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Chapter

Digital Workflow for Homemade Aligner

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Abstract

Advanced digital technology is rapidly changing the world, as well as transforming the dental profession. The adoption of digital technologies in dental offices allied with efficient processes and accurate high-strength materials are replacing conventional aligners workflows to improve overall patients' experiences and outcomes. Various digital devices such as 3D printers, intraoral and face scanners, cone-beam computed tomography (CBCT), software for computer 3D ortho setup, and 3D printing provide new potential alternatives to replace the traditional outsourced workflow for aligners. With this new technology, the entire process for bringing clear aligner production in-office can significantly reduce laboratory bills and increase patient case acceptance to provide high-quality and customized aligner therapy.

Keywords: digital workflow, orthodontics, aligner, thermoforming, 3D Printing, facial scan, planning software, homemade aligners

1. Introduction

The increasing esthetic need of patients for orthodontic devices has lead to the development of clear aligner therapy [1, 2]. Traditionally, orthodontists contract with an outside service to provide clear aligner treatments. Outsourcing to a provider has drawbacks for both the patient and the orthodontist. It can take over a month to produce and deliver an aligner set, and the provider requires a substantial service fee, cutting into potential profits.

Advancements in 3D printing technology, Intra-oral scanners, and 3D setup software improve the production of clear aligners. Nowadays, these solutions are widely available in private dental practices, allowing orthodontists in-house aligner production.

In-house 3D printing accelerates aligner turnaround, increases profitability, and improves patient satisfaction while offering complete workflow control.

In this chapter, we will suggest to orthodontists to centralize the production of aligners in the dental office by detailing the different stages of the production flow. Form acquiring extra-oral and intra-oral patient data and exploring necessary hardware and software for this acquisition. Until the production of the aligners, where we will discuss the equipment and materials mandatory for this production. Going through the planning, this section will detail the different software that an orthodontist can use for the 3D setup and the particularities of each of these softwares.

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2. Materials and methods

The conventional clear aligner treatment is based on a complete outsourcing workflow, in this flow, the orthodontist will be restrained to check the setup proposal and request changes if he judges it necessary. To refer a case the orthodontist uploads the patient's data such as photos, X-rays, and digital dental impressions; then, he submits a prescription setup to aligner labs/companies. After a few days, the practitioner receives a setup proposition for review; the orthodontist evaluates the setup made by a technician and asks for some changes if necessary. Generally, there are 2 to 3 revisions with most aligner's laboratories before achieving a good treatment setup. This interaction between the orthodontist and the technician wastes time. Once the treatment setup has been approved, the orthodontist has to wait for the aligners to be fabricated and shipped to the office. Usually, the whole process takes 2–6 weeks.

In homemade clear aligner workflow, there are three main axes: data acquisition totally made by dental staff, planning of aligner setup, and aligner fabrication; these last two steps can be internalized in the dental office or outsourced to a third party. The outsourcing choice will depend on the time the orthodontist can allocate to planning, the cost/benefit ratio of acquiring software, and hardware and dental staff's ability to expand functions and competencies **Figure 1**.

2.1 Data acquisition

2.1.1 Digital model creation

The maxillary and mandibular digital working models and recording of the patient occlusion can be done directly on the patient by an intraoral scanner or by digitizing the analog impressions and/or plaster models with a desktop scanner or by a cone-beam computed tomography (CBCT).

Extraoral 3D scanners can be used to capture 3D images of both impressions and physical casts to acquire digital models. An optical scanner (OS) is an extra-oral digitization method that uses a white light that is cast on the plaster dental model. Later, the projected pattern is captured using a high-resolution camera, and a 3D image of the model is created. Dental labs often prefer optical digitizers, involving less acquisition time for scan construction [3, 4].

Digital measurements of tooth size, arch width, and Bolton tooth size discrepancy on digital models obtained from plaster dental model scanning and dental impression scanning showed high accuracy and reliability. No statistically significant differences were noticed between direct measurements on the plaster models with a caliper and digital measurements on digital models obtained from plaster dental model scanning and dental impression scanning methods. Digital models can

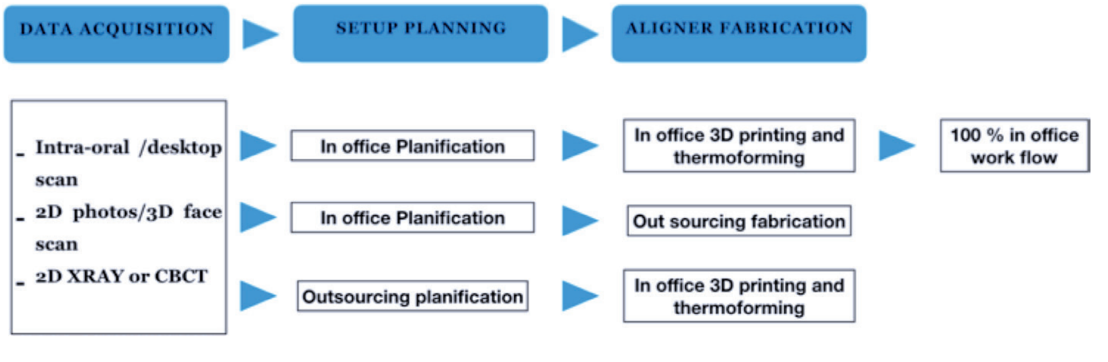

Figure 1.
Different Workflows for in-office aligners.

be alternative to plaster models with clinically acceptable accuracy and reliability of tooth size, arch width measurements, and Bolton analysis [5].

Intraoral scanner (IOS) is an alternative to OS for the digitization procedures of plaster dental models [3]. Various intraoral scanners are available in the market, with many different technologies, each with its own limitations, advantages, and costs [6]. The 3D scanning technologies depend on different physical principles and are defined in the subsequent classes [5]:

1. Laser triangulation 3D scanning technology uses either a laser line or a single laser point to scan across an object.

2. Structured light 3D scanning technology uses trigonometric triangulation.

3. Photogrammetry 3D scan scanning technology (photography) reconstructs 3D from 2D images.

4. Contact-based 3D scanning technology is based on the contact form of 3D data collection and uses a contact probe [7].

Advancements in the CBCT systems have made the digitization of plaster dental models possible [8]. Several CBCT manufacturers have started integrating extra cast digitization tools into their machines to simplify the workflow for data acquisition and surface extraction [3]. CBCT scans are acquired using a volume scan method instead of a surface scan method using a laser or LED source; therefore, CBCT scans are not affected by the angle of irradiation or the shape of the subject around the undercut area proximal contact. CBCT can even be used in cases of crowding without managing raw scanned data [9].

Digital model fabrication using scans of patient impressions obtained with CBCT in a dental office is another alternative method to create a model without an intraoral scanner or a desktop scanner and without directly irradiating the patient. If necessary, digital models and plaster models can be fabricated using a single impression [10].

2.1.2 3D Facial scan

The assessment and analysis of facial soft tissues are essential for orthodontic and maxillofacial diagnosis and treatment planning. In aligner therapy, using a two-dimensional (2D) digital photograph is a basic approach for facial structure assessment. However, this process has been progressively replaced by three-dimensional (3D) imaging. The 3D facial scan enables creating a virtual face that can be integrated with 3D models of the dentition obtained by intra-oral scanners and coupled with 3D radiographic images from CBCT for a 3D orthodontic set-up to achieve virtual patient [11].

There are two classifications of the scanning systems based on the type of equipment of the optical devices, namely stationary systems and portable/handled systems. In stationary systems, the optical devices are fixed on tripods or adjustable frames, while in handled/portable systems, the scanners are movable in real time around the target object [12].

Stationary facial scanning systems based on stereophotogrammetry technology were first introduced in dentistry [13]. Digital stereophotogrammetry captures 3D facial surface data using at least two cameras configured as a stereo pair. This procedure may be: passive or active. In active stereophotogrammetry, structured-light techniques are incorporated for higher resolution [14]. Because of the encumbrance, high cost of this technology, and their operating methods that require frequent calibration, handheld scanning systems using laser or structured-light technology were developed [15].

