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Review

Directly Printed Aligner: Aligning with the Future

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Main Points

- 3D technology enabled the inclusion of a digital lab in the orthodontic office.
- Thermoformed aligners is the main way to perform aligner orthodontic treatment.
- Novel aligner resin has been introduced for the direct aligner printing.
- Printed aligners present significant advantages and some disadvantages.
- Studies have been published concerning the properties of the aligners. More studies have to be conducted in order to investigate and optimize printed aligner orthodontic treatment and create a consistent 3D designing and printing workflow.

ABSTRACT

Orthodontics stands on a junction where traditional analog appliance manufacturing slowly but steadily changes to a digital one with the use of 3D technology. The main cause of this shift was the invention and use of computers. The use of computers, computer-aided design (CAD) software, computerized machines, and newly invented materials allowed this change to occur in a relatively short time in dentistry and orthodontics. The trigger for this transformation is the ability to digitally scan the oral cavity. CAD software and 3D printers already existed. It took a few years to include this technology in orthodontics and continuously apply it in the orthodontic office. Orthodontic treatment is mainly based on the use of fixed appliances, while in the last years, thermoformed aligners have been introduced as an alternative whenever a more invisible treatment modality is preferred. Clear aligner treatment is performed using thermoformed aligner. A new aligner resin has been recently invented to allow direct aligner printing. Directly printed aligner possess many advantages compared to thermoformed one. Research has been initiated to investigate all the aspects of the workflow and aligner printing outcome. More studies must be performed to look into the various aspects of directly printed aligners.

Keywords: 3D technology, 3D printing, directly printed aligner, UV curing unit, nitrogen generator

INTRODUCTION

Orthodontics is the only specialty in dentistry and medicine that uses forces to move human body parts, and teeth. The biology of tooth movement is extensively investigated, and theories have been expressed regarding many aspects of this movement. The unique feature of the continuing movement of our teeth throughout our entire life is used to correct orthodontic problems. The main way to move teeth is fixed appliances, which passed a long way since Angle invented the edgewise appliance.

In 1945, a brilliant mind Dr. Kesling[1] introduced a plastic-made appliance called tooth positioner to move teeth without fixed appliances. The positioner was made of rubber on a dental setup and was used immediately after brackets debonding. Later Nahoum[2] evolved an appliance using a two-block appliance for the upper and lower dental arches, while Sheridan et al.[3] in 1993 introduced an Essix appliance to correct minor orthodontic problems combined with the interproximal reduction first used by ML Ballard in 1944.[4,5] The next big step was made four years later when Zia Christi and Kelsey Wirth founded an aligner system called Invisalign (Align Technology, Santa Clara, Calif, USA). Later, other companies followed that path, while in the last years direct-to-consumers aligner was introduced.

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The major shift in aligner production was performed when computer-aided design (CAD) software, 3D printers, and 3D scanning were introduced in Orthodontics. Aligner manufacturing was performed on several plaster models where teeth had to be segmented, removed, and then placed again in the dental model with the use of wax placed to their bases. The introduction of the plaster teeth segmentation concept to the orthodontic CAD software and the continuation of this process using 3D printers to manufacture several dental models converted the analog traditional aligner production to a digital-centered one. There was no need to pour plaster dental models, cut teeth, and reposition them using wax and then vacuum-form aligner anymore. The "clean" computer environment could handle teeth segmentation, and teeth repositioning (setup) in small increments and finally create all the necessary virtual dental models to be printed, which later would be used in the thermoforming procedure. The ability to have a dustless, plasterless, and clean environment, with fewer machines, allowed the installation of a small digital lab in the orthodontic office. Simultaneously, pushed by this impressive 3D technology revolution, companies started creating printing resin materials that were used to print crowns, splints, dental models, and indirect bonding trays (IDB). Unfortunately, this technological evolution brought an uncontrolled use of 3D printers, post-printing units, and hazardous materials in the orthodontic office without the proper installation, which should be guided by approved protocols. The hazards for the patients and personnel are often overlooked, leading to the improper use and installation of the lab in office places where they should not be. Therefore, dental associations should create protocols and guidelines for the correct lab installation, which should be officially checked and approved by government organizations and dental associations.[6]

Due to this immense digital technological advancement, other technologies evolved simultaneously. Resin material for 3D printing was initially only for dental models, while over time, more resins were introduced for occlusal splints, IDB, and lately brackets. Up to this point, aligners were made using plastic foils supplied by various companies in different thickness and made of different materials.

