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Digital design and fabrication of direct-printed twin block appliances

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Abstract

This paper presents a fully digital protocol for the design and in-house manufacturing of Twin Block and Reverse Twin Block appliances. The protocol is carried out using an open-source CAD program (FreeCAD) and Medit Link (Medit Apps). The digital workflow includes intraoral scanning, appliance and bite block design, 3D printing, and post-processing. Intraoral scanning and digital construction bite recording are conducted with the Medit i700 scanner. The designs of the direct-printed Twin Block and Reverse Twin Block are based on splints and are created with Medit Apps. The bite blocks are designed using FreeCAD. The appliance design starts with the creation of splint baseplates and cutouts to provide space for the blocks. The splint baseplate is united with the bite blocks, and the inner surface is prepared for an accurate fit. The 3D printing is carried out on the Formlabs Form 3B+ using LT Clear V2 resin. The post-processing step includes washing, curing, finishing, and polishing. The digital design allows for the optimization of retention, efficient use of undercuts, accurate reproduction of the mandibular advancement, and an integral fit between the bite blocks. This is an easily reproducible chairside workflow that is cost-effective, saves clinical time, reduces waste, and offers fast production and same-day replacement.

Keywords: Dental software digitally designed Twin Block, Direct-printed appliances, Fully digital protocol, In-house printing, Reverse Twin Block, Twin Block.

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1. Introduction

The Twin Block appliance (TB) is a removable functional appliance commonly used in orthodontic practices for the correction of Class II malocclusions. It is a two-part orthopedic appliance developed by Clark [1].

The TB has been used for several decades. Over the last few years, the digitalization of the orthodontic workflow has led to the digital design and modification of the TB appliance. The classic TB design includes a maxillary and mandibular acrylic baseplate and bite blocks in the premolar area. The acrylic baseplate holds all of the metal components. The most important metal components are the labial bows and clasps (Adams, delta, ball). The main parts of the appliance are the bilateral upper and lower occlusal (bite) blocks. They face each other at 70° or 45° inclinations.

The 70° inclination of the blocks is the most frequently used. The 45° inclination is used in cases when there is severe distal occlusion and the patient has difficulty advancing the mandible (Salloum, et al. [2] and Kalbande, et al. [3]). Clark [1] principle of occlusal blocks interlocking at a certain angle promotes a forced mandibular advancement to correct the Class II malocclusion [3-5].

For the occlusal blocks to be effective and the mandibular advancement to be sufficient, a construction bite (occlusion) is required. The new position of the mandible in three dimensions is sagittal until a Class I relationship is reached; transversal matching the upper and lower midlines; and then vertical at a 2-4 mm distance between the incisal edges of the upper and lower incisors or edge-to-edge occlusion [2].

The TB and RTB have provided favorable skeletal and dentoalveolar effects in growing patients [6, 7]. The TB successfully reduces dental overjet, molar discrepancies, and the severity of malocclusion with a combination of both effects [6, 7]. The dentoalveolar changes are predominant [8]. The appliance is mainly used for treating Class II Division 1 malocclusions with retrognathic mandibles in growing patients [9], affecting mandibular growth. The growth is more prominent in the CS3 phase, and this is the most favorable phase for using the appliance [10]. Soft tissues undergo changes as well; the facial profile improves, the upper lip retracts, and the nasolabial angle increases owing to the reduction in the inclination of maxillary incisors [11].

Although they are functional appliances, they can also be used in the retention phase of orthodontic treatment to maintain alignment and occlusal relationships [12]. Because of its rigid structure, the appliance maintains the achieved transversal changes and the transversal position of the mandible after treatment. Over the years, there have been multiple modifications of the TB. Clark [1] classic design used delta clasps and ball end hooks for retention. McNamara added two expansion screws for stability in the upper baseplate during transverse development and a lower labial bow with acrylic for additional retention [4]. A fixed TB was later developed for noncooperative patients.

