ISSN: 1110-435X
ONLINE ISSN: 281-5258

Egyptian
Orthodontic Journal

Comparison between the effect of PETG and TPU aligner materials on Attachment surface wear

Mostafa K. Abdo*, Kareem M. Mohamed**, Wael M. Refai***

Abstract:

Aim: *The current study aimed to quantitatively evaluate the surface wear of same configuration of attachments in patients during clear aligner therapy using two different types of aligner materials.*

Materials & Methods: *20 lower 1st premolars on the same quadrant from 20 patients were recruited in the study. They were divided randomly into 2 groups (10 per group) one group treated with PETG aligner materials & the other treated with TPU aligner materials. Both groups had vertical composite attachment. The scans were taken just after bonding the attachments T0 and after 4 months T1. The volume of the attachments was calculated and analyzed.*

Results: *Both materials showed significant drop in size volume between the two time points (p-value: <0.001), PET-G was significantly associated with larger difference. The mean drop in volume was -3.9 mm³ in the PET-G group compared to only -2.5 mm³ in the TPU group (p-value: 0.016)*

Conclusion: *PETG aligner material causes more attachment surface wear and attachment damage than TPU aligner material*

Keywords: *PETG, TPU, Attachment surface wear*

Introduction:

Due to the rising demand, the field of orthodontic technology involving clear aligner therapy is expanding significantly[1,2]. Clear aligners are considered more aesthetically pleasing, more comfortable, and more practical for preserving periodontal health when compared to traditional fixed appliances[3,4]. Nevertheless, because of their mechanical characteristics, clear aligners are still somewhat ineffective for treating complicated tooth movements including torque, rotation, and extrusion.[5,6]

In response to patients' desires, auxiliaries such as bite ramps, precise cuts, power ridges, and composite attachments have been introduced by manufacturers enhancing the therapeutic qualities of their products and enabling the use of aligners for the treatment of a wider range of malocclusions[7]. Thanks to the use of composite attachments, different movements of the teeth can be controlled and guided more effectively, increasing the surface area of contact and placing the point of force loading closer to the center of resistance, so enabling a better bodily tooth movement[8]. As a result, composite attachments started to be used exclusively in aligner treatments. However, achieving the intended teeth movement clinically is frequently still difficult[9].

*** Assistant lecturer of orthodontics, Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Aswan University, Egypt.**

**** Associate professor of orthodontics, Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Minia University, Egypt.**

***** Professor and Head of Orthodontics and Dentofacial Orthopedics Department, Faculty of Dentistry, Minia University, Egypt**

In order to transmit the forces from the aligner to the tooth root and crown, aligner attachments are a crucial supplemental tool for many clear aligners. Generally, attachments are automatically positioned in precise spots on teeth that are chosen by a computer program. These attachments regulate the force's direction, application point, and amount. When necessary, the various forms of aligner attachments can improve control and retention of certain tooth movements[10].

Attachments materials should have certain qualities. The mechanical and aesthetic qualities of the materials used for attachments should be adequate. Both stain resistance and color matching to real teeth are essential for these material[11]. In addition, the material must be highly resistant to wear because aligners are taken out frequently. The slow loss and distortion of materials on solid surfaces is referred to as wear. The interactions between two surfaces moving relative to one another, whether mechanical or chemical, cause this phenomenon[12]. The continual maintenance of attachment geometry and integrity is crucial for ensuring full usage of these devices during orthodontic therapy. Treatment results may be impacted by attachment wear, which could compromise the anchorage control[13].