Laser-based scanners function by projecting an eye-safe class 1 laser beam across a subject's face. The beam is scattered by the face and collected at a triangulation distance from the laser's origin. At the same time, Structured-light scanners (SLSs) generate 3D facial models by projecting a full structured light pattern (typically vertical stripes) onto a subject's face, recording deformations in this pattern produced by the face's morphology allow 3D face reconstruction [16].

Although most professional handheld scanners are considered acceptable in terms of their scan image quality, they are expensive and often require considerable training time to learn their complex scanning protocols [3, 9, 10]. Alternatively, 3D sensor cameras based on structured-light technology have been developed for smartphone and tablet devices [15]. Increasing interest is due to mobile devices' high portability, user-friendliness, cost-effectiveness, and popularity [17–19]. The advantages of smartphone face digitization include reducing time for scanning, image processing, technical learning [20, 21], and their high portability [22].

Motion artifacts were considered the primary source of error in the results of portable face-scanning systems [23–25], cautioning that the influence of involuntary facial movements has a more significant impact on mobile face-scan devices than stationary ones [11]. Prolonged scanning time and unstable movements of the scanners may magnify the motion artifacts caused by involuntary facial movements [25]. Therefore, using scanners that conduct a single and quick scan is recommended, mainly when the face scans are performed on children or people with special needs who struggle to stay immobile for a prolonged time [11, 25, 26].

2.1.2.1 3D dentofacial integration

The 3D dentofacial image integration is performed by matching the dental scans to the facial scans. Alignment of the two scans (facial scan and dental scan) can use teeth image only (TO), perioral area without marker (PN), or perioral area with markers (PM) [22].

For the 3D dentofacial integration using teeth images only, the teeth area visible on the facial scan images is used as a reference to match the facial scan with the intraoral scan **Figure 2** [27, 28].

The intraoral scan of the teeth area associated with the scan of perioral structures was proposed to enhance the accuracy of the dentofacial integration [29] **Figure 3**. This procedure aims to provide larger areas that can be used as a reference to coordinate the intraoral scan of the teeth with the 3D scan of the face. The effect of the perioral scan method on image matching depends on the use of artificial markers during the perioral scanning [22]. The absence of clear marks on the skin causes inaccuracy of the scan data obtained when capturing large areas of the perioral structures without the skin marker attachment by the intraoral scanner.

Artificial markers provide distinct references for similar adjacent areas so that they could help the image stitching process. Perioral scan with artificial skin markers significantly improved the accuracy of integration of dental model to the facial scan **Figure 4** [22].

2.1.3 3D X-ray: Cone-beam CT

Major planning solutions for aligners consider only the crown position, not the root shape. Complete tooth architecture information, including crown and root anatomies, would improve treatment planning and provide more predictable results [30].

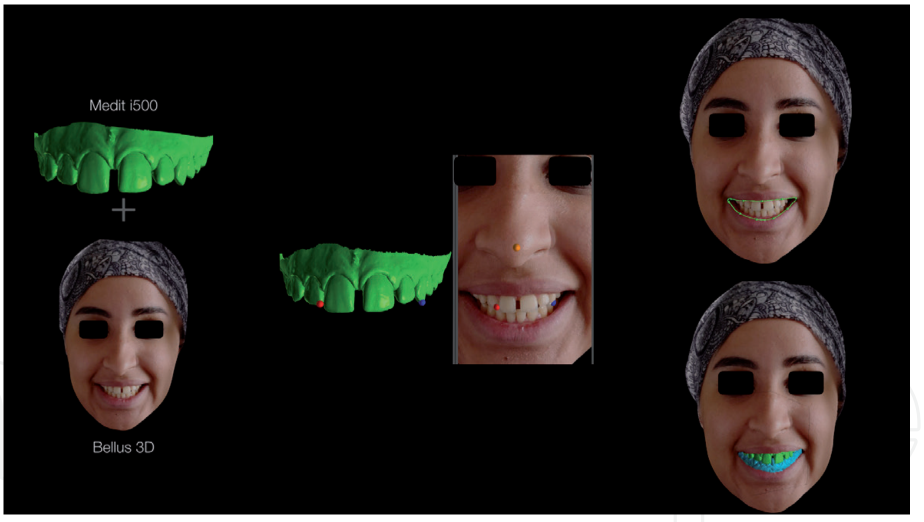

Figure 2.
Alignment of the two scans (facial scan and dental scan) using teeth image only (TO).

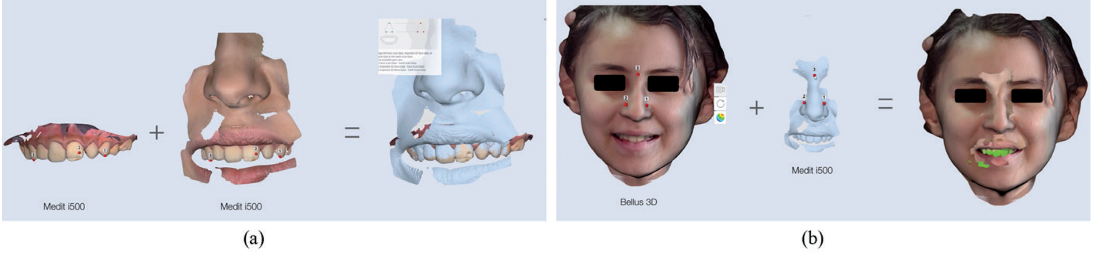

Figure 3.
Alignment of the two scans (facial scan and dental scan) using perioral area without marker (PN) The participant was scanned using Bellus 3D by rotating the head to the right and the left of the camera, following the manufacturer's instructions while maintaining the head at the camera's center. The scanning mode was set in high-definition (HD mode) in the scanning software. The intraoral and perioral anatomical structures were acquired using an intraoral optical scanner mediti500. The perioral structures, including the upper lip, philtrum, and nose, were obtained with the participant's anterior teeth in a broad smile position. a: The first step is matching perioral scan to intraoral scan; fixed mesh is intraoral scan. b: The second step is matching the 3D facial scan with the perioral scan previously aligned on the intraoral scan; the fixed mesh in this step is the perioral scan.

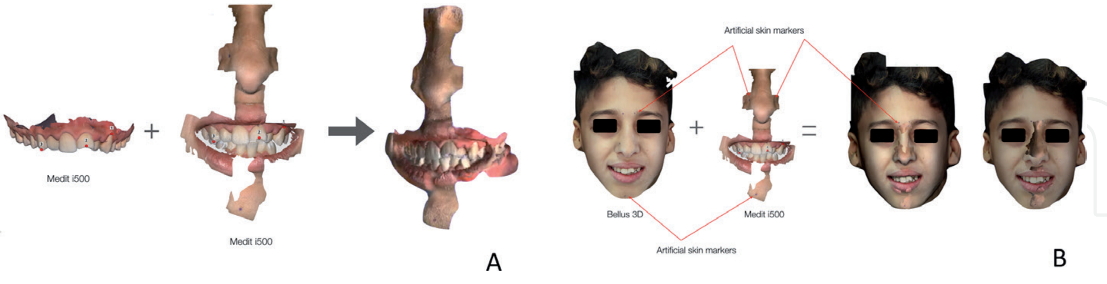

Figure 4.
The two scans (facial scan and dental scan) are aligned using perioral area with markers (PM). A: The first step is matching perioral scan to intraoral scan; fixed mesh is intraoral scan. B: The second step is matching the 3D facial scan with the perioral scan previously aligned on the intraoral scan; fixed mesh in this step is perioral scan. Artificial skin markers provide distinct references for the image stitching process.

