Phrozen aqua grey printing resin was used for printing the models and they were printed using LCD-Phrozen sonic mighty 8k printer,Phrozen tech co.,ltd.Taiwan (Figure 1). Fourteen 3D printed models were fabricated, each with properly fitted anchorage attachments. Two types of attachment templates were used: Erkolen and Erkodur templates; both with a thickness of 0. 6x125mm.Erkolen and Erkodur attachement sheets were adapted onto the 3D models with 14 attachments by thermocycling process (MINISTAR thermoforming machine -Scheu MINISTAR S® 230 V Henry Schein,Inc,Melville,N.Y was used). Once the templates were adapted, to prepare the samples for analysis, the imprints were sectioned buccolingually along the distal surfaces of the molars with attachments using a Microtome sectioning machine. The samples were carefully positioned to ensure that the cuts were made parallel to the long axis of the teeth. (Figure 2).

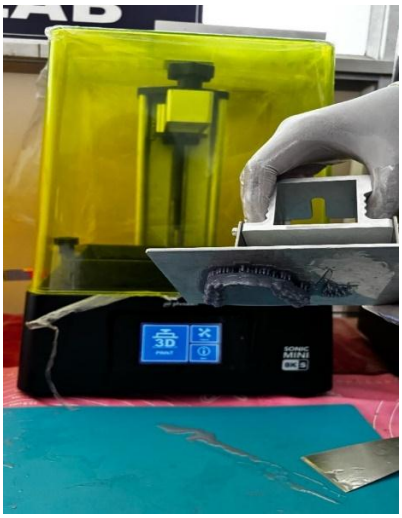


Figure 1: Phrozen sonic mighty 8k printer

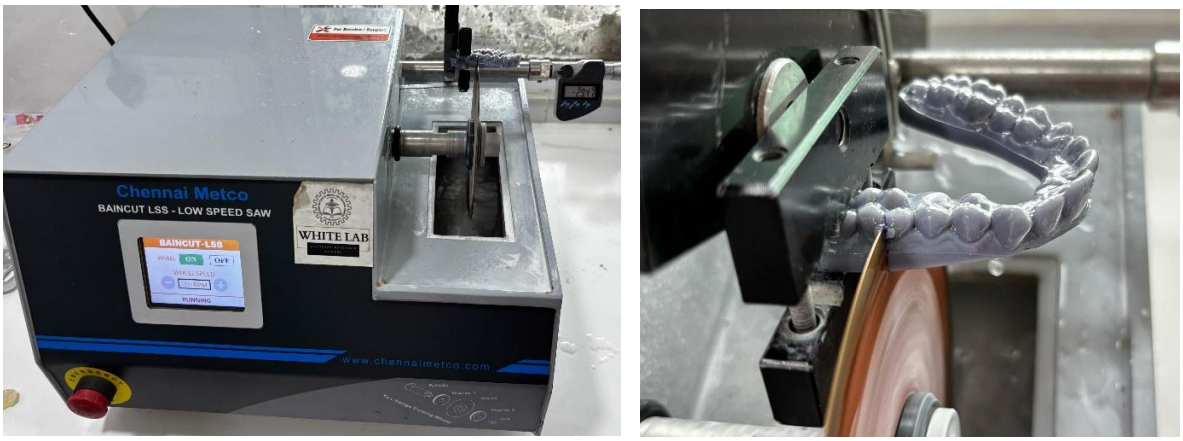


Figure 2 depicts the imprints which were sectioned buccolingually with attachments using a precision cutting machine. The cuts were made parallel to the long axis of the teeth.

Micrometric measurements were performed using a Scanning Electron Microscope (Apreo 2s HiVac-ThermoFisher Scientific,USA).The microphotographs of the prepared sections were captured to assess and document the micrometric gap widths in the fit of the aligners. The primary focus of these measurements was to determine the gap width (in micrometers, µm) between the attachment template material and the attachment on the acrylic imprint.

Measurements were taken at five specific locations on each surface (Figure 3), as outlined below:

- Level 1: The occlusal end of the attachment - A
- Level 2: The occlusal corner of the attachment -B
- Level 3: The labial midpoint of the attachment -C
- Level 4: The gingival corner of the attachment -D
- Level 5: The gingival end of the attachment - E

A total of 70 micrometric measurements were obtained and analysed using Imaje-J software, providing a thorough evaluation of the aligner template's adaptability and fit at each of these key contact points. This detailed assessment allowed for a precise understanding of how effectively the aligners conformed to the attachment points across all measured areas.