Attachment loss may be due to several risk factors, such as variables connected to the operator or the patient. According to a recent study, attachment loss may result from frequent aligner removals (more than or equivalent to five times per day) and traditional attachments. However, using aligners during mealtimes can help avoid attachment loss[14]. Although the effects of clear aligner orthodontic treatment have been extensively investigated, little is known about the occurrence of composite attachment loss and how it affects clear aligner therapy. Most of the existing research on attachment surface wear has been conducted in vitro or as qualitative in vivo investigations. Barreda et al.[15] utilized a scanning electron microscope to study the surface wear of attachments through a six-month period. They stated that after six months of treatment, surface wear started to appear and that the composite resin Filtek Z350 XT (3 M ESPE, USA) showed superior wear resistance. After performing a visual inspection, Lin et al.[16] found that the first-year damage rate for attachments was roughly 12%. Using an in vitro test, Chen et al.[17] examined the wear resistance of three different types of composite resin used for attachments. They came to the conclusion that there was more volume loss in the Filtek Z350 XT Flowable composite resin (3M ESPE, USA). Few in vivo investigations have been carried so far to assess attachment surface wear quantitatively. Accordingly, the aim of the present study was to quantitatively evaluate the surface wear of same configuration of attachments in patients during clear aligner therapy using two different types of aligner materials.

Materials & Methods:

The sample of participants of this study was calculated and 20 teeth with the same attachment were recruited in the study. The sample consisted of 20 patients (10 per each group) among patients receiving orthodontic therapy with clear aligners from the outpatient

clinic in the Department of Orthodontics, faculty of dentistry, Minia University, Egypt. The study protocol was approved by the Research Ethics Committee of the same faculty. All participants signed informed consent forms. The inclusion criteria were as follow: 1) All patients should be free of any systemic diseases that might affect tooth movement and are in permanent dentition. 2) All patients are 18 years old or above with negative history of previous orthodontic treatment. 3) All the patients should have class I malocclusion with crowding less than 4 mm.

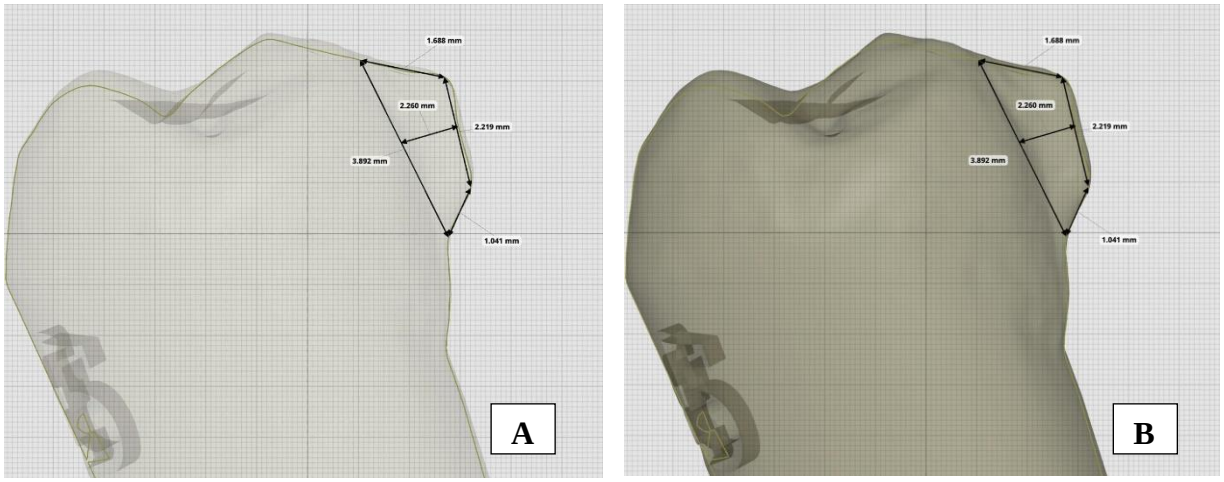
All the candidates in the study were divided randomly using the sealed envelope method into 2 groups: Group A (10 candidates): They had aligners made of Memoflex aligner material as PET-G with vertical composite attachment on the lower 1st premolar. Group B (10 candidates): they had aligners made of Zendura FLX assigned as TPU with vertical composite attachment on the lower 1st premolar. All attachments were placed by the software into the same position having the same size.

Before starting of orthodontic treatment, all the required radiographic and clinical data were collected. Dental malocclusion was already set in the inclusion criteria. Intraoral scanning with Medit I700 was performed at various times: before treatment (T0), immediately after the initial bonding of attachments (T1) and after 4 months (T2) of beginning of orthodontic treatment. All digitized models were saved in stereolithography (STL) format. The clinical information of the attachments, including arch, tooth position, and type, was noted. Lost attachments that were recorded during participants' regular appointments were excluded from the final measurements.