A major evolution in clear aligner treatment was the introduction of the first aligner resin for direct aligner printing. The aligner resin called TC- 85DAC (Graphy, Seoul, Korea) showed up in 2019 and gradually gained ground in the field of aligner production.

Regardless of the current state of directly printed aligner, it seems that the river can go back and that the orthodontist will be able to design and directly print aligner in the office in a self-sufficient environment offering more accurate, easy, fast, and troubleless orthodontic treatments.

Directly Printed Aligner

Credits should be given for inventing the precursors of aligner to Kesling[1], Nahoum[2], and Sheridan[4]. What followed was a natural continuation of the work of those scientists, mixed with the inclusion of digital technology in orthodontics. Invisalign made that big change where 3D technology was mixed, with of artificial intelligence and plastic foil research. Other companies followed serving the same scope, while simultaneously, the in-office concept started showing up, especially with the evolution of 3D printers that became more compact, cheaper, and easy to handle. Software companies realized the in-office aligner production potential and created CAD software exactly for that reason. In the last few years, more and more offices decided to create a small lab at their premises to mainly offer to the patient the option of in-office clear aligner. Posts in social media, webinars, hands-on courses, and conferences dedicated to 3D technology and aligner are a daily phenomenon. Deep inside the orthodontist is excited by the perspective of having a self-sufficient office that is controlled by the orthodontist without the need for an external company to depend on aligner production. Nevertheless, rushing into technology and new materials without research is a phenomenon that is often observed in dentistry and orthodontics. Opposite to medicine, where research comes before drug release, we tend to use machines and materials that are not tested; aligner could not be an exception. On the other hand, the environmental burden from millions of printed dental models and plastic foils, which are not recyclable seems to be overlooked. It is not our intention to criticize the use of aligner but rather to alert the orthodontic community to the possible hazards of the uncontrolled use of non-recyclable materials and the unfortunate trend to use of untested materials and machines.[6]

A solution to the disposal of millions of dental models could be, skipping the dental model printing step. Of course, the ideal solution could be to use a printed aligners that would be recyclable. The ability to directly print aligner which could serve as the next step in aligner treatment is a revolution. The resin called TC-85DAC (Graphy, Seoul, Korea) was the starting point to include directly printed aligner in our armamentarium. At this time, other companies are in the course of releasing their aligner resins too.

Aligner Printing Materials and Units

The workflow for designing thermoformed aligner in the office is more or less known starting from the import of dental scans in dedicated orthodontic CAD software, editing the scans through a procedure, and reaching to the setup where attachments are to be included if needed. From that point, the software designs the models to be printed and later to be used for the aligner thermoforming procedure.[7]

