Applications of Thermoplastic Materials in the Fabrication of Orthodontic Aligners

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The use of thermoplastic aligners has a vast history in the orthodontic field. These appliances have several indications regarding mild malocclusions, tooth replacement, retainers after active treatment, etc. The manufacturing protocol is simple and easy to apply. Several tooth movements are harder to obtain (torque, intrusion, correction of rotations). The aligners must be well fitted and provide enough stiffness in order to maintain the desired orthodontic effect and minimize the unwanted dental movements or anchorage loss. We evaluated a manufacturing protocol for such appliances and analyzed how thermoplastic thickness material, due to the manufacturing process , can influence orthodontic treatment. Several foils were sectioned and measured before and after the manufacturing protocol(0.5mm;0.8mm;1 mm). Although some differences were observed due to foil types and thickness, the appliances are rigid and capable of assuring orthodontic success.

Keywords: orthodontic aligners, thermoplastic materials, foil thickness reduction

Orthodontic aligners, as we know them, have a vast history. Aligners were first used to correct mild malocclusions in 1940 by Kesling, but it was only when Pontiz discovered the thermoformed plastic materials in 1971 when the basis of aligner technology was implemented [1]. Pontiz's ideea of using wax after repositioning teeth on casts model is the starting point for the Invisalign system (Santa Clara CA)[2]. Thermoplastic materials were first used for dental impressions or occlusal registrations. In contemporary orthodontics, impressions are taken using polyvynil siloxane materials, and aligners are fabricated from translucent thermoformed or vacuum formed plastic. Several studies show how biomechanical forces can be measured using resins to replicate the patient's dental situations and how wear off of the thermoplastic materials can influence the orthodontic treatment[3,4].

Invisalign technology consists of dental impressions and CT scans to create a 3D model. A software allows orthodontists to plan different dental movements(torque, rotations, intrusion, distal movements) and to design the series of aligners that are to be made using a predetermined protocol and aligner thickness. The Invisalign system is currently used to correct mild malocclusions. The fabricated aligners need to be changed after a certain period of time. Changing aligners helps maintain enough force related to the strain developed on the aligner surface [5,6].

Experimental part

We analyzed some clinical cases and studied different reviews on this topic, consulting orthodontic literature. This helped us develop a manufacturing protocol for aligners using different thermoformed plastic materials with several thickness. Clear Aligner System uses Duran foils and a specific treatment protocol: 0.5 mm foil thickness during the first week, 0.8 mm in the second week and 1.0 mm in the third week. After three weeks a new impression is taken and a new dental cast is made. The Aligners are then fabricated using the new dental cast for further treatment. Every three weeks the same procedure occurs until the end of the orthodontic treatment. Forestadent, Dentsply (Essix foils), DynaFlex, Clear Correct, Scheu Dental are major companies that produce thermoplastic foils for orthodontic purposes. Most of them are made from plastic, but some of them also have acrylic components (DynaFlex). We prefer Scheu Dental foils in our daily practice. Each foil, regarding material thickness, has a specific indication (table 1).

Material thickness can help us anticipate the duration of treatment and the type of unwanted dental movements that can be expected.

Aligner therapy is an important adjuvant in adult treatment if worn properly (22 h per day). Scheu Dental Technology, because of the translucent thermoplastic aligners, facilitates discrete treatment mechanics, esthetics and periodontal health compared to the classic bracket system [7].

This type of thermoplastic material can be used as an active appliance during treatment, with or without composite attachments, or as a passive one: to maintain space after active orthodontic therapy prior to implant placement or to prevent relapse. Some of the foils can also serve as bleaching, fluoride or transfer trays[1,2] We decided to use Scheu Dental foils to complete our study regarding the process of manufacturing the aligners (fig. 1-6). The manufacturing process has a significant effect on thickness reduction due to heat exposure and material flexibility. We also evaluated how material thickness can influence treatment efficiency.

