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Effect of different Clear Aligner Material Thicknesses on Torquing on Upper Incisor using Attachments.

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Abstract:

Background: Although a variety of factors can affect how well clear aligner therapy works, one that stands out as being extremely important in determining the mechanical and clinical aspects of aligners is the material utilized in their construction.

Objective: The current study's objective was to assess, through a comparative randomized clinical trial, the biomechanical effects of various aligner material thicknesses on upper central incisors with horizontal ellipsoid composite attachments.

Materials and Methods: A total of 32 patients were enrolled in the trial; 16 were treated with 0.8 mm thick PET-G aligners (Group A) and 16 with 0.75 mm thick PET-G aligners (Group B). There are four main phases involved in making clear aligners: 1) Impression. 2) Online configuration and design. 3) 3D printing dental models and exporting STL files. 4) Aligns fabrication and thermoforming. Both before and after therapy, records were gathered.

Results: The migration of the incisal edge and the root apex showed significant variations between Groups A and B in this study. Significant root movement (mean movement: 1.2 mm) was linked to Group A, but no discernible movement in the incisal edge (mean movement: -0.1 mm) was observed. As opposed to this, Group B was linked to nearly exclusively moving incisal edges (mean movement: 2.8 mm), and the root apex moved on average absolutely nowhere (mean movement: -0.2 mm). Thus, a lower thickness of PET-G was strongly linked with controlled tipping movement (p-value: <0.001), whereas a higher thickness of PET-G was significantly associated with root displacement (p-value: <0.001).

Conclusion: Based on our results, it was clear that PET-G with a greater thickness was linked to root movement as opposed to crown movement. Low thickness aligners, on the other hand, caused almost minimal root movement. These results can assist orthodontists in selecting the right aligner material on an individual basis in order to accomplish a range of necessary ideal tooth motions.

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Keywords: Clear aligners, torque movement, PET-G.

1. Introduction

Typically, clear aligner therapy (CAT) consists of a series of snug-fitting clear plastic trays that cover the teeth. The patient is to utilize the CAT plastic trays at all times, with the exception of eating and brushing. After one to two weeks of continuous use, the patient's existing plastic tray becomes detached, and a new one takes its place. To achieve the intended orthodontic tooth movements, this sequential sequence of trays is necessary (1).

Newly developed computer-aided design (CAD) and manufacturing (CAM) methods for biomaterials used in transparent aligners have shown promise as a replacement for traditional fixed appliances (FAs). Over the past ten years, there has been a notable surge in demand for CAT. The aggressive marketing tactics used by commercial clear aligner companies help to partially explain this. Increasing public awareness of alternatives to traditional orthodontic treatment, particularly for adult patients, is a beneficial side effect of these marketing strategies(2).

While there are many variables that could affect how well clear aligner therapy works (3, 4), one that stands out as being extremely important in influencing the mechanical and clinical aspects of aligners is the material utilized in their construction (5).

Manufacturers usually prefer polyethylene terephthalate (PET) and polyethylene terephthalate glycol (PETG), an amorphous copolymer of PET that does not crystallize, among the several materials used to make aligners. This choice is a result of PETG's superior mechanical and optical qualities for the creation of clear aligners (6).

Thermoplastic polyurethane (TPU) is another widely used material. It is a very inventive substance with amazing tensile and elastomeric properties, chemical and abrasion resistance, adhesive characteristics, and machine-easy properties (7,8).

Attachments are used in orthodontics primarily to prevent teeth from slipping during tooth movement and to extrude teeth (9). The force and direction imparted to the tooth are greatly influenced by the form of the attachment. Research has demonstrated that modified ellipsoid attachments with a lower profile and no corners are more mechanically effective than other designs even though they provide a smaller extrusive force (10).