Directly printed aligner designing and printing procedures are different. Essentially the software which is used to design printed aligner is the same as that one for the thermoformed one. The same procedure is followed to reach the setup and attachment virtual placement. Following the setup, the operator must virtually design, at the initial malocclusion model, the aligner that will be used by the software to create all the rest of the aligner (Figure 1). Software available for printed aligner are Deltaface (Coruo, Limoges, France) and Maestro (New Age, Pisa, Italy). A unique feature of the Deltaface software is that it allows the thickening of the aligner in specific areas, where the operator wants to have a stiffer part. For instance, in case there is a need to move a lower central incisor labially the software, following a command, thickens the aligner at the palatal side of the aligner according to the millimetric value that the operator chooses (Figure 2). The new protocol of the aligner design proposes a uniform thickness of 0.5 mm for a week of wearing and 0.7 mm for 10 days of wearing. The aligners are designed and exported from the software as "Standard Tessellation Language" (STL) files. To print the aligner, 3D printers are needed, which fall into the category of VAT technology called also Stereolithography (SLA). Currently, there are three categories of VAT printers: SLA, Direct Light Projection (DLP), and masked SLA or LCD.[7] All of them can be used but the most frequently used are the DLP. Each printer has its software for printing with different tools and ways of support positioning. Supports are essential for successful and accurate printing and should be positioned in the needed areas (it is done automatically). The aligner can be positioned horizontally or vertically on the virtual printer platform. Positioning them horizontally increases the speed of printing due to fewer layers that must be printed but with the disadvantage of more supports. Additionally, less number of aligners can be printed each time. Vertically positioned aligners will be printed more slowly, with fewer supports, while more aligners can be printed immediately but with a higher chance of errors due to the increased number of layers to be printed (Figure 3). The z-axis resolution for printing used is 100 μm, which ensures adequate printing accuracy. The resin to be used must be homogenous, so stirring for some minutes is essential, while the temperature of the resin has to be around 30 °C, otherwise there will be a possibility of failure. When printing is finished, the aligner is removed from the printer's platform and placed in a centrifugation machine with their internal parts facing the outside to remove the excess uncured resin (Figure 4). Centrifugation should take approximately 5-6 minutes with a 500-600 rpm. The next step is to remove the supports and cure the aligner in the dedicated UV curing unit called Tera Harz (Graphy, Korea, Seoul) (Figure 5). The curing unit is manufactured especially for printed aligner with high-intensity

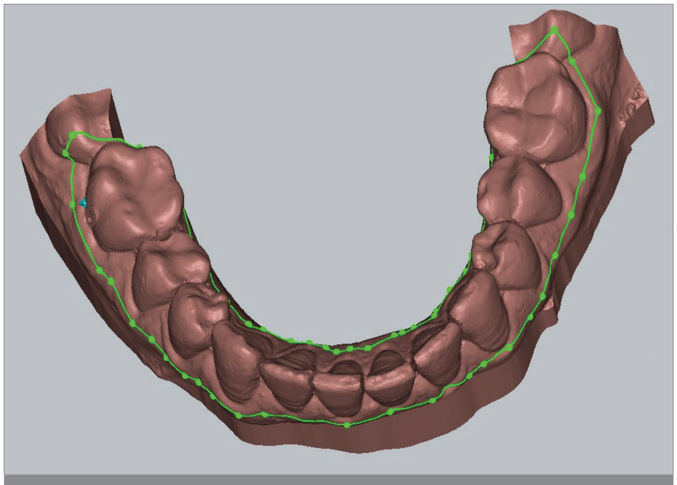

Figure 1. Directly printed aligner virtual design in Brackets software. Thickness can also be adjusted in the printed aligner module

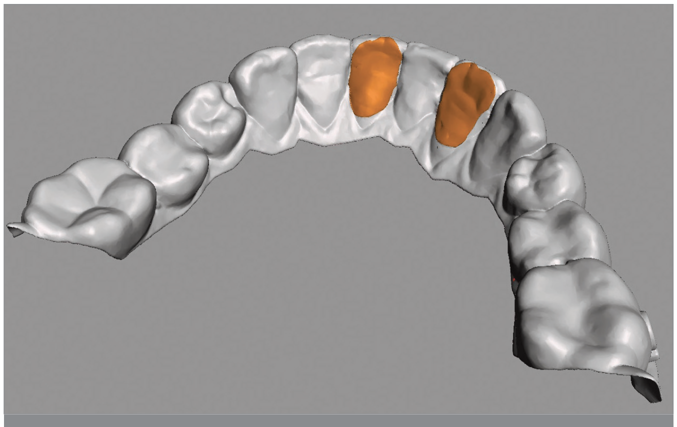

Figure 2. Brackets software enables the clinician to increase the aligner thickness in specific areas where teeth movement occurs. The software detects the areas where movement occurs and adds the extra predetermined material. Note the increased thickness of the aligner at the lingual side of 42 and 31which is planned to be moved labially