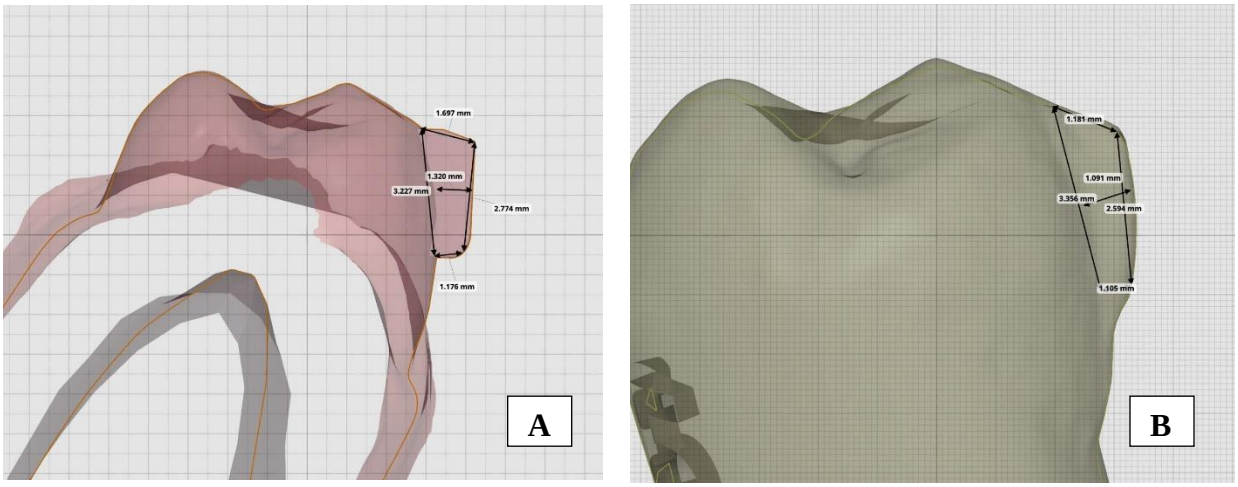
All attachments for the included participants were bonded using Nexcomp. (Meta BioMed, Republic of Korea) flowable nano hybrid composite resin according to the manufacturer's instructions. All participants were instructed to change aligners every 14 days and wear them for at least 22 hours per day. Aligners were to be removed before eating and replaced after tooth brushing. All participants received professional oral hygiene instructions. A one-month follow-up cycle was assigned for each participant.

Teeth and attachments segmentation and Measurements:

All digitalized models were imported into Medit Link software (Medit Labs, Medit Inc, Korea) to accomplish the segmentation of attachments for each model in both groups for T0 & T1 and all recruited lower premolars with vertical composite attachments were analyzed and the length width and height of the attachments were measured by the software. (Fig.1, Fig.2)

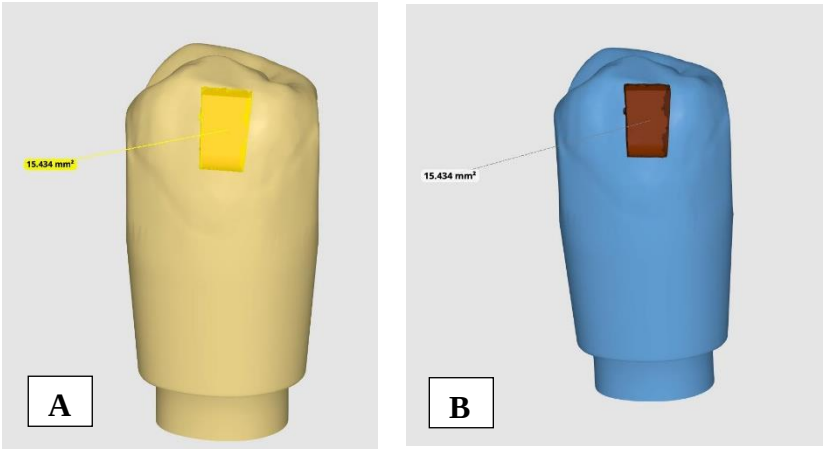


(Fig.1) Digital models with the segmented attachments on Lower premolars at T0, A: resembles the TPU Group, B: resembles PET-G group.