In Gerber [13], the Banded Block was developed, which is a fixed modification of the TB. The appliance is made of stainless-steel wire, which incorporates orthodontic bands in the superstructure that provide support for the mandibular or maxillary acrylic blocks [13].

The modification of the classic TB is the Reverse Twin Block (RTB). The RTB is used for interceptive treatment or prevention when there is a tendency for Class III malocclusions. It has limited indications and is best suited for mild to moderate Class III cases of maxillary deficiency and pseudo-Class III (functional mandibular shift) [14]. It has a favorable effect on mixed dentition [15]. A characteristic trait of the pseudo-Class III is that the patient can move the mandible to edge-to-edge occlusion [16]. The RTB has the same simple design as the classic TB, but it differs in that the bite-block inclinations are reversed, and the occlusal forces exert a Class III traction effect on the jaws, thus not allowing the mandible to advance and temporarily restricting its forward development [14].

Recent modifications of the appliance were made using new technologies and digital software innovations in the field of dentistry and orthodontics, in particular [17, 18]. Various orthodontic appliance design programs have been developed, allowing orthodontists to create different design protocols and workflows [19].

The digital transition began with hybrid designs and a semi-digital workflow that included manual steps for the creation of the appliance. These comprised the thermoformed baseplate modifications of the appliance [20-22]. There is a 3D design of the TB produced by machine milling [23].

The fully digitally designed TB and RTB are the latest variations of the functional appliance [22, 24-26].

An intraoral scanner and suitable software are needed for the full digitalization of the workflow. After that, the appliance can be directly printed in the office with a dental 3D printer or sent to a dental laboratory for printing [27]. The digital workflow offers a range of new possibilities for designing, modifying, and customizing the appliances [28, 29]. There is no need for alginate impressions, dental models mounted on a hinge articulator, and the work of the dental technician to produce the appliances.

This study presents a fully digital protocol for designing and manufacturing the TB and RTB appliances for direct in-house printing that was developed and used in our practice. We describe the workflow in detail and discuss its advantages.

2. Materials and Methods

2.1. Intraoral Scanning and Model Acquisition

The maxillary and mandibular dentition and adjacent soft tissues are registered digitally with the Medit i700 intraoral scanner. A thorough scan is required with no data holes. Leaving data holes compromises the accuracy of the appliance. The hard palate and all of the soft tissues (at least to the mucogingival junction) are captured.

The maxilla and the mandible are scanned using the zigzag pattern that is recommended by Medit. First, the occlusal surface is scanned, starting from the left posterior teeth, using zigzag motions to capture parts of the buccal and lingual surfaces of the teeth. Then, a transition to the lingual surface is made to capture it in detail (plus the hard palate for the maxilla), and the transition to the buccal surface is last. The scanner tip is tilted at a 45° angle to the surface during the scanning process.

The next step is the bite registration. First, the maximum intercuspation position (MIP) is recorded and, after that, the construction bite (Figure 1). The latter occlusion is used for designing the TB and RTB appliances.

The construction bite is obtained with a plastic bite guide (such as Exactobite; Projet or George gauge) and dental silicone (or a horseshoe of wax). For the protocol, Exactobite is used. The plastic gauges provide stability for the new mandibular position while scanning and the necessary vertical distance between the incisal edges.

The Exactobite plastic gauge has a horseshoe shape and incisal grooves on the anterior part: one for the lower incisors and three for the upper. The upper grooves control the amount of mandibular protrusion depending on the severity of the deformation and how much the patient can position the mandible forward. There are two vertical clearances for the Exactobite: 2 mm and 4 mm.

When all scanning stages are checked, one last inspection is performed to see if everything is correct; then the intraoral scanning is completed and the models are generated.

Figure 1.
Central and side views of the construction bite were registered during the intraoral scan and used for designing the appliance.