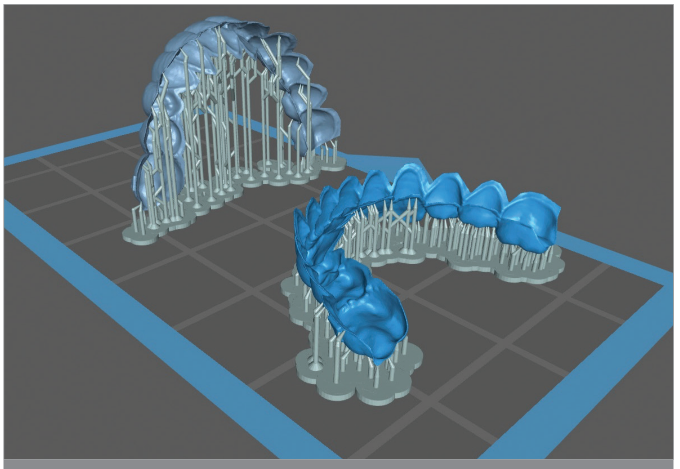

Figure 3. Virtual positioning of the aligner in a vertical and horizontal orientation. Horizontal positioning has the advantage of faster printing, but fewer aligner can be printed each time and more supports are needed. Vertically positioned aligner have the disadvantage of slower printing, but more aligner can be printed each time with the need of fewer supports

Figure 4. Vertically printed aligner with their supports. Note the yellow color which turns transparent after UV curing

leds and is equipped with a nitrogen generator to ensure curing without the presence of oxygen. Oxygen is a factor that inhibits complete polymerization, which could create problems with the mechanical properties of the aligner.[8] Complete polymerization ensures the production of a fully biocompatible aligner while transparency is also enhanced. Following curing, the aligner is polished at the areas where the supports used to be. In the end, the aligner is immersed in hot water for a few seconds to remove any possible remnants of substances that could create problems for the patient.

Clinical and Research Consequences

Printed Aligner Studies and Considerations

As mentioned before, in dentistry we tend to rush and use materials and machines without the proper research while medicine works exactly the opposite way. The nature of the 3D technology, the multistep, sensitive to error procedures, and the use of new materials call for research to create safe and efficient orthodontic appliances. Printed aligners fall into this category where research should be undertaken.

Printed aligners are new appliances that need to be tested both *in vitro* and *in vivo*. The first attempt to study the mechanical properties of printed aligners was done by Can et al.[9] where the effects of *in vivo* aging on their mechanical properties were studied. At that time, the protocol that the aligner was printed was the initial with a regular curing unit and with oxygen presence. Nevertheless, at the end of 1 week of wearing, the mechanical properties of the aligner were lost at an insignificant percentage, while a similar study on Invisalign aligner showed that almost half of the mechanical properties of the aligner were lost after 1 week of use.[10]

Figure 5. Tera Harz UV curing with a nitrogen generator that allows an oxygen-free polymerization

Additive manufacturing or 3D printing as it is known, is a multi-step procedure where each stage should be carefully carried out to ensure a successful printing outcome. Especially in the case of printed aligners, consistent workflow will ultimately lead to consistent results with consistently good quality aligners. The unique feature of printed aligners that differentiates them from other printed objects or appliances is that they are the only active appliances, made to exert force on teeth. All other printed appliances such as occlusal splints, IDB trays, and even brackets, do not exert force. Brackets do not directly exert forces but rather they are the means by which forces from the archwires pass to the teeth.

An important factor that could definitely lead to aligner defects or printing failures is the quality of the 3D aligner file upon exporting. According to the author's experience, even from the same software, aligner files could be of different quality. Even more, different software use could create different quality 3D aligner files even for the same patient. Corrupted files, defects on the aligner mesh, or other problems could lead to problems in the structure of the aligner or printing failures.