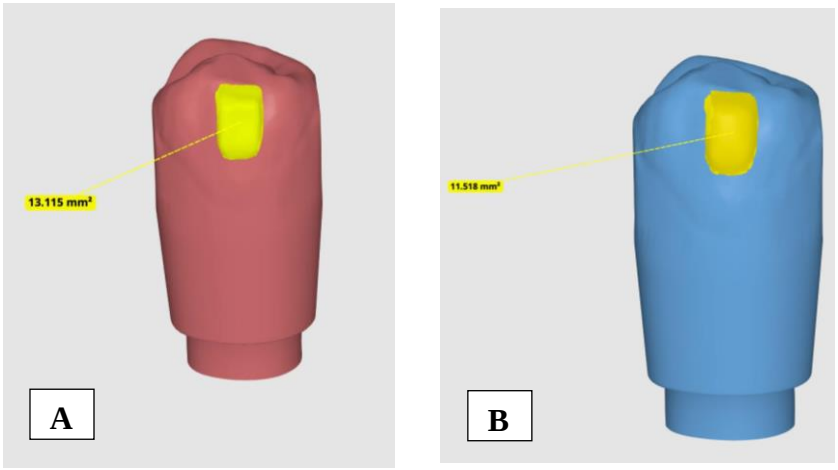


(Fig.2) Digital models with the segmented attachments on Lower premolars at T1, A: resembles the TPU Group, B: resembles PET-G group.

The investigated teeth were segmented from the whole dental arch model. The natural teeth surfaces were selected as a reference to enable the segmentation of each attachment alone from the tooth to which it is attached. The software then calculated surface area of the attachment from which along with previous measurements enabled the calculation of the volume of each attachment in T0 and T1 by using the formula (*Volume = Surface area X Hight*). (Fig.3, Fig.4)



(Fig.3) Surface area measurement for segmented attachments on Lower premolars at T0, A: resembles the TPU Group, B: resembles PET-G group.



(Fig.4) Surface area measurement for segmented attachments on Lower premolars at T1, A: resembles the TPU Group, B: resembles PET-G group.

All the calculated volumes were then collected, calculated and analyzed using R software for statistical analysis version 4.2.1

Results:

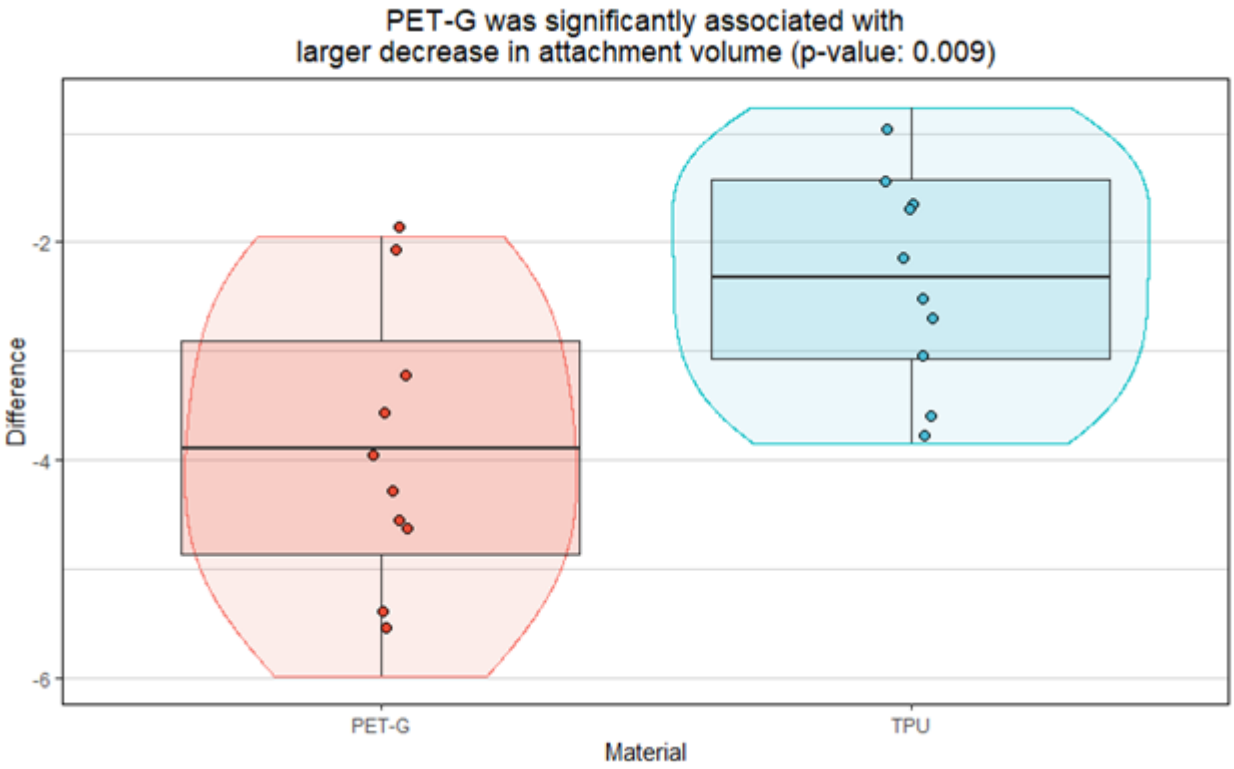
The current study included a total of 20 teeth from 20 patients who were randomly assigned into receiving either PET-G (n: 10) or TPU (n: 10) based aligners. The pre-intervention attachment volume was around 11 mm^3 for all cases. However, the deterioration in volume after removal of the aligners were significantly more pronounced in the PET-G group. After the intervention, the volume in the PET-G group had a mean value of 7.1 mm^3 compared to 8.7 mm^3 in the TPU group. While both materials showed significant drop in size volume between the two time points (Table 1; p-value: <0.001), PET-G was significantly associated with larger difference. The mean drop in volume was -3.9 mm^3 in the PET-G group compared to only -2.3 mm^3 in the TPU group (Table 2; Fig.5; p-value: 0.0092)

Table 1: *Comparing the pre- and post-intervention measurements within each study group.*

PET-G only (n: 10)				
Term	**Overall**	**1. Pre**	**2. Post**	**p-value**
Volume	Avg (SD) 9.1 (2.2)	11 (0)	7.1 (1.3)	**t: <0.001*** **
TPU only (n: 10)				
Term	**Overall**	**1. Pre**	**2. Post**	**p-value**
Volume	Avg (SD) 9.9 (1.4)	11 (0)	8.7 (1.1)	**t: <0.001*** **
α = 0.05. p < 0.05*, p < 0.01, p < 0.001*** **				
P-values obtained from two-sample t-test (t) or Mann-Whitney test (U)				

Table 2: *Comparing the study measurements between the two materials (n: 20).*

Term	**Overall**	**PET-G**	**TPU**	**p-value**
Volume pre	Avg (SD) 11 (0)	11 (0)	11 (0)	t: 1.0000
Volume post	Avg (SD) 7.9 (1.4)	7.1 (1.3)	8.7 (1.1)	**t: 0.0092****
Difference	Avg (SD) -3.1 (1.4)	-3.9 (1.4)	-2.3 (1.1)	**t: 0.0092****
α = 0.05. p < 0.05*, p < 0.01, p < 0.001*** **				
P-values obtained from two-sample t-test (t) or Mann-Whitney test (U)				



(Fig.5) Comparing the pre-post difference in volume between the two materials.

Discussion:

Clear aligner attachment helps to increase the retention of the trays thus provide better control over tooth movements. Attachment surface wear during treatment may compromise such benefit and increase the need for refinement[18].