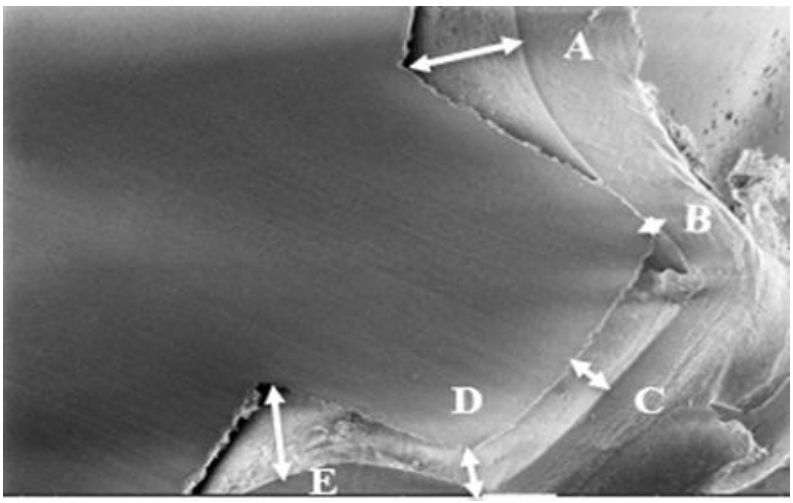


Figure 3. Scanning electron microscope image showing the micrometric measurements for the distance between the appliance and attachment (gap width) at five levels: (A) Level 1: occlusal end of attachment; (B) Level 2: occlusal corner of attachment; (C) Level 3: labial middle of attachment; (D) Level 4: gingival corner of attachment; and (E) Level 5: gingival end of attachment.

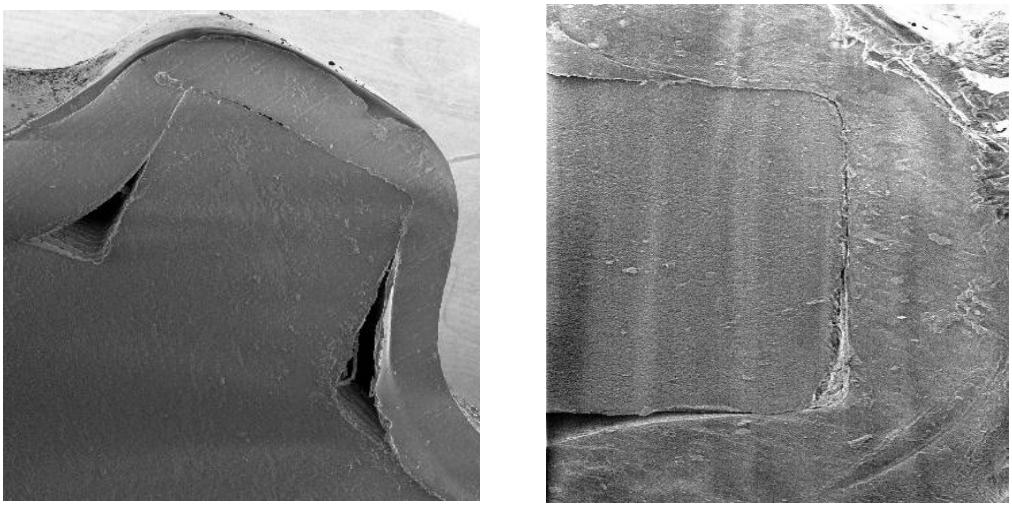
Statistical analysis

A statistical analysis was conducted using SPSS (Statistical Software for Social Sciences) to compare the differences between adaptation of both Erkolen and Erkodur templates. An independent samples t-test was used

to evaluate the significance of differences in mean values between the two attachment templates within each group. The results showed no statistically significant differences between both the groups in any of the attachment level, as indicated by p-values greater than 0.05. Point A exhibited the highest mean values for both template types, while points B, C, and D showed relatively lower values. The standard deviations varied across groups, with some showing higher variability in measurements. Overall, the statistical analysis indicated no significant differences between Erkodur and Erkolen across all tested conditions.

III. Result

Scanning electron microscope (SEM) images that depict the fit of aligners with different attachment templates are shown in Figure 4. At all attachment levels, the Erkolen and Erkodur attachment templates showed similar mean gap width values ,However least mean gap width was noted at the middle of the labial surface of the attachment (with average value of 7.56 µm) and the highest mean gap width at occlusal (average of 291.715µm) and gingival end of the attachment (average of 199.98 µm) as shown in Figure 4(A and B).The largest mean gap widths found at the occlusal and gingival corners of the attachments, indicating a less optimal fit in these areas. The statistical analysis revealed no significant differences in the aligner fit between the two attachment templates.