At the next step where the aligner is positioned on the printer's platform, a question arises whether printing in a horizontal position creates aligner with different mechanical properties compared to vertically positioned aligner. Transparency could also be different since the horizontally printed aligner consists of fewer layers while vertically printed much more. The roughness of the aligner is another factor to be examined. More layers, that are present at the vertically printed aligner, could contribute to the creation of a rougher surface, which could be aggravated by the *in vivo* aging of the aligner. A study concerning the comparison of the mechanical properties between vertically and horizontally printed aligner has already been conducted.

In a recent study by Zinelis et al.[11], was proved that different 3D printers create aligner with different mechanical properties. This finding is critical as it is determining the quality of the aligner that will affect the ability of the aligner to move teeth efficiently and predictably. Each printer uses different technology to polymerize the resin either using a beam of laser, light projector, or led. Other important parameters known as "irradiant exposure conditions" that include power and exposure time/velocity might play a role in the difference between the printing outcomes. LED printers in this study provided better mechanical properties (i.e., hardness) to the aligner, which are significant from a clinical standpoint. Despite the findings, there is not yet any evidence that the significant mechanical properties found affect the clinical efficacy of orthodontic therapy.

Another factor that should be investigated is the possibility that the same printer could print the same aligner file in repeated printing sessions with different mechanical properties. Intravariability printing examination is critical as it will prove the printer's ability to accurately print the same aligner every time having the same mechanical properties.

The next step after printing is centrifugation for 5-6 minutes at 500-600 rpm. The reason for that is to ensure that excess uncured resin is entirely removed. Failure to do so might lead to excess resin curing and bad fitting of the aligner due to the increased internal thickness of the aligner. Immediately after printing, aligner is yellow, sticky, and very soft with a shape memory property. UV curing that follows centrifugation is the one to give the final properties to the aligner. It is possible that centrifugation could alter the shape and fitting of the aligner. Therefore, it is essential to investigate the effect of centrifugation on the aligner as accurate fitting is critical for aligner treatment.

The last and one of the most important stages in the whole workflow is the UV curing of the aligner. UV curing units can be found in the market with different led power intensities and other functions. UV curing polymerizes the outer shell of the aligner, which is always not fully polymerized after printing. As mentioned before, the only active appliance that exerts a force on teeth and is manufactured by the 3D printing process is the printed aligner. For this reason, UV curing should be complete to ensure that all potential properties of the aligner will be expressed. Initially, Graphy released a UV curing unit called Cure M, which was dedicated to the curing of aligner. It seems that following company research, the printed aligner was not ideal concerning its properties. It is well known that oxygen inhibits the full polymerization of oligomers and monomers to polymers.[8] For this reason, a free-oxygen environment is desirable to ensure that the aligner will be fully polymerized. A new UV curing unit recently released called Tera Harz includes a more sophisticated technology where a nitrogen generator connected to a high-pressure (5-6 bars) air connection compresses nitrogen into the curing chamber of the unit. Resins, as it is stated also at the leaflets of the liquid, are toxic, irritating, and allergic. In this pre-polymerization state, they are certainly not biocompatible. Resins gain their biocompatibility at the printing stage but mostly at the UV curing stage. Incomplete polymerization is a factor that possibly initiate irritation or even allergic reactions to the patient. Therefore, leaching of materials in an incompletely cured aligner should be taken seriously. For this reason, complete polymerization, and the inclusion of a nitrogen generator in the curing unit is essential. Apart from the biocompatibility perspective, complete polymerization could be a contributing factor in creating adequate aligner transparency, which will be kept high until the end, decreased roughness after *in vivo* aging, and better mechanical properties. All these hypotheses should be tested using scientific research.

The resin manufacturing company states that after UV curing and aligner polishing, the aligner should be placed in hot water for a few seconds. Although it is not proven scientifically, they claim that it might remove remnants of particles on the aligner surface that could cause reactions to the patient's oral cavity. Additionally, the immersion of the aligner in hot water before placing it into the patient's mouth instantly transforms the aligner into a very soft object that can be immediately placed into the teeth of the patient with easiness. Again, at this point, the change in the mechanical properties of the aligner before and after the immersion in hot water should be scientifically investigated.