The protocol listed above is easy to apply. The aligners are made in the same day so the treatment can begin immediately. The number of needed aligners can be evaluated by taking into account a few parameters: force, material thickness and hardness and the severity of the malocclusion. Light forces are preferred for dental

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Table 1
MATERIAL THICKNESS, DIMENSION AND INDICATIONS OF THERMOPLASTIC FOILS

Product	Dimensions (thickness)	Applications
Duran(Scheu Dental)		
PETG(amorphous polyethylene terephthalate)-multi layer foil	0.5mm 0.625mm 0.725mm 1mm 1.5mm 2mm 3mm	Fluoride splints Mini Trays Retention Splints
Duran Soft(Scheu Dental)		
PC(Polycarbonate foils)	1.8mm 2.5mm	Night guard Bite splints Mini trays
Copyplast(Scheu Dental)		
PE (polyethylene foils)	0.5mm 0.6mm 1mm 1.5mm	Invisible retainers Orthodontic aligners
Bioplast		
EVA(ethylene vinyl acetate)	1mm 1.5mm 2mm 3mm 4mm 5mm	Night guards(bruxism) Positioners Model duplications
Bioplast Bleach		
EVA(ethylene vinyl acetate)	1mm	Bleaching trays
Imperlon S		
PC(polycarbonate foils)	0.5mm 0.8mm 1mm 1.5mm 2mm 3mm	Invisible retainers Bite splints

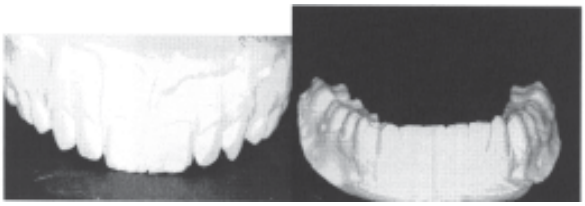


Fig.1. Dental cast prepared for fabrication of thermoformed plastic aligners.

Fig.2. The thermoplastic isolation foil Isofolan (Scheu Dental).

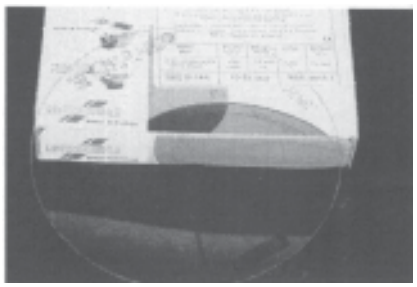


Fig.3. The thermoplastic material used for aligner manufacturing.

movements in order to maintain pain control, patient compliance,periodontal health and stability [8,9] Regarding the information stated above, our research was

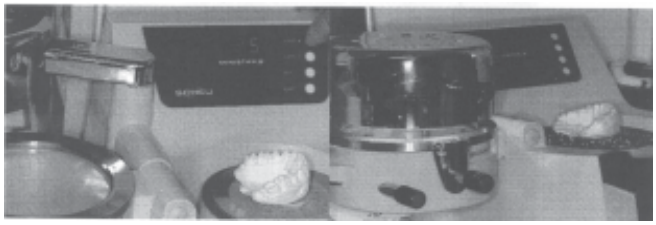


Fig.4. Manufacturing the thermoformed aligners-using Ministar (Scheu Dental).

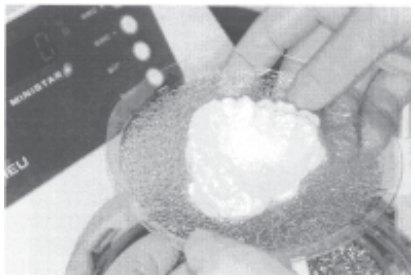


Fig. 5. The aligner after ultrasonic cleansing and before removal of excessive plastic material.

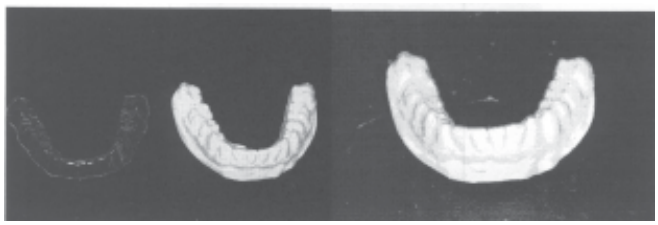


Fig.6. The final aligner

conducted on three different foil thickness: 0.5 mm, 0.8 mm, 1 mm. Every foil was sectioned in its center and its lateral area. The objective was to determine the effect of the tooth configuration on the foil thickness evolution, considering the foil outline. The material deformation (d) in its lateral area was approximately 0.8mm, while the corresponding radius (r) in its central area was 1.5 mm. The values that we obtained after all measurements were made have been expressed in "%" compared to the initial foil thickness. These results must be understood as thickness reductions compared to the original dimensions of the foils.