2.2. Designing the Direct-Printed TB and RTB Appliances

The direct-printed TB (DPTB) and direct-printed RTB (DPRTB) designs use the Medit Link software (Medit Corp.) and its Medit Apps—Medit Splints and Medit Design. Medit Apps are applications that utilize the 3D scan data. Medit Splint is used for the quick creation of printable dental splints, and Medit Design is for editing and transforming 3D data.

The design of the bite block is obtained with FreeCAD, an open-source 3D computer-aided design program. FreeCAD is a general-purpose parametric 3D computer-aided design (CAD) modeler intended for mechanical engineering. This allows us to precisely define the 70-degree inclination. The external CAD program is needed because Medit lacks a CAD program for the creation of the bite block.

The TB and RTB are designed in several steps. The first step involves designing the bite blocks. The second step is creating the baseplate of the appliance in Medit Splint. The third step is using Medit Design to unite the baseplate and bite blocks and complete the appliance.

2.2.1. Occlusal Block Design

The design of the occlusal block is conducted in FreeCAD, the external CAD program. After the block is created in FreeCAD, it is exported as a Standard Tessellation Language (STL) file for improved compatibility with dental software.

The bite block is imported into the Medit Design app. There, the block is copied to create the necessary number of occlusal blocks (Figure 2). First, the bite block is duplicated. The two blocks face each other on the 70° side; then, the pair is mirrored.

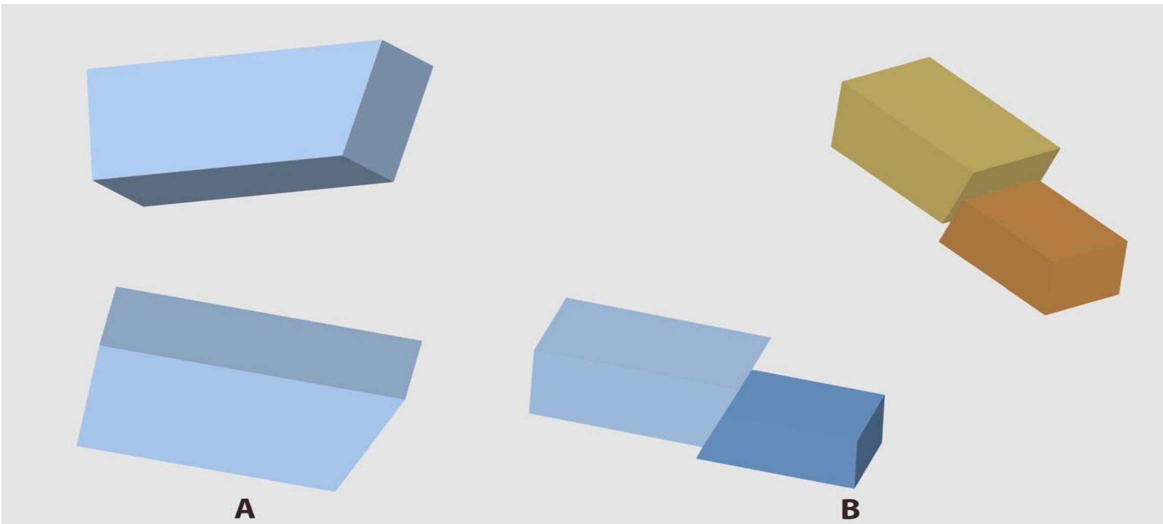

Figure 2.
Design of the bite blocks: **(A)** the initial bite block imported into the Medit Design app; **(B)** the 2 pairs of bite blocks facing each other on the 70° side, ready to be adjusted to the baseplate in the Transformation mode.

Once the two pairs of occlusal blocks for the TB and RTB are prepared in the Medit Design app, they can be saved as templates and used for other projects. The only difference between the blocks for the TB and the RTB is that the bite blocks for the RTB have reversed inclinations (Figure 3).