Aligner fitting is one of the most important factors that determine the treatment outcome. It was shown in aligner studies that aligner tend to have a distance from the surface of the teeth, which affects their ability to perform teeth movements.[12] For example, in cases of round-shaped teeth where rotations should be performed, the above issue could lead to loss of tracking and failure to derotate the teeth. In the same study, Koenig et al.[12] compared two thermoformed aligner and one printed aligner in terms of accurate fitting. The study presented better accuracy for the printed aligner compared to the two thermoformed aligner. The physical properties of the printed aligner were found to have lower yield strength and elastic moduli compared to conventional PETG. The initial force for stress relaxation (which is one of the most important properties of aligners) under high temperature (80 °C) was 18N, but for 1% elongation, the residual static force was greatly reduced to about 1N. An interesting finding for repeated loads, stress relaxation decreased and residual static force increased. Nevertheless, due to the multi-step inconsistent printing workflow, in another printing instance, fitting could be different.

Another unique feature of aligner in general is that they are the only orthodontic appliances that are renewed every 1 or 2 weeks, depending on the protocol. This feature is of great importance for the patient's safety. Renewal of aligner means that every time the aligner changes new increased chemical substances amount could be released in the mouth. In the case where the aligner is not fully tested for material leaching or where the aligner is proved to release chemical substances, the effect on the patient could be damaging. We could think of it as taking every week an amount of the same medicine that is harmful to the human being. For this reason, as mentioned before, a thorough *in vitro* and *in vivo* investigation should be carried out before the material release.

Cytotoxicity is defined as the toxicity caused due to the action of materials on living cells. To exclude the possibility of cytotoxicity of the aligner to human cells, a study was recently conducted by Pratsinis et al.[13] Aligner was immersed in sterile deionized water for 14 days. The cytotoxicity of the released factors was assessed by MTT assays (solvent) on human fibroblasts. The authors concluded that if there were any factors released, those were not found to be cytotoxic.

A major issue regarding material release in our days is the release of bisphenol-A (BPA), which is found in dental materials (composites). BPA is a substance that is accused to cause estrogenicity, which is the action of endocrine-disrupting chemicals that mimic, block, or interfere with hormones in the body's endocrine system. Apart from dental materials, plastic has been accused of BPA release. BPA generally creates problems for males but also other problems for both genders such as type 2 diabetes, obesity, growth inhibition, behavioral changes, cardiovascular diseases, and certain types of cancer.[14-16] Composite attachments that are widely used in aligner treatments and which are designed in block-like different shapes seem to be an issue taking into account that often they are used in almost every tooth and that in refinements, they are removed and then repositioned.[17] An ideal evolution of the aligner is to be able to move the teeth without the need for composite attachments. In the same study where cytotoxicity was investigated, estrogenicity was also examined showing no estrogenicity signs.[13]

A study performed to investigate the possible release of urethane (UDMA monomer) by the aligner presented the release of this monomer.[18] The repeated intraoral exposure to this substance due to the weekly renewal of the aligner could have potential health hazards for the patient. Previous studies have shown that urethane could induce cytotoxicity in human dental pulp cells. Nevertheless, this could not be justified in this study.[19,20]

Surface roughness was assessed for printed aligner compared with Invisalign appliances. The findings showed an increased surface roughness for the printed aligner compared to Invisalign both for the control group (unused) and the used ones.[21] Increased roughness could lead to aligner discoloration or pigmentation increases the accumulation of plaque and increased material leaching.[22,23]

Advantages and Disadvantages of Printed Aligners

Even though printed aligners have just appeared in the orthodontic field, they possess some advantages compared to thermoformed. With the proper and targeted research, printed aligners could displace thermoformed aligners allowing for better, more efficient, safer, and faster orthodontic treatments.

1. The environmental burden is an issue that concerns all humanity. Materials that are not recyclable, burden nature leading to problems for all living beings on the planet. From the time when dental models are made, and following 3D printing, the planet experiences a slow, silent gathering of millions of non-recyclable printed models every year. Printed aligner could be a solution since no dental models are needed. Ideally, a printed aligner could be recyclable. In this way, this could be another advantage compared to thermoformed one.