2.1.3.1 Procedure

Dicom file is imported into 3D setup software; the orthodontist performs segmentation to have a 3D reconstruction of root morphology, then he stitches 3D segmented teeth to STL IOS model. Afterward, the orthodontist can adapt the position of the virtual tooth to segmented roots to have a correct pivot. Integrating 3D data from an optical scanner with volumetric data from CBCT imaging provides an optimal spatial reference for the most accurate hard and soft tissues models. **Figures 5** and **6**.

2.2 Digital treatment planning

Selecting software is the main concern for most clinicians to get started with homemade clear aligners. All 3D setup ortho planning software have typical workflow **Figure 7**. The software's options have comparable abilities at the core; however, some specific features add value and are determining when choosing a software. **Table 1** summarizes the different software available on the market with their respective options.

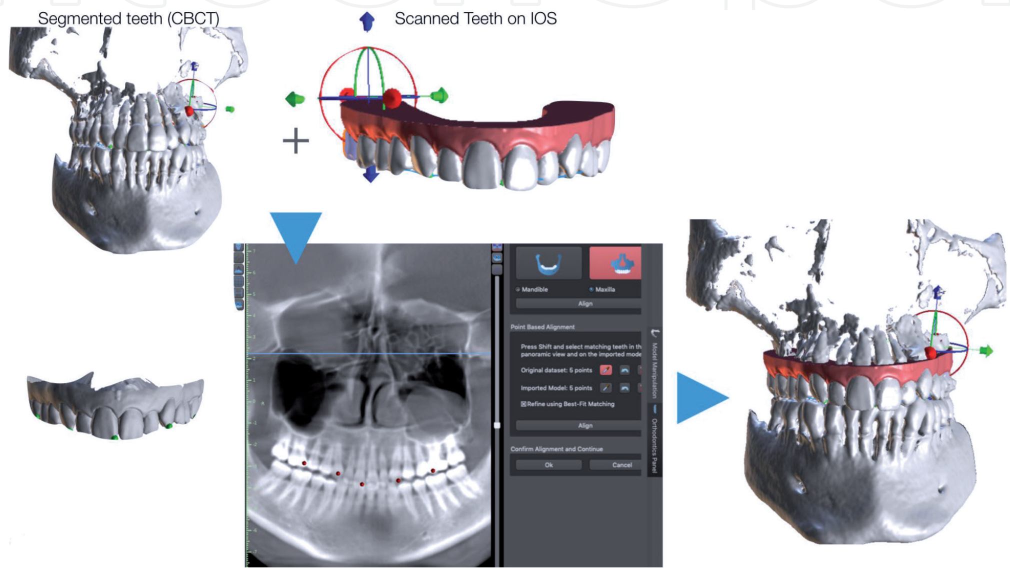

Figure 5.
Aligning 3D segmented Teeth (Roots & Crowns) to IOS Scanned teeth using teeth as references.

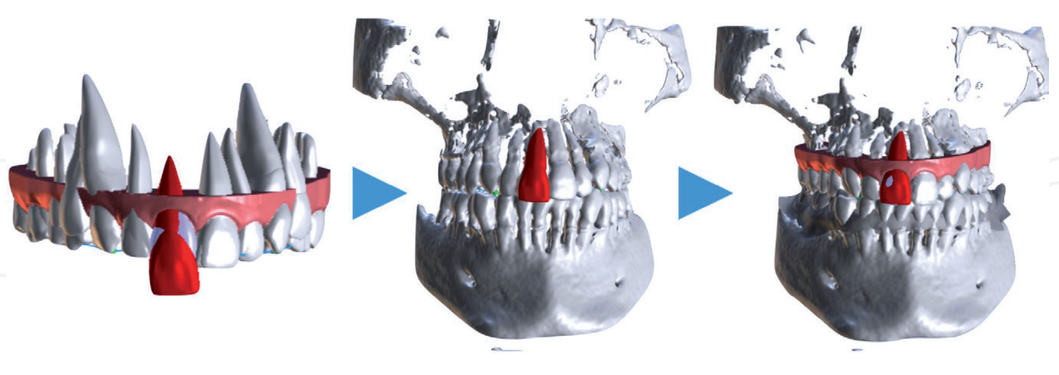

Figure 6.
Aligning virtual teeth of 3D setup software according to segmented roots (CBCT).

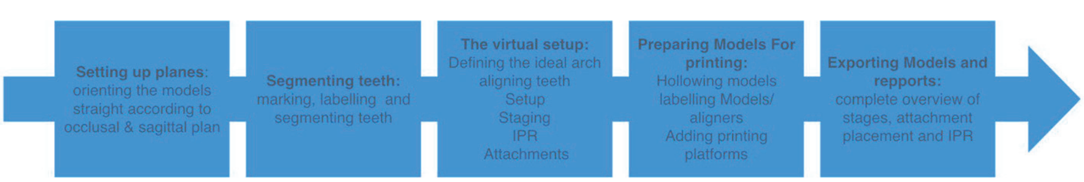

Figure 7.
Typical workflow for 3D ortho setup software.

	3shape		Sursmile	C+ model	Ulab	Ortup	BSB Ortho	ArchForm	SoftSmile
Grid overlay features	✓	✓	✓		✓	✓	✓	✓	✓
Automated Segmentation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual or group movement of teeth	✓	✓	✓	✓	✓	✓	✓	✓	✓
Customize attachement size/ dimension	✓	✓	✓	✓	✓	✓	✓		✓
Auto place attachment					✓	✓	✓	✓	✓
IPR adjustment per contact		✓	✓	✓	✓	✓	✓	✓	✓
Staging IPR steps		✓	✓	✓	✓	✓			
Same day starts	✓		✓		✓			✓	✓
Automated set-up		✓	✓	✓	✓	✓	✓		
Print horizontal	✓	✓	✓	✓	✓	✓	✓	✓	✓
Print vertical: add platform				✓	✓		✓	✓	✓
Printing hollow				✓	✓		✓	✓	✓
Labels Models	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aligners setps on models		✓		✓	✓		✓	✓	
Atomated aligner trimming for milling machine					✓		✓		
Predectibility and gradiant difficulty for tooth movement				✓					
License fee	✓	✓	✓		✓	✓		✓	✓
Fee per case/ aligner exported				✓	✓		✓		
Directly print Aligner		✓					✓		
Pontic for extraction Cases			✓			✓			
Virtual root		✓				✓	✓		✓

Table 1.
Different software available on the market with their respective options.

2.2.1 Automatic segmentation

Almost all programs offer an automatic segmentation feature. Artificial intelligence (AI) algorithm finds the gingival border of each tooth. Using AI, the software will automatically segment and identify the teeth. Next, they will label the teeth and then automatically create a long axis, center groove line. If necessary, the software can manually adjust borders with an intuitive brush-editing feature, edit tooth labels, correct grooves, and adapt the long axis if needed [31, 32].

2.2.2 Realtime simulation

3D ortho setup software authorizes real-time simulation with features as intuitive alignment, enabling easily drag teeth to where they need to be, occlusal contact collision calculation, and IPR options. Also, 3D ortho setup software allows aligning the teeth to a customizable arch shape by adjusting the arch shape using the control points placed around it [33].

However, not all programs allow skeletal movements, evaluation of multiple treatment strategies, and creating treatment simulations for surgical, restorative, and extraction cases [34]. Plus, features relative to model capabilities as Bolton analysis on every model, automated measurements of tooth width, arch width are not available in all software.

The SoftSmile, Blueskyplan orthodontic, Deltaface, and Orth'up aligner software [31–36] create a 3D model of the orthodontic treatment plan, including a representation of teeth roots and movement of the lower jaw during the treatment. It creates optimized teeth movement and suggests, along with the knowledge and skill from the orthodontist, the exact number of aligners needed for reaching better results.

2.2.3 Advanced staging & sequencing

3D setup softwares make a staging proposal; the user feels the difference in the possibility of customizing this staging. BSB ortho, uLab, et ArchForm enable the orthodontist to select the teeth to move first, achieving sequential distalization and establishing the order of teeth movements [32–35].