The doctor needs to keep an eye on how the anterior muscles' torque control is being introduced and developed. If not, it will be difficult to reclaim control once it is gone. The final action of thermoplastic aligners must be fully understood in light of the complex biomechanics underlying torque. In the bracket system, torque is usually established by forming a pair inside the bracket to wire complex that has equal and opposing moments. Torque is achieved in thermoplastic aligners by either attaching attachments to the tooth surface or by making a force-inducing projection in the aligners(11). Only a few research have examined the biomechanical consequences of thermoplastic appliances, despite the fact that the movement of teeth with these appliances has been amply reported.

The aim of the present study was to evaluate the biomechanical effects of different aligner material thicknesses on upper central incisor with horizontal ellipsoid composite attachments —a comparative randomized clinical trial.

2. Materials and Methods

The research design was authorized by the research ethics committee board at Minia University in Egypt's faculty of dentistry. It was a randomized double-armed clinical trial that was set up in the outpatient clinics and planned in accordance with consortium criteria. Following the following eligibility requirements, the patients were recruited for the study after signing a comprehensive informed consent form: 1) All patients should have permanent dentition and be free of any systemic illnesses that could impair tooth movement. 2) Every patient has a negative history of prior orthodontic treatment and is at least 18 years old. 3) There should be crowding and class I or II malocclusion in every patient. The enrolled participants were randomized using the sealed envelope method into either of the study arms.

For sample size estimation purposes, the main outcome of our study may well be defined by the difference between the study arms A and B, where:

Delta A: post intervention root apex - pre intervention incisal edge

Delta B: post intervention root apex - pre intervention incisal edge

The torque movement that we are targeting has a substantial pre-post delta, which suggests that the movement was mostly at the root apex rather than the incisal edge. Based on the difference between deltaA and deltaB, the sample size estimation will be determined if it is hypothesized that one aligner material will cause torque movement to be much greater than the other. We need an estimated 14 study participants in each study arm to meet a statistical power of 80%, assuming that the genuine difference between mean delta values within our arms may be as little as 0.35mm. This computation is predicated on a two-sided alternative hypothesis with an α cut-off value of 0.05. Sample size calculation was done using the R programming language for statistical computing version 4.2.1.(12)

To confirm the diagnosis and plan of therapy, diagnostic data for a total of thirty-two patients were gathered. These records included digital intraoral and extraoral pictures, cone beam computed tomographs, and intraoral scans using an intraoral scanner. (Fig 1-2).