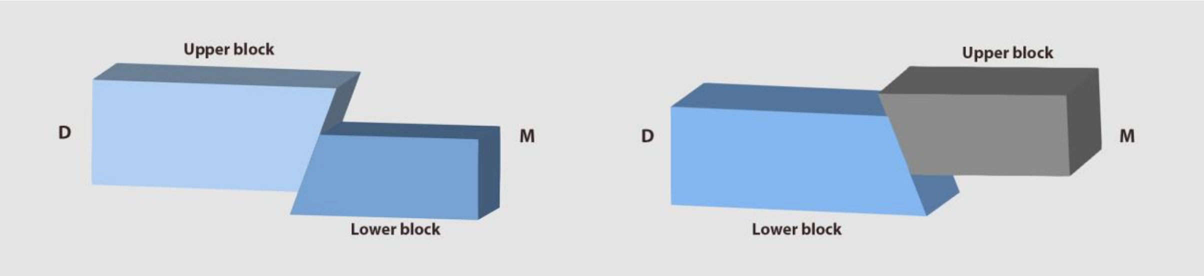

Figure 3.
The difference in the inclinations between the bite blocks for the DPTB and the DPRTB.

2.2.2. Splint Baseplate Design

The splint used for the appliances is based on the Michigan splint. This splint is a night guard and covers all the teeth and their occlusal surfaces. The steps for designing the appliance splints are the same as those for the Michigan splint.

The same splint bases are used for the TB and the RTB. The splints are designed using Medit Splints and its Manual Creation mode, which allows us to exactly define the borders of the splints.

The first step is importing the intraoral scans from the construction bite in the application. The next step is adjusting the bite opening and distance to the antagonists.

The bite opening sets the degree of opening in the virtual articulator. The distance to the antagonist is the closest point between the occlusal surfaces of the maxilla and mandible.

When using the Exactobite gauge, there is no need to adjust these values. Adjustment is needed if the construction bite is obtained without a bite gauge. The desired bite opening is 2-4 mm, which allows for about a 1 mm distance to the antagonist.

The next step is the inner surface creation. This stage is skipped and options are left on default because the inner surface is prepared in the Medit Design app in the later stages.

After that, the borders of the splint are outlined. The splints must cover all of the erupted teeth and include several millimeters of attached gingiva on the buccal and oral sides. The upper splint is designed with reduced palatal coverage for patient comfort and to reduce the size of the appliance (Figure 4).