This study demonstrated that the volume of attachment surface wear increased during the treatment. The mean amount of attachment surface wear was 3.9 mm^3 in the PET-G group and 2.3 mm^3 in the TPU group. The wear of attachment surfaces in aligners can be influenced by several factors, including material hardness, flexibility, and interaction with the oral environment. PETG is known for its rigidity and high strength, which can contribute to reduced deformation under stress but may also lead to more pronounced wear due to its brittle nature. In contrast, TPU offers greater flexibility and elasticity, which may result in less surface wear but increased deformation over time. This can be a cause for our results. This deduction came in accordance with Tamburrino et al's results, who achieved higher tensile strength results with thermoformed PETG material when compared to TPU.[19]

A study by Chen W. et al.[17] reported a lower wear volume (approximately 0.75 mm3) for Filtek Z350 XT composite resin attachments in an in vitro wear test compared to the Nexcomp flowable nano hybrid composite resin used in our investigation. This difference might be attributed to several factors. Firstly, clinical

wear of attachments likely involves a combination of influences beyond those examined in a controlled setting. These factors could include tooth brushing habits, dietary choices, biting forces, aligner removal frequency, and the oral environment itself. Patients using clear aligners typically brush more frequently and remove their aligners more often than those with just posterior restorations. This increased friction might contribute to greater attachment wear. Secondly, the observed wear volume discrepancy could be due to inherent variations between the composite resin types used in each study. The wear resistance of composite resins is known to be impacted by the characteristics and composition of the material, including the size, quantity, distribution, and geometry of filler particles, the type of monomers used, and the strength of the bond between the organic matrix and the fillers[20]. Research suggests that reducing the size and spacing of filler particles while enhancing the matrix-filler bond can improve the wear resistance of composite resins[21, 22]. Finally, discrepancies in measurement techniques might also play a role. Variations in scanner precision, superimposition methods, and superimposition software accuracy could all contribute to slight differences in wear volume measurements across studies[23].

There are some limitations to the current study that cannot be ignored. Since only one type of composite resin (Nexcomp flowable nano hybrid) was used, it is not possible to connect the results solely to the aligner materials. For such limitation additional groups should have been recruited with different types of composite resin to be compared together with the same aligner material to know exactly what the best kind of composite resin is to be used for bonding attachments. A larger sample size will yield more accurate results, allowing for a more comprehensive analysis of additional potential risk factors if more types of composite are to be used in the study.

Conclusions:

PETG aligner material causes more attachment surface wear and attachment damage than TPU aligner material as PETG aligners exhibited a higher degree of surface roughness compared to TPU aligners. The rigidity of PETG leads to more abrasive wear, particularly at the points of attachment contact. TPU aligners, on the other hand, showed smoother surfaces, indicating less aggressive wear amounts.

Author Contributions:

Conceptualization, M.A & K.M.; methodology, M.A. & K.M.; validation, K.M.; investigations, M.A. & K.M.; data curation, M.A..; writing—original draft preparation, M.A. & K.M.; Writing—review and editing, M.A., K.M. & W.R.; visualization, M.A., K.M. & W.R.; supervision, K.M. & W.R. All authors have read and agreed to the published version of the manuscript.

References:

[1] P. P. Camila, B. Jeremy, and F. M. Carlos, “Patient satisfaction and quality of life changes after Invisalign treatment,” American Journal of Orthodontics & Dentofacial Orthopedics, vol. 153, no. 6, pp. 834–841, 2018.

[2] F. D'Apuzzo, L. Perillo, C. K. Carrico et al., "Clear aligner treatment: different perspectives between orthodontists and general dentists," Progress in Orthodontics, vol. 20, no. 1, p. 10, 2019.

[3] Gao M, Yan X, Zhao R, Shan Y, Chen Y, Jian F, et al. Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving clear aligners and fixed appliances during the initial stage of orthodontic treatment. Eur J Orthod. 2021;43(3):353–9.

[4] Jiang Q, Li J, Mei L, Du J, Levrini L, Abbate GM, et al. Periodontal health during orthodontic treatment with clear aligners and fixed appliances: a meta-analysis. J Am Dent Assoc. 2018;149(8):712–20.