Fig. 1: Intraoral Photos

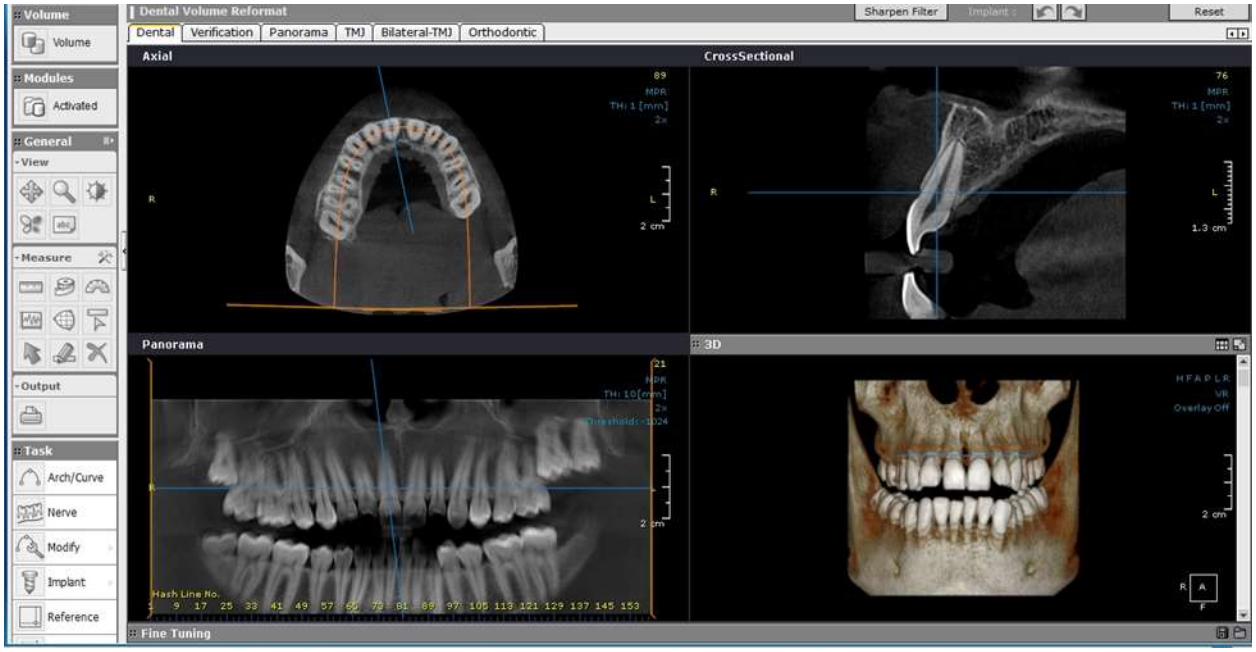

Fig. 2: Cone beam computed tomography view

There are four essential procedures involved in making all clear aligners: 1) Impression. 2) Online configuration and design. 3) 3D printing dental models and exporting STL files. 4) Aligns fabrication and thermoforming.

The final aligners' accuracy and quality can be affected by a variety of technologies and approaches that can be applied at each stage. We used an intraoral scanner in our investigation to take precise impressions. (Fig 3).

Fig. 3: intra oral scan using medit I700

Maestro 3D Ortho Studio software was utilized to build the aligners based on the impression. Following design completion, Anycubic Photon Mono X 3D printer was used to manufacture all of the virtual dental models setup, turning them into tangible items. (Fig 4)

Fig 4: 3D printed models

The last stage was thermoforming, which was done for each group utilizing an aligner material sheet (Forestadent, 0.8 mm thick, and Memoflex, 0.75 mm thick) and a Scheu Ministar thermoforming pressing machine. Various thermoforming plastic foils are used in conjunction with vacuum or positive pressure thermoforming equipment in this method.

Al-Nadawi et al.'s recommendation was for all candidates to wear each aligner for 20–22 hours each day for 14 days (13). Following a six-month period of routine follow-up visits, the patients engaged underwent another round of record-keeping to determine whether or not the necessary torque was obtained.

All CBCT images were obtained using same machine with the same specifications and dicom files were obtained to be used with DDS-Pro version 1.6_2016© JST Sp. Software to perform the CBCT measurements (Fig 5,6).

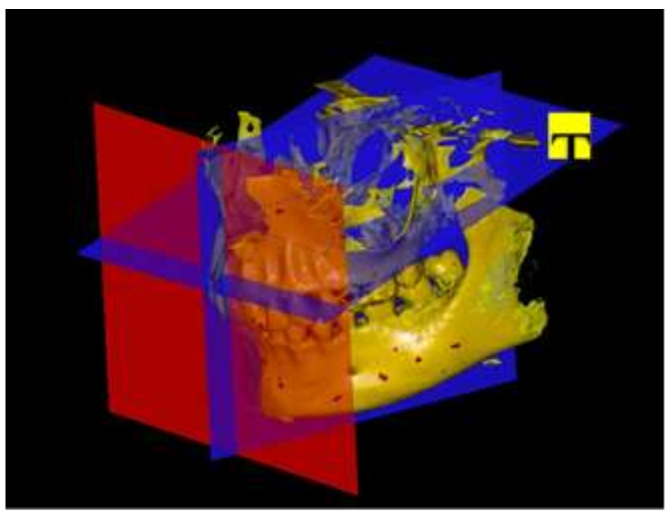

Fig 5: Sagittal Plane (Blue), Frontal Plane (Red), Transverse Plane (Blue with letter T)