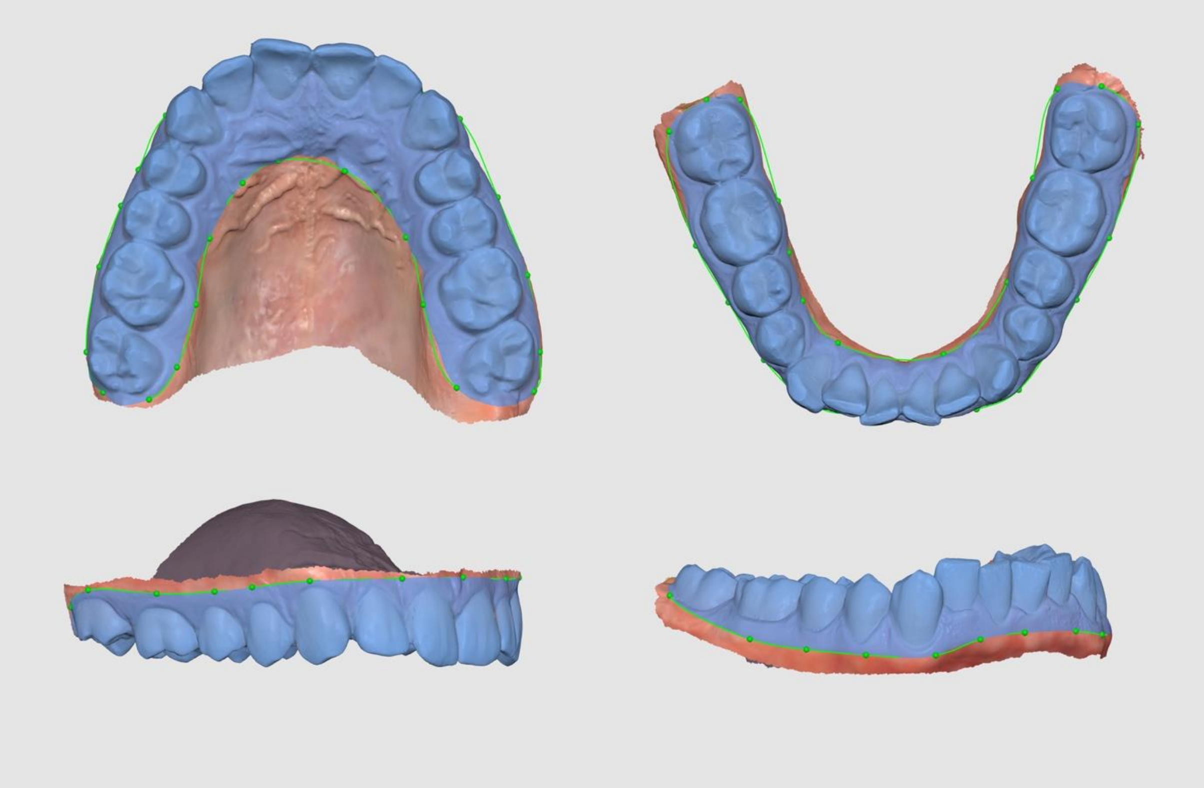

Figure 4.
Borders of the upper and lower splints used for the base plates of the DPTB and DPRTB appliances.

After that, the splint is generated with the Dual Layer Splint option enabled. This creates a splint with two layers: a thick outer layer and a thin inner layer.

The thin inner layer is used as the splint baseplate for the appliance. The inner layer's thickness can be changed to exact values in the Medit Design app (Figure 5).

The purpose of the double-layered splint is to enable the operator to create layers for dual-material printing; at the same time, it offers a thin inner layer that conforms to the shape of the teeth and the dental arch. This recent addition to the Splint application has broadened the possibilities for designing orthodontic appliances.

The outer layer is too bulky to be used successfully, and its thickness cannot be precisely controlled in the later stages.