A B

Figure 4. Representative SEM images for aligner fit using different attachment templates: A-Erkodur, B-Erkolen (crosssection, 35x magnification)

IV. Discussion

Over the past few decades, orthodontic treatment has undergone a significant transformation, with a growing preference for more aesthetically pleasing and minimally invasive solutions. Traditional fixed appliances, such as metal brackets and wires, have been increasingly supplemented by alternative options that enhance both functionality and appearance. This shift has been largely influenced by the rising number of adult patients seeking orthodontic care, where aesthetics is a key consideration.

The material composition of clear aligners plays a crucial role in determining the effectiveness of the treatment[3-6,8-10]. As these aligners exert force on the teeth, their mechanical properties degrade over time. This process, known as stress relaxation, reduces the aligner's ability to maintain the necessary force for tooth movement.[11,12]

An aligner attachment template is a thin, disposable plastic sheet used to mark the location of attachments on teeth. The attachments are small, tooth-coloured buttons that are glued to the teeth to help move them into the desired position. Each one has a distinct function and comes in a variety of shapes. To achieve a particular movement of those teeth and aligner retention, they are positioned strategically on particular tooth sites. Ellipsoids, which are typically 3 mm tall, 2 mm wide, and 1 mm prominent; rectangular, which are typically 3, 4, or 5 mm tall, 2 mm wide, and 1 mm prominent, and rectangular beveled, which are typically 3, 4, or 5 mm tall, 2 mm wide, and 0.5-1.25 mm prominent, are the shapes of conventional attachments. When placed on molars, these traditional attachments are primarily utilized for anchoring and aligner retention. The incorporation of composite attachments in clear aligner treatments enhances rotational forces, while their application in both vertical and horizontal shapes has been shown to significantly improve tooth displacement.[15-17]

In this study, Erkolen and Erkodur of thickness 0.6mm were used as attachment templates to find micrometric gapwidth between the template and the attachment. Erkolen is manufactured by Erkodent Erich Kopp

GmbH. They are available in various thicknesses. Different thickness has different applications. Erkolen is thermoformed to fabricate intra-oral appliances such as copings (thickness 0.5 – 0.8 mm), spacer for fluoride (thickness-1.0 mm), temporary appliances-only mould (0.8 and 1.0 mm) and bracket transfer/etching masks (0.8 and 1.0 mm). The thickness recommendations are non-binding suggestions based on market observation. Erkolen material is soft, resilient, inodorous and transparent.

Erkodur template is also manufactured by Erkodent Erich Kopp GmbH. They are hard,elastic and resistant material. It is made from polyethylene terephthalate glycol (PETG), offering high stability, durability, and precise fit. They are used for different applications depending on their thickness:manufacturing of harder casting mold parts (0.5 and 0.6mm),corrective/aligner splints, retainers (0.6 - 2 mm),stabilization splints (0.8 - 1.5 mm),anti-bruxism splints,dressing plates, occlusal splints , orientation splints , planning and radiographic splints (1 - 5 mm).However,0.6mm of both Erkolen and Erkodur can be used as attachment templates.[13]

The primary goal of the study at hand was to evaluate the adaptational changes in two distinct clear aligner templates through the use of Scanning Electron Microscopy [14]. Micrometric gap widths from SEM image were analyzed using Imaje -J software and these measurements were taken by a single individual to minimize errors. By comparing these materials, researchers can assess how different properties of aligner materials affect the fit and effectiveness of the treatment[3-6,8-10]. In doing so, the study aimed to investigate the fit and alignment of the clear aligners in relation to different attachment templates and varying attachment levels.