2.2.4 Attachments

Adding an attachment is a standard option in 3D setup software. Some softwares stand out by features such as automatic attachment placement depending on the tooth movement or customized attachment with adjustable attachment size and gingival tilt to control tooth movement [35–37].

2.2.5 Ready to print models

From finishing the treatment plan to starting a print, much valuable time is lost on preparing printable.STL. All softweares allow STL export, but some make the entire manufacturing process smooth, intuitive, and straightforward.

Blueskyplan ortho, Archform and ULab automatically prepare models for 3D printing: in few clicks, all models are made hollow, and a bar for vertical printing without support is attached to them [35–37]. Usually technicians spend 5–7 minutes on the preparation of each model, but with BlueSkyPlan Ortho 2 minutes are spent on preparing the whole case's models. Features like hollowing models and vertical printing with optimized tilt make the virtual setup process smooth, quick and convenient, saving resin and printing time [35].

Labelling models is a standard feature that enables adding letters and numbers on models to identify patients and orthodontists. Nevertheless, special labelling such as auto labelling imprints onto the aligner is specific to only some software like BSB ortho, Archform, and Ulab [35–37].

2.2.6 Automatic pontics for concealing gaps and missing teeth

Developed especially for extractions cases, this functionality is not available in all software. On Archform, and ORTH'UP softweare [33, 37], teeth can be extracted at any stage during treatment planning. The two software allow clinicians to place a pontic that will change dimension as the space is closed. The pontic can have the same form as the extracted tooth, a mirror of the tooth on the other side, or a tooth selected from a library [37]. With SureSmile, either gaps are opened for an implant or closed after an extraction; once a space is bigger than 3 mm, a virtual tooth is added to fill the gap [34]. Efficient and fast, this functionality allows significant time-saving in the preparation of cases for the dental assistant.; avoiding manual waxing on printed models before thermoforming aligners [33].

2.2.7 Variable trim line

With BSB ortho, doctors can freely choose the trim line design; individualized positioning bases are added to the aligner to be trimmed in a high-precision automated laser cutting machine [35]. The Aligner Trim curve will be generated automatically based on the parameters "Curve Shape" and "Trim Margin" in Preferences. Both parameters can be adjusted as well and regenerate directly on the orthodontics panel. The export of the curve will be available in the last step for the automatic trimming of the aligners in the milling machines [35]. ORTH'UP software offers the possibility of calculating the aligner boundary at each step of the treatment plan and converts it into a 3D marking on the printed model. This visual reference makes cutting the aligners by the dental assistant faster and much more precise [33].

2.3 3D Printing

The dental sector has been undergoing radical change for many years, thanks to the digital dentistry movement. Additive manufacturing, in particular, has enabled the dental industry to expand its use of digital technologies. Indeed, the dental sector is a promising market for 3D printing technology because it responds to the issue of customized items.

3D printing is now easily approachable for orthodontists; 3d printing for orthodontics reduces production time and costs, and its potential is still growing [38].

2.3.1 Fused deposition modeling (FDM) 3D printing

Fused Deposition Modeling (FDM) 3D printing consists of creating several layers by injecting a molten plastic filament through a heated extruder. Any material that can be injected through a heated nozzle at melting temperature is printable by this technology. It comes in a long filament with a 1.75 to 3 mm diameter wound in a 500 g or 1 kg coil. Polylactic acid (PLA), Acrylonitrile butadiene styrene (ABS), and GreenTech pro are the most suitable materials for orthodontic models. Their prices vary from 20 to 40 euros [39].

PLA is a fully biodegradable polymer by industrial composting. It is obtained from the fermentation of starch, beet, corn, or sugar cane. It has the advantage of not giving off toxic fumes during printing. However, its glass transition temperature is around 60°, which limits its use under thermal stress, which goes against the thermoforming of aligners [39, 40]. PLA is generally used in 3D printing due to its very affordable price also in dental 3D printing to make dental models. New reinforced forms are proposed to endure mechanical and thermal stresses. (Pla Ultra, PLA-X3,) [40, 41].

Acrylonitrile butadiene styrene (ABS) is a thermoplastic polymer with excellent mechanical and thermal resistance. It is very affordable and is easily recycled by steaming [42, 43].

GreenTech pro is a 100% biodegradable biopolymer (DIN EN ISO 14855), made from organic, CO2 neutral, and environmentally friendly materials. The FDA has approved it for food contact. It has a mechanical and thermal superior resistance to ABS and PLA, ideal for dental models subject to thermoforming constraints [44].

2.3.2 Stereolithography 3D printing

Stereolithography 3D Printing (SLA) is the most widely used technology in dentistry, both for its precision and well-finished surface. For the same layer thickness, the surface roughness is far well finished compared to FDM. Stereolithography (SLA) is an additive manufacturing process that refers to the Vat Photopolymerization family. In SLA, an object is formed by selectively curing a polymer resin layer-by-layer using an ultraviolet (UV) laser beam [45, 46].

UV light can be a simple micrometers laser beam that will sweep the entire layer, point by point, just like a colored pencil that colors a 2D drawing to follow the same way on the next layer [45]. UV light projection can also be a light projection of an entire layer by a DLP projector (Direct Light Processing), resulting in a single-shot polymerization of the entire layer. Compared to SLA, the DLP is definitely faster [45].

Among the leading manufacturers of 3D SLA printers, 3D Systems, is at the origin of this technology, but also more recent players like Asiga, which was the first to have launched the Direct Light Processing (DLP) 3D printers in 2011, and Formlabs, which initiated the introduction of in-office 3D printers to the dental practice through its FORM2 printer allowing 3D printing dental materials.

This technology uses 385 nm or 405 nm photopolymerizable resins depending on the wavelength of projected light. There are many resins dedicated to dental models which have the advantage over other resins of being very fast in printing and having a color that helps thermoforming control and good mechanical and thermal resistance.

2.3.2.1 Dental model resin

All resin manufacturers began to produce dedicated dental resins for both prosthodontic and orthodontic models. Compared to standard resins, those resins have faster print speed, are very precise, and have a significantly lower degree of shrinkage. Dental models resins have a beige color [47].

2.3.2.2 Dental long term (LT) ® clear resin

It is a class IIa long-term biocompatible resin for printing rigid splints, durable orthodontic appliances, and night guards. According to some preliminary studies, this resin may be suitable for clear aligner direct 3D printing because it has good geometric precision and comparable mechanical properties to the thermoformed aligners [48, 49].

2.3.2.3 Tera Harz TC-85

Graphy, a South Korean-based company of 3D printable photopolymer resins, has revealed a dental 3D printing material mark, Tera Harz, intending to overcome the constraints posed by other 3D printable resins used within the dental field.

Graphy's Tera Harz has obtained CE, FDA, and KFDA medical device certification and is available in clear (TC-85DAC) or white (TC-85DAW). The clear Tera Harz resin is fully transparent and has high durability agreed with orthodontic treatment device purposes. In comparison, the white Tera Harz material features esthetics alongside durability **Figure 8**.

2.3.2.4 Post treatment

Objects produced with 3D printing technologies usually need some degree of post-production treatment. This crucial step of the 3D printing workflow is known as post-processing. First, 3d printed models must be washed in isopropyl alcohol (IPA) or tripropylene glycol monomethyl ether (TPM). For optimal cleaning, users have to shake parts around in the solvent as well as soaked. Habitually, cleaning 3D Printed models requires two washes in IPA or TPM to be fully clean.

When an SLA part finishes printing, the polymerization reaction may not yet be completed. Wich means that parts have not reached their final material properties and may not function as expected, particularly tough parts under strain. Exposing the printed objects to light and heat, called post-curing, will help solidify its materials properties. A UV box post-treatment is usually required to achieve the light-curing process and maximize material strength.

Post-curing is not mandatory for standard resins. Other resin types require post-curing to achieve their optical-mechanical properties. Each material should be submitted to the curing process for a specific amount of time. Printed models should be cleaned and cured before removing supports [46].