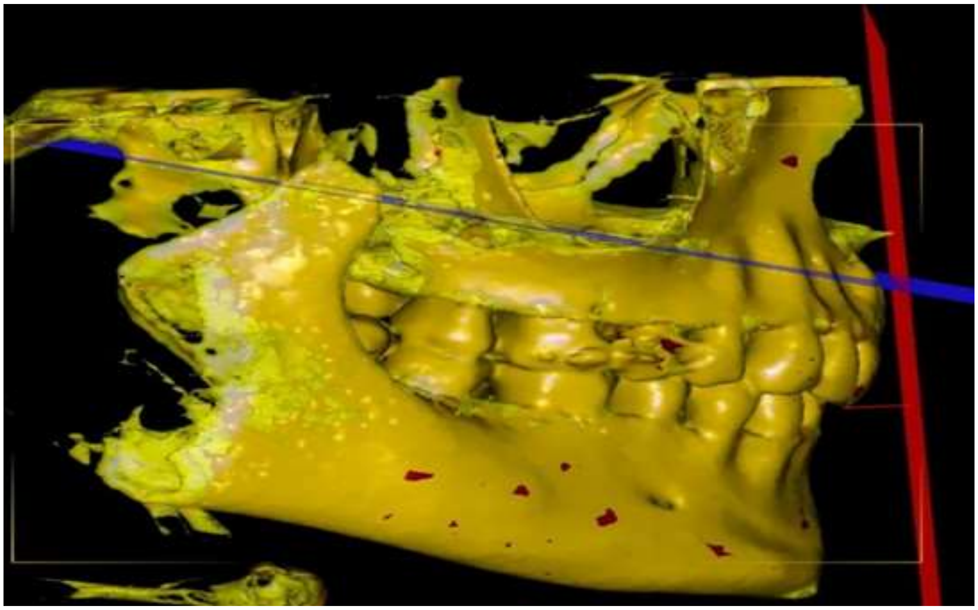

Fig 6: Measurements of UR1

3. Results

This study included a total of 64 measurements from 32 recruited cases, 16 received 0.8 thickness aligners (Group A) and 16 received 0.75 thickness aligners (Group B). Four measurements were taken from each patient (2 before the intervention and 2 after the intervention). For each case, upper right central was considered. Per tooth, measurements for both the incisal edge and the root apex were taken.

The average preoperative measurements for group A were 5.7 mm overall, with the incisal edge and root apex having averages of 6.2 mm and 5.2 mm respectively. The difference between the two benchmarks was statistically significant (p-value: 0.0374*). Postoperatively, the overall average measurement decreased to 5.2 mm. The averages for the incisal edge and root apex also changed to 6.3 mm and 4.1 mm respectively. The difference between the two benchmarks was statistically significant (p-value: <0.001***). The average difference in measurements (postoperative - preoperative) was 0.5 mm overall. For the incisal edge and root apex, the average differences were -0.2 mm and 1.1 mm respectively. The difference between the two benchmarks was statistically significant (p-value: <0.001***).

For the group B, the average preoperative measurements were 6.7 mm overall, with the incisal edge and root apex having averages of 8.4 mm and 5 mm respectively. The difference between the two benchmarks was statistically significant (p-value: <0.001***). Postoperatively, the overall average measurement decreased to 5.4 mm. The averages for the incisal edge and root apex also changed to 5.5 mm and 5.3 mm respectively. The difference between the two benchmarks was not statistically significant (p-value: 0.6338). The average difference in measurements (postoperative - preoperative) was 1.3 mm overall. For the incisal edge and root apex, the average differences were 2.8 mm and -0.3 mm respectively. The difference between the two benchmarks was statistically significant (p-value: <0.001***).