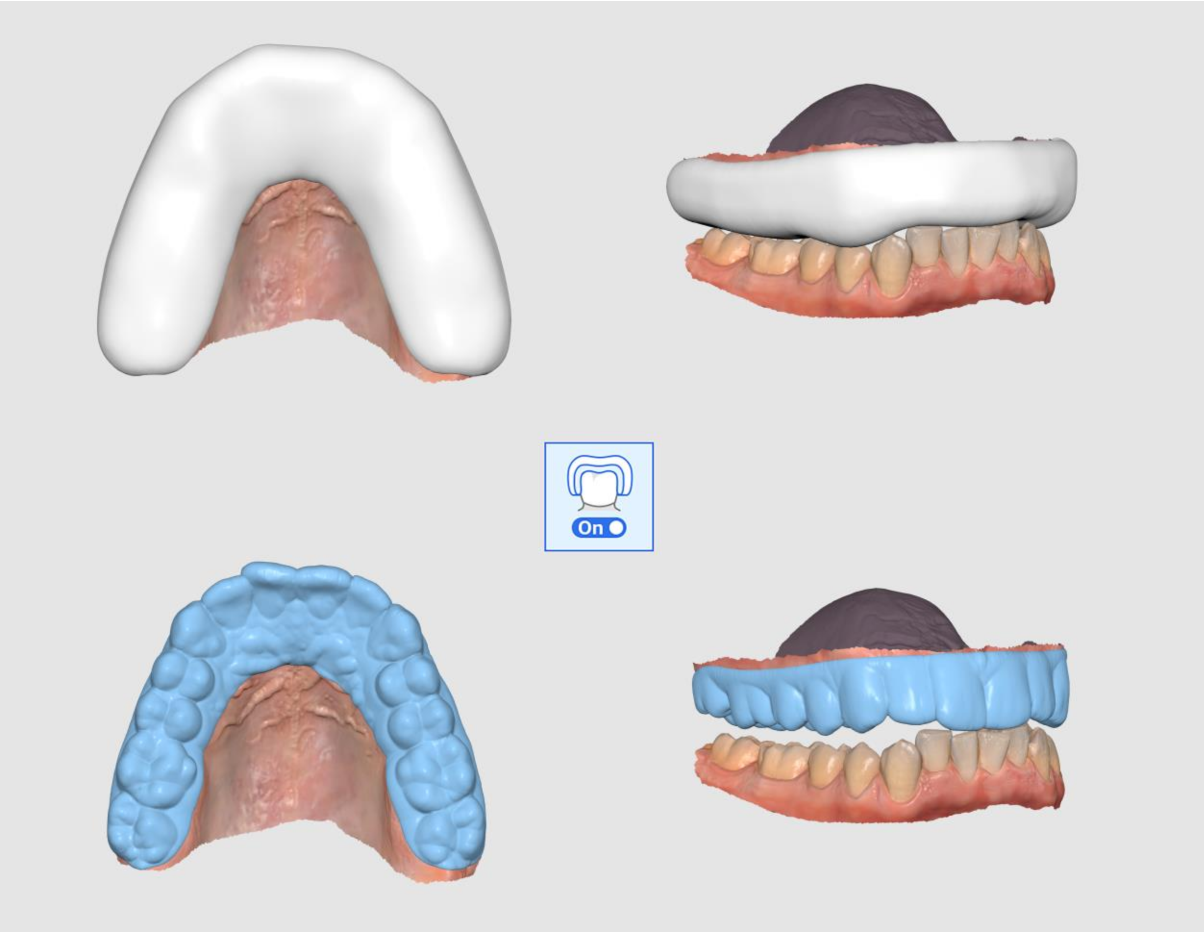

Figure 5.
Dual Layer Splint option, when dual-material printing is needed. The white bulky splint is the outer layer and the blue one is the inner thin layer, which follows the shape of the teeth and can be used as a baseplate for designing different orthodontic appliances.

2.2.3. Appliance Design

After the occlusal block template and the splint baseplate (the thin inner layer of the splint) are produced, they are imported into the Medit Design app along with the maxillary and mandibular models.

The following steps for the digital design of the appliance are conducted in Medit Design.

2.2.3.1. Making Cutouts in the Baseplate

To ensure additional space for the occlusal block placement, cutouts in the splint baseplate are made.

For the TB, the cutouts in the maxilla are made at the upper first and second premolars in permanent dentition and the upper first and second primary molars in mixed dentition. For the mandible, they are made at the lower second molars and the distal half of the lower first molars for permanent dentition and the lower first permanent molar and the distal half of the lower second primary molar for mixed dentition (Figure 6a).

For the RTB, the cutouts are the opposite. For the maxillary splint, the cutouts are at the upper first molars and second molars for permanent dentition and the upper second primary molar and first permanent molar for mixed dentition. For the mandible, the cutouts are at the lower second premolars and the medial half of the lower first molars for permanent dentition and the lower first primary molar and the medial half of the second primary molar (Figure 6b).

The cutouts are made using the Trimming tool and selecting the appropriate tooth areas. For this, the Smart Single Tooth Selection sub-option is used on the inner and outer surfaces of the splint baseplate. The mesh of the selected tooth areas is deleted, and the mesh holes between the two surfaces are filled using the Fill Holes tool to restore the integrity of the 3D data.