2.4 Thermoforming aligners

The first aligners developed by Align Technology corresponded to a single-layer rigid polyurethane produced from methylene diphenyl diisocyanate and 1,6-hexanediol. To enhance its mechanical proprieties and transparency Smart Track (Align Technology, 2012) developed a new thermoplastic polyurethane [50, 51]. The expansion in demand for clear aligners has commanded the development of additional thermoplastic materials for clear aligners by other entreprises, such as e. g. Invisalign, Duran, Biolon, Zendura, Erkodur, ClearCorrect, Erkoflex 95, Erkoloc pro, etc. [52, 53] **Table 2** summarizes the different sheets currently on the market [54].

The manhood of current aligner companies uses transformed polyethylene terephthalate glycol (PETG), although polypropylene, polycarbonate, thermoplastic polyurethanes, copolyester, and many other materials are also used [50].

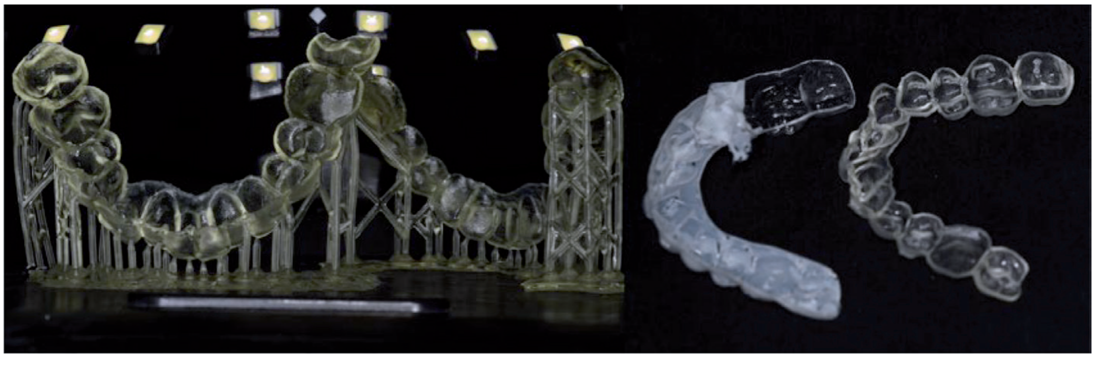

Figure 8.
Directly printed aligners with Tera Harz TC-85 resin (TC-85DAC) put, after post-treatment side by side with thermoformed aligner (Biolon 0,75 mm).

Product name	Component	Manufacturer
Zendura	Poly-Urethane (PU)	Bay materials
Zendura FLX.	Thermoplastic Polyurethane (TPU)	
Essix ace+	Copolyesther	Dentsplay
Essix c+	Polypropylene/ethylene/copolymer	Dentsplay
Clearaligner	Polyethylene terephthalate glycol (PETG)	Scheu Dental
Biolon	Polyethylene terephthalate glycol (PETG)	Dreve Dentamid gmbh)
Smilers	Polyethylene terephthalate glycol (PETG)	Biotech Dental
Smiletech	Polyethylene terephthalate glycol (PETG)	Ortodontica Italia srl
Taglus tuff	Polyethylene terephthalate glycol (PETG)	Allure Ortho
Clearcorrect	Zendura: POLY-URETAN (PU)	Strauman group brand
Duran	Polyethylene terephthalate glycol (PETG)	Scheu Dental
Track A	Polyethylene terephthalate glycol (PETG)	Forestadent
Track B	Polyethylene terephthalate glycol thermoplastic polyurethane (TPU/PET-G)	Forestadent
Erkodur-al	Copolyester	Erkodent gmbh

Table 2.
Different sheets currently on the market.

The mechanical characteristics of dental polymers exhibit a myriad of influence factors, such as intrinsic factors (molecular and crystal structures, etc.) and extrinsic factors (temperature, humidity, etc.) [55, 56]. The used polymers are either amorphous or semi-crystalline. Low crystallinity of polymers typically means high flexibility, high elasticity, and adaptability to the tooth shape, but on the other side, they present low tensile strength, low chemical resistance, and stability [56]. From a clinical perspective, polymers with high flexibility and elasticity are more convenient for patients to insert or remove the aligners. Furthermore, they adjust better to the complexity of the tooth anatomy, attach perfectly to any surface. Correlated to aligners of rigid materials, they also guarantee continuity of force expression during the orthodontic treatment [56].

2.4.1 Thermoforming machines

Thermoforming consists of hot shaping thermoplastic products made of polymers. There are two types of thermoforming machines:

- Vacuum forming machines that operate on the principle of air depression. A draft takes place below the model to be thermoformed, thereby ensuring the plastic material's suction above. Example: Essix Machine®, Tray Vac®, Econo Vac®, Erkopress 240® [57].

- Pressure forming machines that generate pressurized air above the thermoplastic material to press it against the model. Steel granules partially coat the model limiting thermoforming to uncovered areas. Example: Ministar®, Erkoform® or Drufosmartscan® [57] **Figure 9**.

Vacuum forming machines are not recommended for making aligners because they are not accurate enough. The aligner must have a tight fit on the models to

Figure 9.
Pressure forming machines for aligner's fabrication.

transfer that fit over the teeth and have the proper amount of force. For this purpose, pressure-forming machines are more adapted. These machines are usually already present in the dental office for making retainers, night guards, etc.

The selection of a forming machine will be made according to the compatibility of the machine to different brands of trays, the space allocated to thermoforming in the dental office, the Drufosmart® for example, takes up a little less space than the others because of its vertical forming design, or according to features that will facilitate and automate the task of dental assistants, such as the barcode reader where the materials setting are just scanned, or the possibility of thermoforming several models at the same time for mass production.

2.5 Tray trimming and polishing

After thermoforming, the aligner is first cut on the 3D printed model with large chisels; then, it is delicately removed to avoid permanent deformation on the aligner. The cutout is finished with curved scissors. Polishing the edges is done with polishers to avoid having sharp edges. Solutions for automated trimming exist on the market like Inlase for dental practices with an expanded production volume of aligners [58]. There are solutions for automated trimming on the market like iNLASE®, which is a laser trimming machine that automatically cuts thermoformed aligners in less than 15 seconds, without the need for manual cutting or polishing **Figure 10** [58].

2.5.1 Scalloped VS continuous curve

According to Cowley et al. [59], there are three designs for aligners at the gingival margin:

- A scalloped gingival margin design, along the gingival zenith, which is used by Invisalign and Orthocaps.
- A straight line gingival margin along the gingival zenith.
- A straight-line gingival margin above the gingival zenith (which is used by CA Clear Aligner) [59].

The difference between the techniques was remarkable. The straight cut 2 mm from the margins was about twice as retentive as the scalloped cut for clear aligners

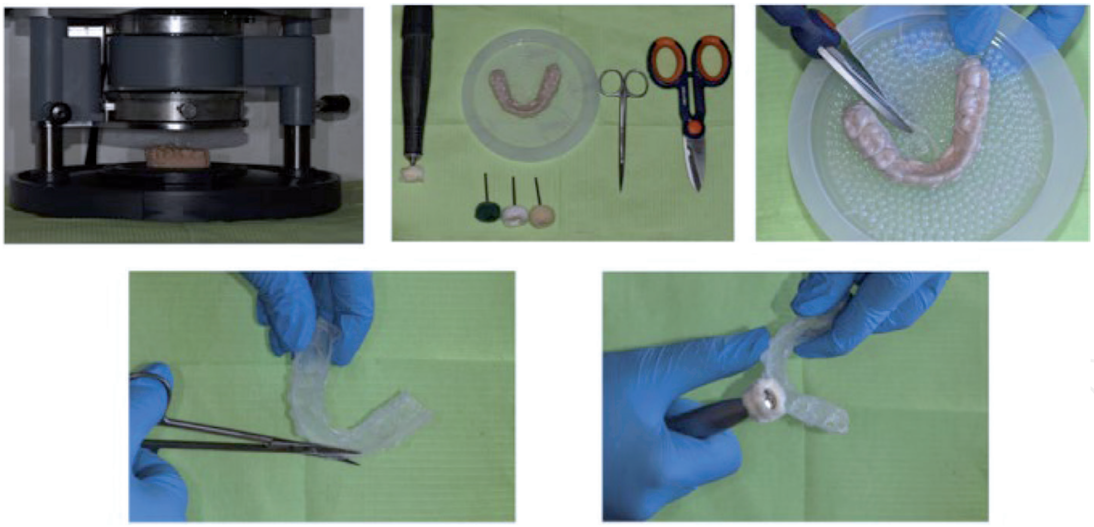

Figure 10.
In-office trimming of aligners.

without engagers. For clear aligners with attachments, the straight cut 2 mm from the margins was over four times as retentive as the scalloped cut.