Table 1: A subgroup analysis comparing benchmark measurements within each material:

Group A (n =32)				
Term	**Overall**	**Incisal edge**	**Root apex**	**p-value**
Pre (mm)	Avg (SD) 5.7 (1.4)	6.2 (0.7)	5.2 (1.7)	**t: 0.0374***
Post (mm)	Avg (SD) 5.2 (1.7)	6.3 (0.8)	4.1 (1.6)	**t: <0.001*****
Difference (mm)	Avg (SD) 0.5 (0.7)	-0.2 (0.2)	1.1 (0.3)	**t: <0.001*****
Group B (n =32)				
Term	**Overall**	**Incisal edge**	**Root apex**	**p-value**
Pre (mm)	Avg (SD) 6.7 (2.2)	8.4 (1.1)	5 (1.6)	**t: <0.001*****
Post (mm)	Avg (SD) 5.4 (1.5)	5.5 (1.3)	5.3 (1.7)	t: 0.6338
Difference (mm)	Avg (SD) 1.3 (1.6)	2.8 (0.3)	-0.3 (0.3)	**t: <0.001*****

Table shows that, for the incisal edge benchmark, the average preoperative measurements were 7.3 mm overall, with group A and B having averages of 6.2 mm and 8.4 mm respectively. The difference between the two materials was statistically significant (p-value: <0.001***). Postoperatively, the overall average measurement decreased to 5.9 mm. The averages for both groups also changed to 6.3 mm and 5.5 mm respectively. The difference between the two materials was statistically significant (p-value: 0.0389*). The average difference in measurements (postoperative - preoperative) was 1.3 mm overall. For both groups, the average differences were -0.2 mm and 2.8 mm respectively. The difference between the two groups was statistically significant (p-value: <0.001***).

For the root apex benchmark, the average preoperative measurements were 5.1 mm overall, with group A and B having averages of 5.2 mm and 5 mm respectively. The difference between the two groups was not statistically significant (p-value: 0.7922). Postoperatively, the overall average measurement decreased to 4.7 mm. The averages for group A and B also changed to 4.1 mm and 5.3 mm respectively. The difference between the two materials was statistically significant (p-value: 0.0491*). The average difference in measurements (postoperative - preoperative) was 0.4 mm overall. For group A and B, the average differences were 1.1 mm and -0.3 mm respectively. The difference between the two groups was statistically significant (p-value: <0.001***).