2. Since the steps of model printing and thermoforming procedure, aligner removal, and trimming are excluded from the procedure, direct aligner printing is a faster procedure. For instance, in cases where the orthodontist would like to instantly deliver aligner printing in a horizontal orientation would allow the fast delivery of the aligner/s to the patient.

3. The thermoforming procedure entails the use of units (handpiece) to remove the aligner from the dental model. Additionally, the aligner must be polished at their extremities. All this process creates a cloud of dust that creates a dirty office environment but also entails hazards for the operating personnel. Printed aligners are manufactured in a dust-free environment, which is advantageous for both the office and personnel.

4. According to a Koenig et al.[12], printed aligners exhibit higher fitting accuracy compared to two commercially available plastic foils that were tested and which are often used in our orthodontic offices. Fitting accuracy is indeed one of the biggest problems of aligner. The loss of tracking and inability to move teeth, for example in, rounded-shape teeth, is due to bad fitting.

5. A major advantage of printed aligner is the ability to print aligner with uniform thickness. Uniform thickness has the advantage of delivering uniform forces to all teeth. According to a study by Koenig et al.[12], there was a thickening of 12% of printed aligner, while thermoformed aligner had a significant decrease in thickness. Another study showed that thermoformed aligners have less thickness after the thermoforming procedure compared to the initially used plastic foil.[24]

Lee et al.[25] performed thermal deformation of the aligner foil in a standardized block model. They reported a thickness change of 54% or more through this process. At the thermal deformation, shrinkage and expansion of the material may occur, which results in a difference in the thickness of each different tooth. Such morphological variation can be a problem in our effort to improve our clinical results in tooth movement.[26]

6. Foils for a thermoforming process come in a specific thickness. Thus, they cannot be intentionally altered. In contrast to the thermoformed, printed aligners are more versatile in allowing increasing the aligner thickness in specific areas. Deltaface CAD software includes a command tool where the software detects the teeth' movements and applies the selected extra thickness to those areas. In this way, the operator selects the overall thickness of the aligner and then by selecting variable thickness sets the value of the extra thickness needed. Upon aligner design, the software automatically adds the extra thickness only on areas where teeth are being moved. For instance, in the case of labial lower incisor movement, the software adds material to the lingual part of the incisor (Figure 2). The added thickness increased the stiffness of the aligner at that point. Nevertheless, it is not scientifically proven that increased thickness could have a favorable effect on the efficacy of aligner treatment. Added thickness could be added by the software on the occlusal surfaces of posterior teeth if an open bite needs to be corrected (Figure 6). In the same way, aligner thickness could be increased on the palatal side of the upper incisors in cases of deep bites (Figure 7).

7. 4D printing is the next step of the technology of 3D Printing that was invented by Hull[27] in 1984, which introduces time as the fourth dimension. Smart material printing is another name of 4D printing. Smart materials reconstruct the shape or action of a printed object in response to external stimuli such

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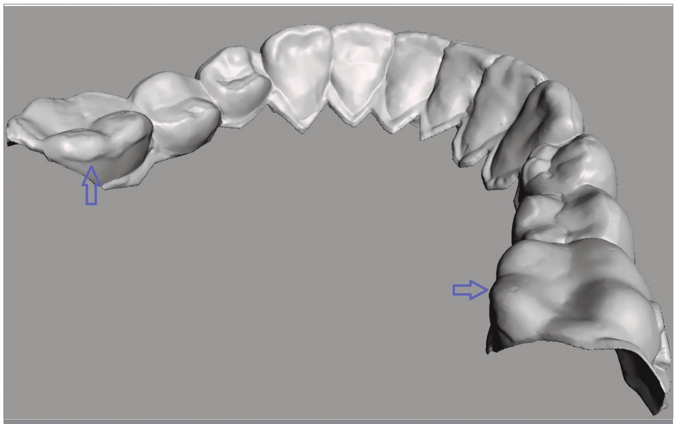