Cutting the aligners differently had more of an impact than supplementing or excluding attachments. Aligners are more comfortable with this technique because the aligners impinging on the unattached marginal gingiva is less risk. The edge of the aligner is covered further under patients' lips during everyday use; this should also slightly increase the discreetness of the aligners.

2.6 Packaging and delivery

Packaging and labelling is a step that is often overlooked in aligner fabrication. Standards bags with a zip-lock function can be easily found on the market and handled for aligner packaging. Practitioners can easily utilize labels and print office logos and patient information. A bag or a box can be used to deliver the aligners to the patient; custom printed plastic bags are preferable to boxes. Besides being more cost-effective, custom printed bags take up less space and are easier to stock and deliver to the patient, particularly when only a few stages are required. From a branding perspective, practices with in-house aligner production should package the aligners in a way that promotes their office **Figure 11**.

2.7 Delegation

Delegation is a fundamental concept in management. It allows the practitioner to "optimize his diploma" by performing only acts or tasks which fall solely and

Figure 11.
Homemade packaging for aligners.

specifically within his competence. On the other hand, it helps develop team motivation. Delegating tasks relating to new technologies such as 3D printing or digital impression helps to motivate and, above all, enhance dental assistant work.

For homemade aligners, 90% of the tasks can be delegated to a dental assistant. 10% of the remaining tasks concern planning of 3D setup, some steps of which can also be delegated. When outsourcing 3D setup, the whole production chain is delegated. **Table 3** shows the distribution of tasks relating to the homemade aligner.

The dental assistant must do all patient records. Indeed intraoral scanning, taking 2D or 3D X-rays, and face scanning all these tasks can be delegated to a well-trained dental assistant.

The dental assistant will import /export various STL/OBJ files either to prepare the 3D setup or to print the various stages. The dental assistant will also process data such as tooth segmentation, labelling, and nesting models on 3D printer software. The interoperability and intuitiveness of the software will allow the dental assistant to switch from one software to another seamlessly.

		Orthodontist	Dental assistant
Clinical work	Digital models		• Intra-oral scan • Closing model's holes • Exporting for set-up • Software/outsourcing
	2D X-Ray-CBCT		Taking 2D X-Ray/ CBCT
	Facial		2D photos 3DFacial scan
	Aligner's Initial insertion		Seats check
Laboratory work	Planning Software	• Aligning teeth • Choosing attachments • Staging	• Loading models in software • Marking teeth • Segmenting teeth • Pre-aligning teeth • Labeling models • Adding Platform • Exporting for 3D (hollowing models)
	3D printing		• Nesting models in 3D printer • Software
	Post processing		• Removing models • Washing & drying models • UV Curing models • Taking off platform /supports
	Aligner fabrication		• Thermoforming • Cutting/trimming • Polishing • Packaging

Table 3.
The distribution of tasks relating to the homemade aligner.

All tasks relating to 3D printing are delegable: removing models from building platforms, washing, drying, curing models, and removing supports. When choosing a 3D printer, the practitioner should consider user-friendly and intuitive 3D printing software that exports the models with the bases set at the correct angle. Likewise, selecting a 3D printer with features like calculating the amount of resin or filament needed for 3D printing to not run out of materials is crucial for overnight 3D printing. Samely when purchasing post-treatment hardware, the practitioner must choose automated systems for washing, drying, and curing models to make the task as efficient as possible for the assistant.

Aligner fabrication is a fully delegable task; the dental assistant must do the entire process, thermoforming, cutting, polishing, and packaging. Thus, the dental assistant performs the initial insertion of the appliance to check its fitting.

3. Results

Invisalign is the most common clear aligner option that is outsourced. The cost for Invisalign treatment is 575 $ for five aligners, 1199$ for 14 aligners cases, and 1779$ for full cases. For ClearCorrect, the price for five aligners is 395 $, 935$ for 14 aligners cases, and 1495$ for unlimited cases.

When aligners are homemade, the cost for five aligners treatment turns around 70$. This includes printing, materials, assistant time to fabricate the aligner, and software fee. The cost per printed model is for resin models 1,75 $, and it depends on the brand of the resin and the use or not of supports while 3D printing. The cost per clear aligner sheet is 1,5$ (biolon 0,75 mm), and it also depends on the brand of the aligners sheet. In the USA dental assistant's average wage per hour is $ 25; for aligner fabrication, a dental assistant takes 5 minutes to make each clear aligner, so the cost per aligner for assistant time is roughly 2$. The total fabrication cost per aligner for homemade aligners is 5,25$. For an in-house clear aligner software, the fee per case is 20 $ for two arches (Bluesky plan ORTHO) and 10$ if only one arch is processed. If the orthodontist wants to outsource the planning, the cost for outsourcing planning is $ 200 (LabPronto). **Table 4** recapitulates the different costs according to the treatment options and the number of aligners.

	Invisalign	Clear correct	In-office printing & thermoforming*	In-office fabrication out sourcing planning **
5 aligners	575 $	395$	72$	252$
10 aligners	925 $	695$	125$	305$
14 aligners	1199 $	935$	167$	347$
30 aligners	1779$	1495$	335$	515$
Revision	125$	95$	..	..

**5 $ fabrication cost per aligner and 20 $ software cost per case (2jaws) (10$ one jaw). Cost per aligner include materials cost/ printing cost and assistant's time to fabricate the aligner.*
***200$ for outsourcing planning (Labpronto).*

Table 4.
Comparison cost fee for different aligners systems.

4. Discussion

Orthodontic practices that integrate in-house aligners solution into their operation gain full control over the workflow eliminate outside lab fees, and achieve faster production turnaround time. Internalizing aligners manufacturing in the dental office reduces by at least half of the cost compared to commercial aligners suppliers **Table 4**.

Being able to reduce aligner fees for patients will increase profit line and case acceptance. Nowadays, direct to consumers companies propose clear aligners with competitive cost compared to conventional aligner treatment. Thus the do-it-yourself (DIY) aligners companies are trying to eliminate the orthodontist from the equation. With the homemade aligners the orthodontist can be competitive even with such companies.

In-office aligner's production allows complete management for the entire aligner-making process. Compared to a custom commercial aligners laboratory, this flow enables complete control over the treatment plan because planning is done by the orthodontist and gives particular options like having additional aligners/refinement or producing several aligners for the same step in different thicknesses for specific case's need.

Orthodontists have also control of the 3D printing process: by controlling materials, resolution, printing direction, models Hollowing, etc.. and managing aligner sheets materials in terms of composition, thickness, toxicity (Bisphenol A (BPA) free) [60], and the trim line, also being able to customize this factors for each specific clinic case. All these aspects have a significant impact on the efficiency of clear aligner therapy.

In-house aligner production authorizes faster processes for patients; Aligner production can begin as soon as the patient is ready to undergo oral scans. Practices can provide same-day or next-day starts service depending on the patient queue. In a same-day appointment, an orthodontist can take oral scans, plan out treatment, and print and form the first aligner stages before the patient leaves the office or within a few hours of the appointment. The expedited service provides optimal customer service and an immediate customer lock-in advantage.