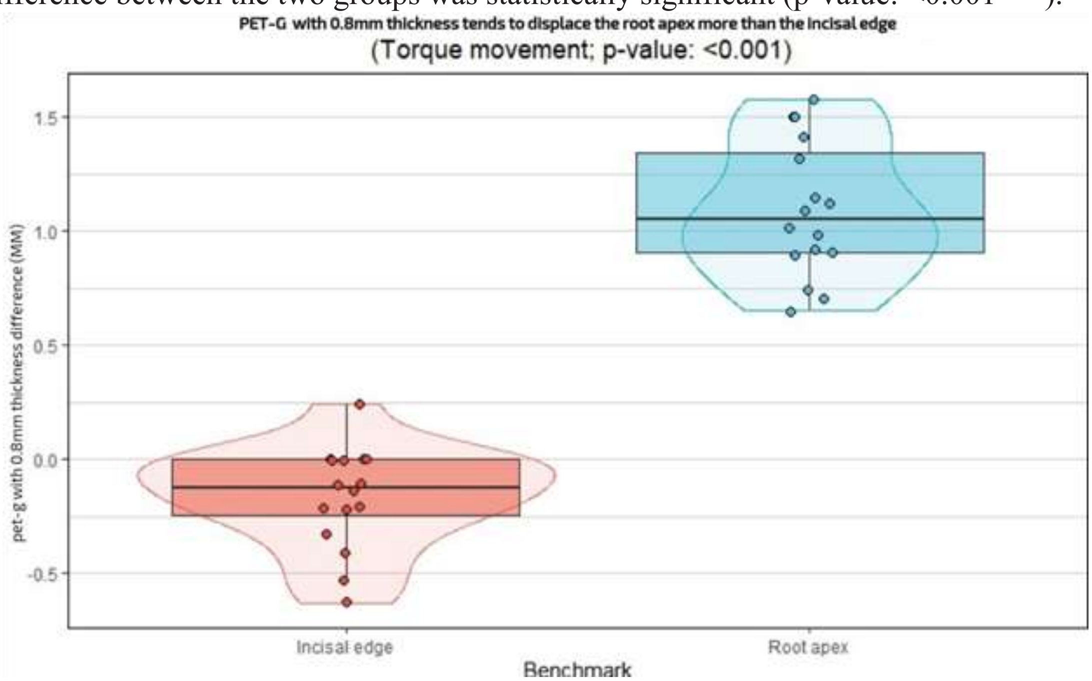

Fig 7: Comparing the pre-post intervention difference in PET-G with 0.8 mm thickness material per benchmark (n= 32)

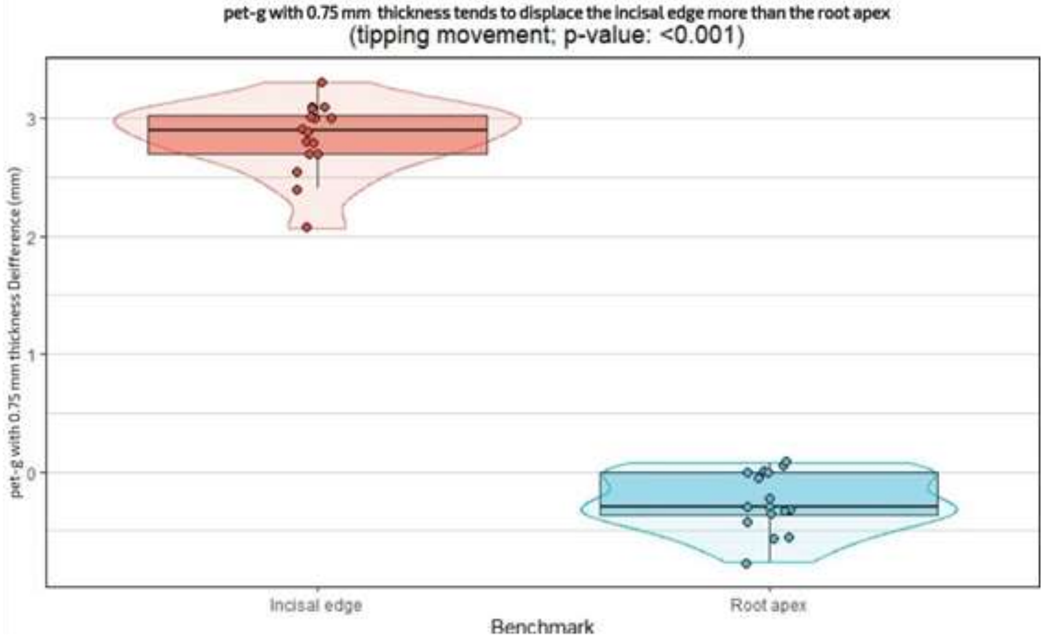

Fig 8: Comparing the pre-post intervention difference in PET-G with 0.75 mm thickness material per benchmark (n = 32)