Results and discussions

The manufacturing process of the thermoplastic foils has the effect of full tooth coverage but throughout this process some thickness reduction is expected. These values are expressed in %. The 1 mm foil turned out to be rigid, so the thickness was reduced taking into account the foil outline (fig. 7. a, b)

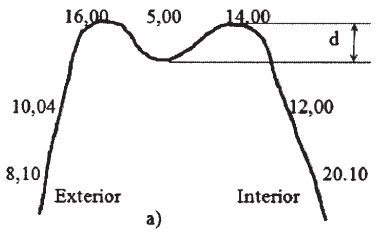
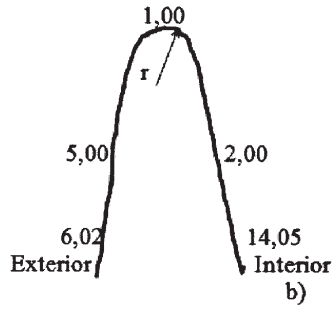


Fig. 7. Thickness reduction, 1 mm foil /%/.



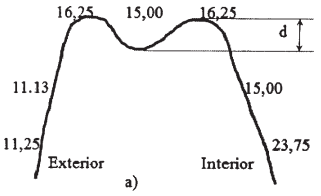
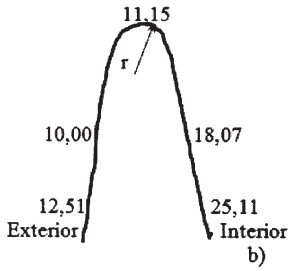


Fig. 8. Thickness reduction, the 0.8mm foil /%/.



Thickness reduction was greater on the interior. In its center, although the outline is curved, no significant thickness differences were encountered.

The 0.8 mm foil (fig. 8 a, b) was less rigid than the previous one.

In this case, the reduction regarding material thickness was double in the interior part of the aligner compared to the exterior part.

The last foil that we evaluated (0.5mm) turned out to be much more sensitive to the manufacturing process because of its flexibility. The foil was well fitted on the supporting teeth but had a significant thickness reduction after being exposed to the thermoforming process (fig. 9.a,b).

Aligners wear off after a certain period of time because the tension decreases as teeth align. We discovered that material thickness does not influence activation time but the hardness does. Increasing the material hardness also increases the aligner wear off therefore activations must be done weekly. Using composite attachments seems to have a positive effect because composite resins are wear-resistant materials. Combining the advantages of the thermoformed plastic materials and composite resins may shorten the treatment time or the numbers of aligners (each aligner can produce 0.25mm of tooth movement). Composite attachments may also express better certain dental movements like torque, extrusion, bodily movement, up-righting molars . Care must be taken to properly fit the thermoplastic aligner into the attachment so that unwanted moves can be minimized [1].

Conclusions

Regarding plaque accumulation, these appliances can increase the risk of gingivitis and plaque deposits but this risk is not greater compared to brackets [9].

Some studies show that activations of the aligners can be done weekly or every other week but no significant differences were observed in the treatment duration [6].

Thermoformed plastic aligners seem to be more comfortable than fixed appliances, easier to manufacture and clearly more esthetic and more suitable for adult treatment. There is no need in over whelming the patient with thick and bulky aligners but the hardness must be taken into account as a systematic staging in treatment mechanics [10 - 12]. The significant thickness reduction

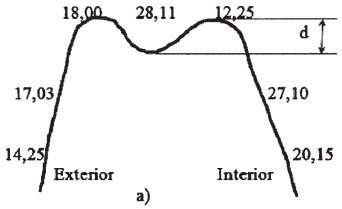
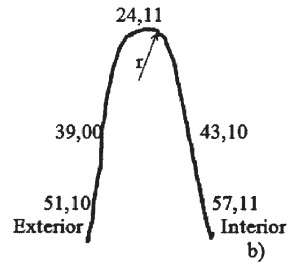


Fig.9.Thickness reduction, 0.5 mm foil /%/.



differences among foil types has a certain effect on orthodontic forces during treatment with Clear Aligner therapy. Although the geometric configuration of the aligners is extremely complex, the manufacturing process provides a rigid appliance, capable of assuring the success of the orthodontic treatment. Combining composite attachments with thermoformed plastic materials will become the future in orthodontics and the most popular choice for adults and also for teenagers, with the developing of The Invisalign Teen System [1].

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