4.1 Digital model creation

Digital models offer more advantages such as instant accessibility of 3D information without the need for the retrieval of plaster models from a storage area, reduced need for large areas for plaster model storing, and less time-consuming analysis [61]. With 3D digital models, clinicians can evaluate dental models in three-dimensional aspects and perform dental analysis in more detail. Interrelation between maxillary and mandibular arches can be better observed in occlusion on different scenes in 3D software [62]. Digital models also provide virtual treatment and virtual setup [63]. 3D models can be processed to analyze specific teeth and to estimate the axis or position of individual teeth, which provides a three-dimensional prediction of tooth movement by superimposing dental changes on stable reference structures [5].

Desktop Optical Scanning is a simple, fast, and straightforward procedure; models do not require a second scan due to the scan's lack of data or non-completion. Likewise, the OS procedure is an entirely delegable task. However, despite all the advantages, it is very cost-intensive and therefore unaffordable for many dental offices and labs, and for impression scanning procedures, the record of the patient's occlusion cannot be obtained [3].

Intraoral scanners introduce innovations in orthodontics such as monitoring dental movement through digital model superimposition aligners [64, 65], further customization of orthodontic appliances such as removable retainers [65], and last but not least, more accurate diagnosis, treatment planning and even simulation of possible orthodontic movement on appropriate software [66, 67]. Furthermore, scanning requires more chairside time, but it was found less unpleasant than the standard procedure of impression taking [68]; evidence exists that patients when asked which type of impression satisfy them more, choose digital due to patient-centered outcomes [69].

A systematic review [70, 71] of the accuracy of intraoral scans reported that inter-and intra-arch measurements from intraoral scans were more reliable and accurate in comparison to those from conventional impressions. Another systematic review in prosthodontics [72] reported that dental restorations fabricated using digital impressions exhibited a similar marginal fit to those fabricated using conventional impressions [73].

Many factors affect the accuracy of the IOS, such as [74, 75]:

1. Scanner: capacity to register details and its accuracy.

2. OperatorUser: scanning fundamentals and path's scanning.

3. Scanning area: the dimension of the scanning area, arch length, and surface irregularities.

4. Intraoral environmental factors: temperature, relative humidity, illumination, shiny, reflective, or transparent objects [7]. Solabrietta et al. denoted that the differences in accuracy between the scanners are rudimentary, and the characteristics that make everyday work easier and more pleasant for the doctor and the patient seem to be much more relevant [61].

After a conventional alginate impression, a median of 22 minutes is required for plaster modeling, including pouring and trimming. In Park JY, study [9], the digital models were obtained within 5 minutes after a rubber impression, with 14 seconds for the CBCT scan of the impression, 1 minute for CBCT file export, and 2 minutes for generating an STL file for each arch. In terms of efficiency, digital modeling using CBCT seems to be clinically feasible and is correlated to reduced laboratory time. No significant differences were found in most measurements between the cast scan models and CBCT digital models. CBCT may be suitable for use in clinical practice because of its advantages, including a reduced working time for digital model rendering [9]. For a dental professional who previously has a CBCT or an IOS device, the acquisition of another digitization system might seem redundant [3].

However, the 3D ortho setup is done on maxillary and mandibular 3D models in occlusion. Using a CBCT to digitalize dental arches is undoubtedly possible. However, the registration of the occlusion, which is indexing one model in relation to the other with this method, is not as intuitive as with an OS or IOS and will require additional CBCT scans of the models in occlusion and the passage through a third-party software to align, relate and index the models before importing them into the 3D setup software.

For Emara A, OS is the best choice for dental models' digitization. The CBCT, however, proved to be a highly precise option. Even if the tested IOS showed the lowest results in terms of accuracy, it is still a valid affordable option for model digitization, with results falling within the "clinically acceptable" range [3].

4.2 Facial scan

Facial scanner using a mobile device 3D sensor camera has been captivating much interest in recent years because it is highly portable and cost-effective and because of the popularity of mobile devices [14]. Smartphone- and tablet-compatible 3D facial scanners have been described to be a valuable tool for clinical use in prosthodontic treatment [12, 15–18]. However, the digital facial impression accuracy obtained with mobile device–compatible face scanners has not been investigated [15].

No significant difference was found between stationary and portable face-scanning systems concerning the accuracy of the resultant digital face models. Within the comparison of scanning methods, stereophotogrammetry, laser, and structured-light systems showed similar levels of accuracy in generating a digital face model [11].

The accuracy of mobile device–compatible face scanners in the 3D facial acquisition was not comparable to that of professional optical scanning systems, but it was still within the clinically acceptable range of <1.5 mm in dimensional deviation [15].

Amornvit et al. [76] and Liu et al. [77] reported that mobile device–compatible face scanners are comparable to professional 3D facial scanners when scanning simple and flat areas of the face such as the forehead cheeks, and chin. However, scanning accuracy was relatively low when mobile device–compatible face scanners were used to capture complex facial regions, such as the external ears, eyelids, nostrils, and teeth [76–79]. Higher inaccuracy was found in the facial areas with defects, depending on the depth of the defect [15, 20]. The teeth scan quality for the smartphone 3D face scan could be lower than that of the stereophotogrammetry because of the high sensibility to the depth of the smartphone facial scanner [16, 22].

The accuracy of the image integration using teeth images only principally relies on the spatial accuracy and the resolution of the captured anterior teeth image in the digital facial scan [28]. When only the teeth region was used for image matching between the facial scan and intraoral scan images, the alignement could be predisposed to error because of the image deformations of the 3D facial model at the mouth area due to the difficulties in scanning the complex structures of the teeth and the gingiva [22, 28].

The accuracy of virtual dentofacial combinations was mainly reliant on perioral scans and artificial skin markers. The most trivial midline deviation and frontal plan canting were found when the perioral image with artificial markers was used. In contrast, the highest divergences were found when the perioral image obtained without markers was employed for image alignment. Although stereophotogrammetry face scan generally showed higher accuracy of virtual dentofacial integration than the smartphone 3D depth camera face scan, the difference between the devices was not significant when the perioral scans were used as references for image matching.

4.3 Setup planning

Unique features make some software high valuable, when choosing software for homemade aligners, orthodontists should look for a program that includes the functionality of matching CBCT data to IOS data and the possibility of positioning the virtual roots of the 3D setup software according to 3D segmented teeth from CBCT. Accurate superimposition of the intraoral scan over the CBCT data would allow the orthodontist to clearly view a dimensionally true representation of a tooth and its root relative to the alveolar ridge [80, 81]. While the conventional virtual setup focuses on moving the crowns, the 3D digital model includes root positions, thus enabling a better outcome [82–84].

BSB ORTHO offers advanced options such as integration of CBCT and facial scan data, the superposition of these data with the 3D models is seamless with BSB ORTHO software, also import and export high definition models to have as little decimation as possible and achieve a good fitting of the aligner [35].

Archform, uLab, and 3Shape software create the same-day functionality without spending time creating a complete treatment set-up. This adds value for the clinician offering super-speed turnarounds and bringing instant orthodontics into their practices [84].

Carestream's Model+ software is a relative newcomer to the aligner software space; Carestream's Model+ software has a unique feature that only is within their software. Model+ allows the clinician to assess individual tooth movements and grade both case complexity and predictability of individual tooth movements [84].

ArchForm can be used across multiple computers and keep patient data in synchronization. For example, the orthodontist can start a design on the office computer and continue it on his laptop at home. Plus, the software keeps patients on track, turning around refinements in one day by instant adjusting treatments mid-course for faster treatment and more precise results [37].

ArchForm and ULab's AI-assisted software includes one-touch bracket removal features that make finishing bracket cases in aligners or preparing finishing retainers in advance easier by allowing easy removal of the brackets post-scanning [85].