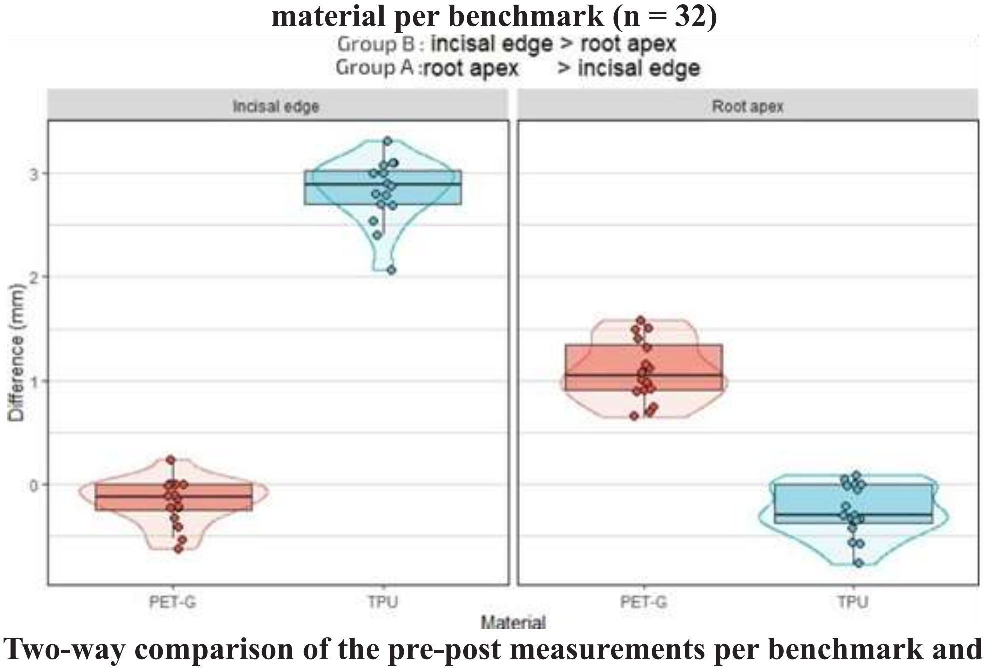

Figure 9: Two-way comparison of the pre-post measurements per benchmark and thickness used (n = 64)

4.Discussion:

Since Kesling first using aligners in 1945, many materials and treatment modalities have been employed (14, 15). The control over the location of the teeth in the three planes of space has improved thanks to technological advancements in aligner materials and production processes (16). Manufacturers of aligners currently use thermoplastic materials such as ethylene vinyl acetate, polypropylene, polycarbonate (PC), thermoplastic polyurethanes (TPU), modified polyethylene terephthalate glycol (PETG), etc. (17). We examined in our study the effects of aligner material thicknesses on torquing when combined with the forms of ellipsoid composite attachments. First things first: if the impression is inaccurate, the patient will probably feel uncomfortable during the treatment, and the results will be damaged. The impression is the input data that the entire procedure depends on. The Medit I700 intraoral scanner was utilized because of the following benefits. For the patient, it is a far more comfortable experience. It's secure. It's true. Unlike actual impressions that need to be packaged and delivered, digital scan files can be sent with a single click to a lab or a colleague for evaluation.

For the purpose of creating orthodontic aligners, software such as Maestro 3D Ortho Studio is frequently utilized, and these applications have comparable features. Teeth can be adjusted individually with a special tool or by entering the required movement or angulation numerically. When there is insufficient room for virtual tooth movement, Interproximal Enamel Reduction (IPR) is required. The mesial and/or distal side of the afflicted tooth is where the program locates and shows the necessary IPR amount. A critical component of the design of clear aligner therapy (CAT) is the division of tooth motions into phases. It is not advised to attempt the whole correction in one step because the software is unable to identify the best order for a successful and seamless course of treatment.(18) The staging was displayed on a computer screen and exported as a PDF file for printing on paper. The attachments required for these motions were positioned during the setup procedure. Numerous attachments (elliptical, horizontal, vertical, half-sphere, etc.) can be located in the relevant software library. Depending on the requirements of each patient, their dimensions are easily adjustable. By altering the aligner's form, the teeth can move more freely. Disparities in the aligners may generate the pushing force required to shift the teeth. The clinical crown is subject to this pushing force, which does not pass through the tooth center resistance. As such, movement of the aligner tooth always causes movement of the crown tip.(14,19)

The movement of the root apex and the incisal edge varied significantly amongst PET-G samples of varying thicknesses, according to the study's findings. Significant root movement (mean movement: 1.2 mm) was linked to Group A (0.8 mm thickness), but no discernible movement in the incisal edge (mean movement: -0.1 mm) was seen. The root apex movement averaged nearly zero (mean movement: -0.2 mm), while group B (0.75 mm thickness) was linked to nearly exclusively occurring incisal edge movement (mean movement: 2.8 mm). As a result, low thickness PET-G was strongly linked with controlled tipping movement (p-value: <0.001), but higher thickness PET-G was significantly associated with root displacement (p-value: <0.001).