[5] Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique–regarding incisor torque, premolar derotation and molar distalization. BMC Oral Health. 2014;14:68.

[6]. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. Angle Orthod. 2015;85(5):881–9.

[7]. Sheridan, J.J.; LeDoux, W.; McMinn, R. Essix retainers: Fabrication and supervision for permanent retention. J. Clin. Orthod. 1993, 27, 37–45. [PubMed]

[8]. Krieger, E.; Seiferth, J.; Marinello, I.; Jung, B.A.;Wriedt, S.; Jacobs, C.;Wehrbein, H. Invisalign® treatment in the anterior region: Were the predicted tooth movements achieved? J. Orofac. Orthop. 2012, 73, 365–376. [CrossRef]

[9]. Putrino, A.; Barbato, E.; Galluccio, G. Clear Aligners: Between Evolution and Efficiency-A Scoping Review. Int. J. Environ. Res. Public Health 2021, 18, 2870. [CrossRef]

[10] S. Abela, "Interceptive orthodontics: a practical guide to occlusal management," European Journal of Orthodontics, vol. 39, no. 3, p. 342, 2017.

[11]. Feinberg KB, Souccar NM, Kau CH, Oster RA, Lawson NC. Translucency, stain resistance, and hardness of composites used for Invisalign attachments.

[12]. Dionysopoulos D, Gerasimidou O. Wear of contemporary dental composite resin restorations: a literature review. Restor Dent Endod. 2021;46(2): e18.

[13]. Mantovani E, Castroflorio E, Rossini G, Garino F, Cugliari G, Deregibus A, et al. Scanning electron microscopy analysis of aligner fitting on anchorage attachments. J Orofac Orthop. 2019;80(2):79–87.

[14] R. C. Huang, G. P. Xiong, Z. S. Lin, and X. Huang, "An analysis of influencing factors of attachment loss in clear aligner treatment," Chinese Journal of Orthodontics, vol. 25, no. 1, pp. 12–16, 2018.

[15]. Barreda GJ, Dzierewianko EA, Muñoz KA, Piccoli GI. Surface wear of resin composites used for InvisalignR attachments. Acta Odontol Latinoam. 2017;30(2):90–5.

[16]. Lin S, Huang L, Li J, Wen J, Mei L, Xu H, et al. Assessment of preparation time and 1-year Invisalign aligner attachment survival

using flowable and packable composites. Angle Orthod. 2021;91(5):583–9.

[17]. Chen W, Qian L, Qian Y, Zhang Z, Wen X. Comparative study of three composite materials in bonding attachments for clear aligners. Orthod.Craniofac Res. 2021;24(4):520–7.

[18] O. Charalampakis, A. Iliadi, H. Ueno, D. R. Oliver, and K. B. Kim, "Accuracy of clear aligners: a retrospective study of patients who needed refinement," American Journal of Orthodontics and Dentofacial Orthopedics, vol. 154, no. 1, pp. 47–54, 2018.

[19] F. Tamburrino, V. D'Antò, R. Bucci, G. Alessandri-Bonetti, S. Barone, and A.V. Razionale, Mechanical Properties of Thermoplastic Polymers for Aligner Manufacturing: In Vitro Study, Dentistry Journal, 2020.

[20] Dionysopoulos D, Gerasimidou O. Wear of contemporary dental composite resin restorations: a literature review. Restor Dent Endod. 2021;46(2):e18.

[21] Turssi CP, Ferracane JL, Vogel K. Filler features and their effects on wear and degree of conversion of particulate dental resin composites. Biomaterials. 2005;26(24):4932–7.

[22] Nihei T, Dabanoglu A, Teranaka T, Kurata S, Ohashi K, Kondo Y, et al. Three-body-wear resistance of the experimental composites containing filler treated with hydrophobic silane coupling agents. Dent Mater. 2008;24(6):760–4.

[23] Lawson NC, Radhakrishnan R, Givan DA, Ramp LC, Burgess JO. Two-year randomized, controlled clinical trial of a flowable and conventional composite in Class I restorations. Oper Dent. 2015;40(6):594–602.