Direct 3D printing of aligners is more innovative and is gradually gaining market share, especially with the emergence of more suitable resins. It is a breakthrough. Deltaface & BSB Ortho are the only two software on the market that offer this functionality; the rigidity of the aligner is set on that software by locally adjusting the thickness of the aligners. This technic offers many advantages, notably: better precision, saving of time by eliminating the steps of thermoforming, cutting, and polishing; it also allows a saving of resin by removing the need to print the models, which has an ecological virtue [31, 35].

Many software options require monthly subscription fees, pay-per-case export fees, or pay-by-aligner pricing, and it is crucial to select cost-effective and functional software for the office.

4.4 3D printing

FDM printer extrudes a resin that has been heated just beyond its melting point, placing it layer by layer. The heated material hardens immediately after being extruded, thus minimizing inaccuracies. Of the available materials, the most common are polylactic acid and acrylonitrile butadiene styrene (ABS). These often come on spools that can easily be replaced as needed. FDM 3D printing has the advantage of printing at a low cost and not needing post-processing, but it is relatively slow and less well finished than stereolithography. However, it offers relatively sufficient precision for orthodontic models because it easily makes dental models print with 100 to 50 microns accuracy with semi-professional 3D printers like the Ultimaker S5 and Raise3D E2. It is possible to recycle old ortho models through filament extrusion machines (for example: 3DEVO) to achieve almost zero production cost and ecological production [86].

Nanometric particles are emitted during ABS 3D printing process and are harmful if inhaled. To avoid the harmful inhalation of these particles, practitioners who want to integrate this technology in their practice area should use a fully enclosed 3D printing room equipped with a fume extractor-ultrafine particle emissions from desktop 3D printers [87]. Adding adherent agents on the printing bed is strongly recommended to limit the warping (Detachment of the part from the plate during printing) of the ABS [86].

Generally, there is no post-processing for FDM 3D printed dental models as they are generally horizontally printed and do not need any supports or printing platform. Despite being slow, this technology requires the minimum intervention from the operator because after detaching the model from the printing bed, models are prompt for thermoforming process.

In the aligner-manufacturing context, biocompatibility resin is not mandatory except in direct 3D printing aligners that will emerge soon. However, according to other authors, the Dental LT could be subject to an overall thickness inaccuracy compared to the designed file, leading to undesired movements [88]. In addition, 3D printing orientation and post-processing conditions; (exposure time to UV light and heat) could impact mechanical properties and biocompatibility of Dental LT resin [53, 89]. Further studies both in vitro and in vivo are needed based on these claims to test this resin and other direct aligner printable resins [90].

With the evolution of materials, the direct printing of aligners will take over the thermoforming process, save a considerable amount of models resin, streamline production, and reduce costs [91].

4.5 Thermoforming aligners

4.5.1 Influence of thermoforming

Ruy et al. examined the impact of thermoforming on the physical and mechanical properties of various thermoplastic materials for clear aligners (Duran, Essix A+, Essix ACE, and eCligner). They observed that the optical transparency, the tensile force, and the elastic modulus of the aligner materials decline after the thermoforming process, while water absorption was increased [92].

Moreover, they recommended evaluating these materials' durability after thermoforming to characterize their properties for their clinical application [92]. From a clinical perspective, the authors also proposed choosing the polymers depending on the treatment required, as some of them show a significant decrease in flexural strength after thermoforming and exhibit permanent deformation during treatment. On the other side, the application of large forces to the teeth can lead to absorption of the apical root [92].

Kwon et al. [51] assessed the force delivery properties of thermoplastic orthodontic materials. They found that the forces delivered by thin materials were more significant than those delivered by thick materials of the same brand [92].

4.5.2 Esthetic appearance

Transparency is evaluated to investigate the esthetic aspect of the materials. The transparency of materials decreased with an increase in their thickness. In addition, with decreased thickness after thermoforming, the transparency also decreased, which can be explained by the structural deformation of thermoplastic materials resulting in decreased transparency. Nevertheless, this transparency change did not compromise the esthetic appearance of clear aligners [92].

Many studies evaluate the stability of the materials after their average use of two weeks through the colorimetric alterations of aligners [93]. Bernard et al. affirm that there are foods that stain more than others (above all black tea) and that the Invisalign aligners (TPU) were more prone to pigmentation than the ClearCorrect (PU) or the Minor Tooth Movement devices (PET-G) after exposure to coffee or red wine. Black tea caused important stains on the surface of the three tested brands [93, 94].

4.5.3 Water absorption

Water absorption can negatively influence the mechanical properties of polymers leading to irreversible deterioration because water absorption is often appended to swelling and, thus, a deterioration of the polymers [95, 96]. Besides the deterioration effect, the swelling also leads to dimensional variations of the mouth devices, which affects the orthodontic forces [96]. Therefore, an ideal thermoplastic material for a clear aligner should have a low water absorption [54].

Tamburino et al. investigated the properties of materials for the thermoforming production of aligners. The materials used in their study were: Duran® (PETG, Sheu dental GmbH), Biolon (PETG, Dreve Dentamid GmbH) and Zendura® (PU, Zendura Dental). Artificial saliva was used as an aging agent at a temperature of 37°C for 7 days [97]. The liquid absorption of Duran material is only almost half of the Zendura one. In addition to higher water uptake, the authors observed a decline of the mechanical properties of the Zendura that can be related to the mechanism of intramolecular bond destruction by water molecules [97].

Ryokawa et al. [8] reported that water absorption by both PETG and copolyester increased to 0.8 wt% in their 2-week experiment. In addition, water absorption by PETG differed depending on the type of thermoplastic material [55]. Zhang et al. [93] reported that water absorption increased when polyurethane was added to PETG during the development of new thermoplastic material for thermoformed aligners [92].

4.5.4 Mechanical properties

Tamburino et al. investigated the mechanical properties of the aligner materials Duran, Biolon, and Zendura in the as-delivered state, after thermoforming, and after storage in artificial saliva [97]. The authors found that the tensile yield stress of the Duran and Biolon materials only slightly changed after thermoforming (9% increase for Duran, 6% decrease for Biolon), while it decreased by one-third for the Zendura [54]. After exposure to artificial saliva, the tensile yield stress of the Duran material decrease back to it as-supplied strength, while the tensile yield stress of Biolon and Zendura materials slightly increase (to −3% respectively to −28%). Based on their finding, these authors propose to select a material for orthodontic devices after characterizing its mechanical properties after the corresponding manufacturing process and storage test in an intraoral simulation environment [54].

4.5.5 Elastic modulus

A higher elastic modulus is beneficial for aligners as it increases the force delivery capacity of the aligner under constant strain [98, 99]. Plus, materials with a higher elastic modulus can produce the same forces from thinner thickness [99]. The elastic modulus is proportional to the material stiffness. In their study [97], Tamburino et al. also examined the elastic modulus of the aligner materials Duran, Biolon, and Zendura in the as-delivered state, after thermoforming and after storage in artificial saliva. The elastic modulus of the Duran and Zendura materials increased by 11% respectively 17% after thermoforming, while the one of the Biolon material falls by 7%. Looking at the elastic modulus after artificial saliva exposure of the materials shows different behavior [100]. The elastic modulus of Biolon and Zendura material is relatively stable, while a significant decrease was observed for Duran. This decrease can be explained by water uptake happening during the storage in artificial saliva fluid [54].

5. Conclusions

Practice owners need to invest in material resources, but they also need to invest in education to help their team implement homemade aligner workflow. While 3D printing aligners in-house require that practices invest time and money, eliminating lab fees and the ability to provide same-day high-quality, consistent services justifies the investment by increasing profit margins, decreasing treatment timelines, and improving patient satisfaction. In-house production of aligners is the best option for practices that want more profitable and faster service. It just requires flexibility and an openness to learning new workflows that will carry the practice forward.

Conflict of interest

The authors declare no conflict of interest.

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