There is still a dearth of previously published research on torque movements related to the use of transparent aligners (20,23). A force couple must be acting on the tooth in order to cause a torque movement. Hahn et al. gave a thorough explanation of the biomechanics of these movements using transparent aligners. This particular tooth movement is difficult to accomplish with clear aligners for a variety of reasons, some of which are related to the biomechanics of the aligners. There should be visible motions inside each aligner if the aligner is unable to fit the tooth crown precisely. Notable but reversible deformations can also occur on the gingival borders of the aligner. These distortions are reversible, but they may make it more difficult to apply the proper amount of force couple (21).

The movement of the teeth with and without attachments was not different, according to the authors of a related article (p-value: >0.05). The root movement of aligners with varying thicknesses was found to be substantially larger for the higher thickness aligner than for the lower thickness aligner (p-value: <0.001). Crown movement, on the other hand, was similar for the two materials (p-value: >0.05).(3) These results are consistent with our own, which showed that uncontrolled tipping movement was substantially linked with the lower thickness group's PET-G (p-value: <0.001) and root displacement with the greater thickness group's PET-G (p-value: <0.001).

Additionally, it has been noted that the lingual crown tip of the maxillary incisor had a greater torque than the labial crown tip, and that it was much more accurate in positioning them than the labial crown tip and crowns; however, the roots of the anterior teeth could not be moved to the intended places. Furthermore, a systematic review and meta-analysis found that whereas anterior buccolingual inclination cannot be effectively controlled with clear aligners, the posterior buccolingual inclination may (20,19, 3).

It was also possible to identify other parameters that lower the success rate of torque movements using clear aligners. It was found that a higher degree of root movement increase within steps was correlated with a lower success rate. The writers clarified this with a further observation. The aligners were not perfectly bonded to the teeth in cases where there was a larger increase in the expected root movement between phases. Instead, there was a slight elevation of the aligners. Furthermore, there was not much contact between the aligner's inner surface and the incisor edge. These result in inadequate torque motions due to an inappropriate force couple (24).

There were two things to take into account in order to have improved tooth movement using aligners. The first is the application and shape of the attachment, and the second is the choice of aligner material. It is commonly known that when various dental movements are performed to specific teeth, the results might be highly unpredictable. These comprise rotational and torque movements applied to the cuspids and maxillary laterals. Bonded composite attachments were developed on the foundation of this basic fact. The purpose of these attachments was to improve the surface area of contact between the teeth and the plastic aligners, enabling improved tooth grip (25, 26).

Because attachments act as anchors to stabilize the aligners during the teeth-moving process, they are essential to the planning and execution of anticipated motions. Thus, one major benefit of employing aligners is their large number of anchors, which act against a very small number of teeth that need to shift (27).

In a different study, the amount of root movement accomplished between clear aligners constructed with power ridge attachments and ellipsoid attachments was compared. More crown movement to power ridge attachments was reported by the authors. Conversely, ellipsoid attachments showed a stronger correlation with root mobility. The mean root movement of 0.3 mm reported by the authors is similar to the 0.2 mm and 0.1 mm mean root movement with PET-G aligners that we saw in our study (22).

Other researchers came to the conclusion that because of the force and moment transfer to the tooth's center of resistance, the horizontal ellipsoid composite attachment would be more effective at producing lingual root torque (28).

5. Conclusion

According to our results, PET-G that was thicker was clearly linked to root movement as opposed to crown movement. Conversely, less thick aligner materials caused virtually little root movement. These results can assist orthodontists in selecting the right aligner material on an individual basis in order to accomplish a range of necessary ideal tooth motions.

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