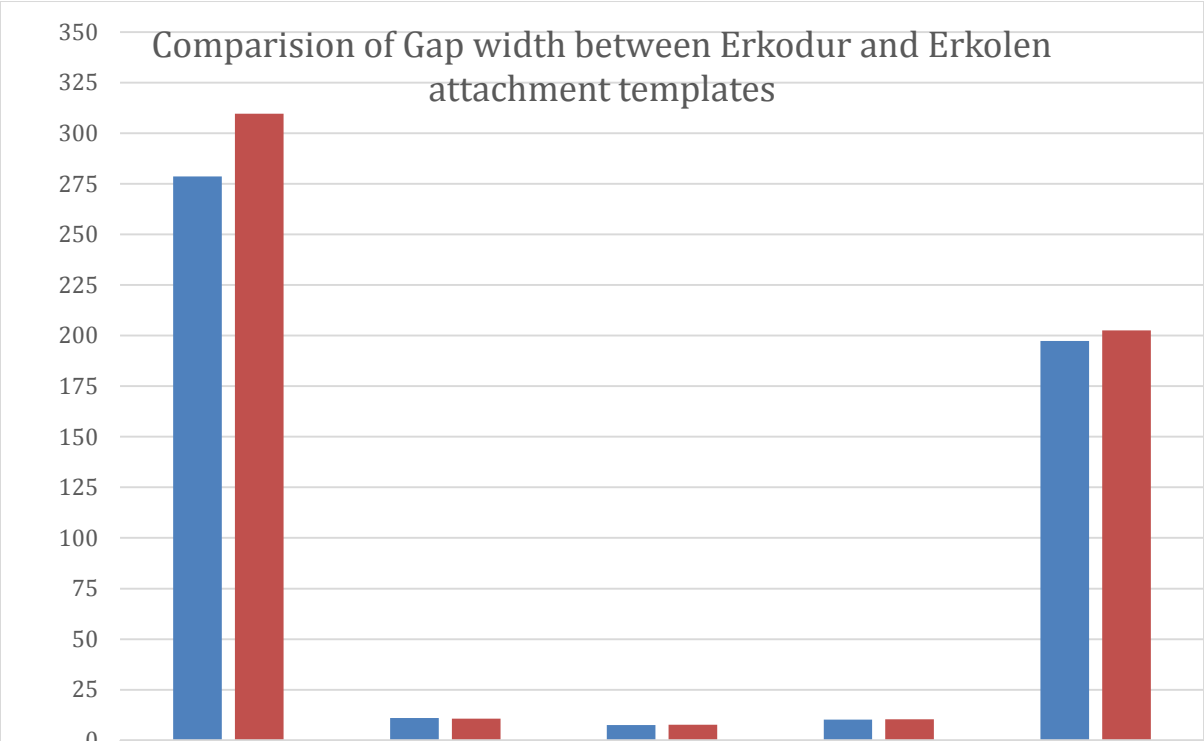
On statistical analysis between the adaptation of two different clear aligner attachment template materials,it has been concluded that there is no statistical significant difference between Erkodur and Erkolen as shown in Table 1.

GROUP	ATTACHMENT TEMPLATES	N	MEAN GAP WIDTH (in µm)	STANDARD DEVIATION	p - value
A	Erkodur	7	278.7443	49.7245	0.224
	Erkolen	7	309.6943	91.5205	
B	Erkodur	7	11.0429	1.7939	0.375
	Erkolen	7	10.7371	1.7141	
C	Erkodur	7	7.4786	2.7405	0.454
	Erkolen	7	7.6543	2.8266	
D	Erkodur	7	10.2586	6.3688	0,494
	Erkolen	7	10.3271	9.1658	
E	Erkodur	7	197.33	49.3227	0.442
	Erkolen	7	202.64	79.5632	

Table 1: Shows the mean gap widths between the two attachment templates – Erkodur and Erkolen evaluated at five levels – A, B, C, D, E

The increased gap width at A (occlusal end) and E (gingival end) compared to the reduced gap at B, C, and D is likely due to the inability of the template materials to adapt at sharp points and extremity. The middle regions (B, C, and D) experience greater contact pressure during aligner wear, ensuring better adaptation and reducing the gap width. Insertion and removal forces also play a role, as they distribute pressure unevenly across the attachment. Furthermore, minor discrepancies in the manufacturing or thermoforming process can contribute to variations in fit, leading to more space at the occlusal and gingival ends.

The statistical analysis demonstrated that there were no substantial differences in the fit of the aligner when comparing the two attachment templates (Table 2). The measurements and evaluations indicated that both templates provided a comparable level of adaptation, with no statistically significant variations in gap width or overall fit accuracy.



	A	B	C	D	E
Hard	278.7443	11.0429	7.4786	10.2586	197.33
SOFT	309.6943	10.7371	7.6543	10.3271	202.64

Table 2: Represents the comparison of micrometric gap widths at level A, B, C, D, E for Erkodur(Hard) and Erkolen (Soft)attachment templates

V. Conclusion

Both Erkolen and Erkodur attachment templates are effective and viable options for orthodontic use. However, the Erkolen template stands out for its user-friendly design, making it easier to handle and apply, which can enhance efficiency during clinical procedures. Despite this advantage, the final choice between the two templates should be guided by the orthodontist's preference, taking into account the specific clinical requirements and the unique needs of each patient.

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