2.2.3.2. Baseplate thickening

After the cutouts are made, the splint baseplate is thickened. The thickness is set to 1 mm (Figure 7a) because, in the authors' experience, it gives the appliance enough strength and rigidity without making it too bulky.

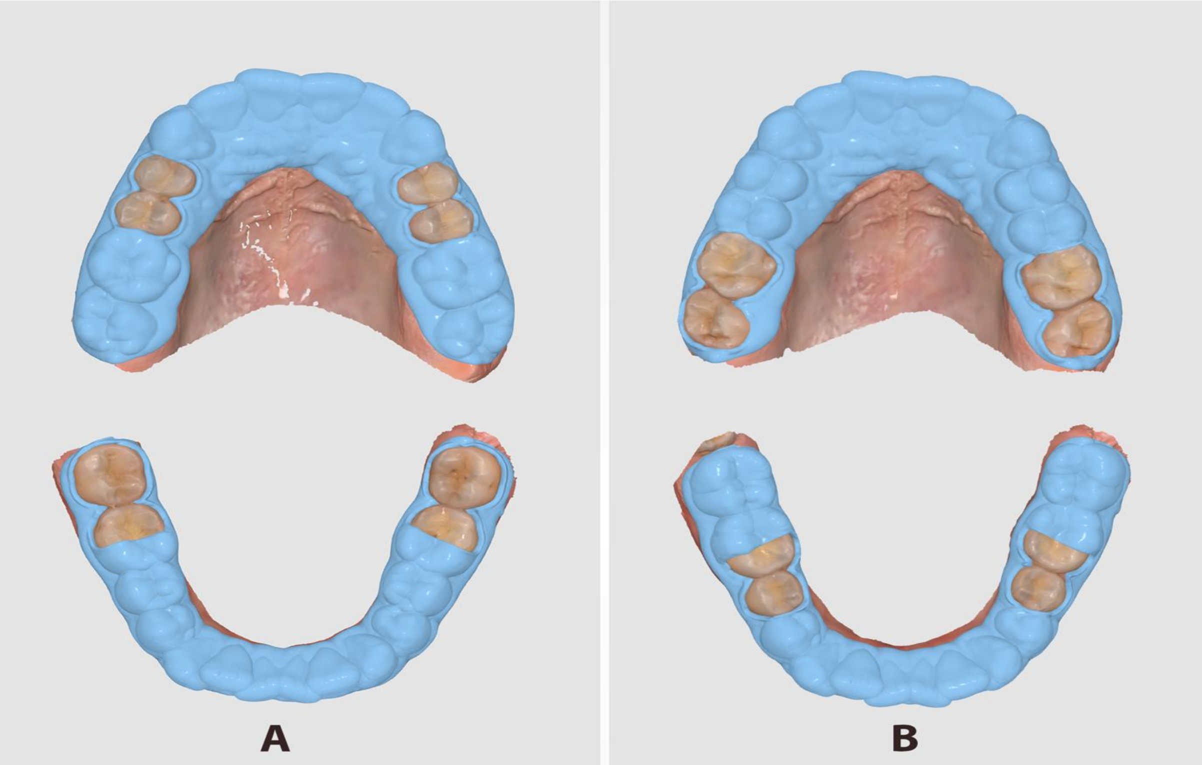

Figure 6.
Visualization of the cutout splint baseplates: **(A)** upper and lower cutout splints for the DPTB; **(B)** upper and lower cutout splints for the DPRTB.

2.2.3.3. Unification of the Baseplate and the Bite Blocks

The next step is adjusting the bite block template to the splint baseplates in the Transformation mode. The Transformation mode allows resizing and moving objects along the three axes. The positioned occlusal bite blocks are united with their corresponding upper and lower thickened splint baseplates using the Boolean Union function (Figure 7b).