Figure 6. In cases of open bite, the orthodontist can choose to increase the thickness of the aligner at the molars to facilitate bite closure

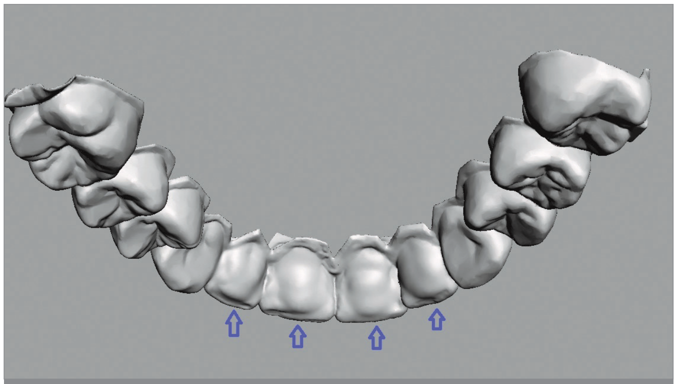

Figure 7. In cases of deep bite, the orthodontist can increase the thickness of the palatal side of the upper incisors to correct the deep bite.

as mechanical, electrical, chemical, or thermal over time.[28] A resin with smart material properties could be the solution to problems such as loss of tracking in tooth movement, excessive use of attachments, etc. For instance, the resin could be sensitive to a specific wavelength light cure, and its action and application on specific aligner areas could change the amount or duration of force delivery.

Usually, new technologies also present some disadvantages that over time are reduced. For example, a major disadvantage is the fact that the whole printing and post-printing procedure is inconsistent and depends on multiple steps. An error in one step affects the following stages and can create problems. For this reason through extensive research, a scientific evidence-based protocol should be conducted, which will allow a consistent and high-quality outcome. Another disadvantage is the somewhat higher cost of equipment compared to the thermoformed aligner production. Apart from the software that exists in both kinds of aligner, a printer should be purchased together with a UV curing unit. Of course, one should not forget that there is no need for a thermoforming unit that has a price equal to a descent 3D printer. One should also calculate the number of aligner that can be printed per ml and the price of each thermoformed aligner that is created. This should include the price of the plastic foil and the 3D-printed- model that is needed.

CONCLUSION

3D printing has introduced a new way of designing and manufacturing appliances. Orthodontic treatment due to this technology can become more efficient, easier, faster, and with fewer problems for the patient. Aligner in their thermoformed form have gained a relatively big piece of the overall orthodontic treatment appliances. Nevertheless, their ability in correcting orthodontic problems is questioned, especially in specific types of teeth movements. Printed aligner seem to be a new aligner treatment modality that could solve the problems that arise from the use of aligner. The advantages of printed aligner that were mentioned before compared to the thermoformed ones are enough to motivate companies to invent new aligner resins and evolve them to try reaching the efficacy of fixed appliances. Mechanical properties must be optimized to have printed aligner equal to or even better compared to the existing thermoformed aligner. Safety is another issue that must be addressed and solved, although studies have shown that at least the specific printed aligner are safe to use. Due to the release of materials from aligner that are renewed every 1-2 weeks, and which are not easy to be detected (studies are targeted to detect specific released materials), there is a necessity to create a material that will be changed less often (i.e., every 1-1/2 months). This could help decrease the amount of material released by the aligner and increase the safety level in aligner treatment. Of course, the invention of such material should be accompanied by better mechanical properties, which will not be affected by prolonged aligner use, while aligner transparency should be kept high for aesthetic reasons. Smart materials are already been used in engineering and proof-of-concept experiments. The next step is to use this technology in the orthodontic field, which will be advantageous for our orthodontic treatments. The in-office concept is here to stay. Nevertheless, orthodontic and dental associations should create protocols and guidelines for digital laboratory installments in orthodontic offices. The observed uncontrolled installation of 3D printers, post-printing units, and toxic and irritating materials in orthodontic offices should be controlled through protocols that will be applied and often checked by dental associations. Scientific studies should be conducted before the release of new materials and technologies resembling the medicine way.

Ethics

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