The created united upper and lower model meshes are then smoothed (Figure 7b). These models are the bases for the DPTB and DPRTB and, for convenience, are called the united smoothed models (USMs) (Figure 7c).

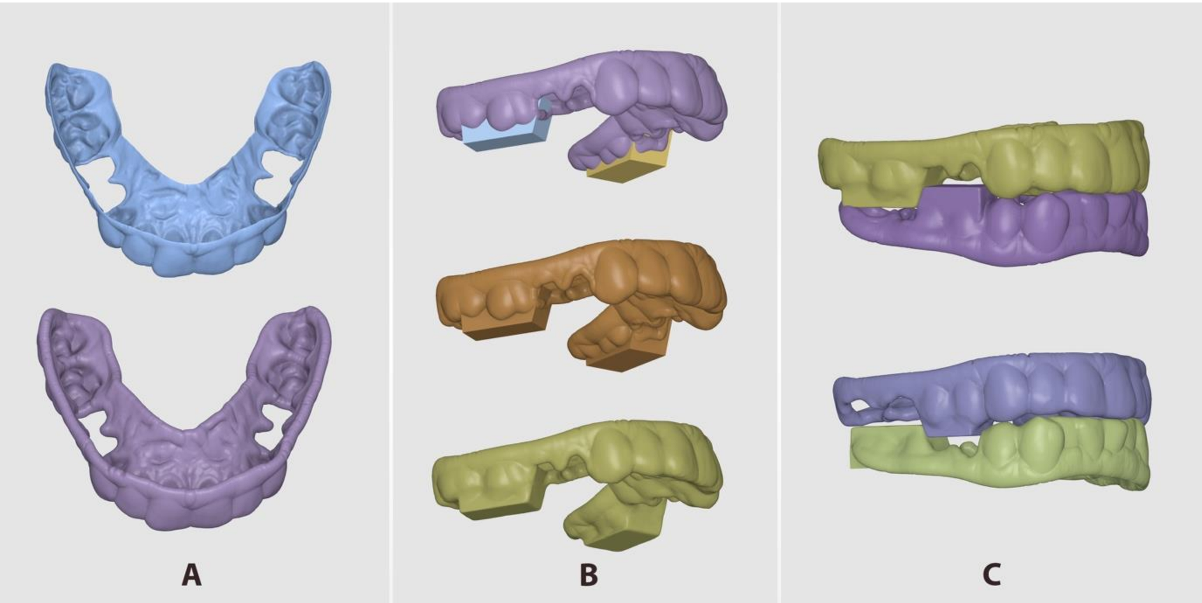

Figure 7.
Design stages of the DPTB and DPRTB appliances: (A) thickening to 1 mm of the splint baseplate to give durability to the appliance; (B) from top to bottom: the thickened splint (purple-colored) with the adjusted bite blocks in the Transformation mode; in the middle: the mesh (brown-colored) obtained after the combination of the elements; and the bottom: the mesh after smoothing the edges—USM; (C) on the top: the upper and lower USMs of the DPTB; on the bottom: the upper and lower USMs of the DPRTB.

The last two steps in the creation of the DPTB and DPRTB are preparing the outer and inner surfaces of the upper and lower USMs.

2.2.3.4. Outer Surface Preparation

The outer surface is prepared for contact with the antagonist arch using the Boolean Cut function. The Boolean Cut function removes one object B from the other object A, thereby eliminating the mesh from object A that intersects with object B.

From the upper USM, the mandibular arch model is cut, and from the lower USM, the maxillary arch model is cut. After that, any intersections between the two USMs are smoothed out.

The outer surface preparation is performed to ensure there are no premature contacts between the appliance and the teeth or between the two parts of the appliance. This provides a precise fit of the occlusal blocks with each other when worn by the patient.

2.2.3.5. Inner Surface Preparation

The inner surface preparation of the appliance starts with blocking the undercuts of the maxillary and mandibular models and defining the insertion direction of the appliance (Figure 8).

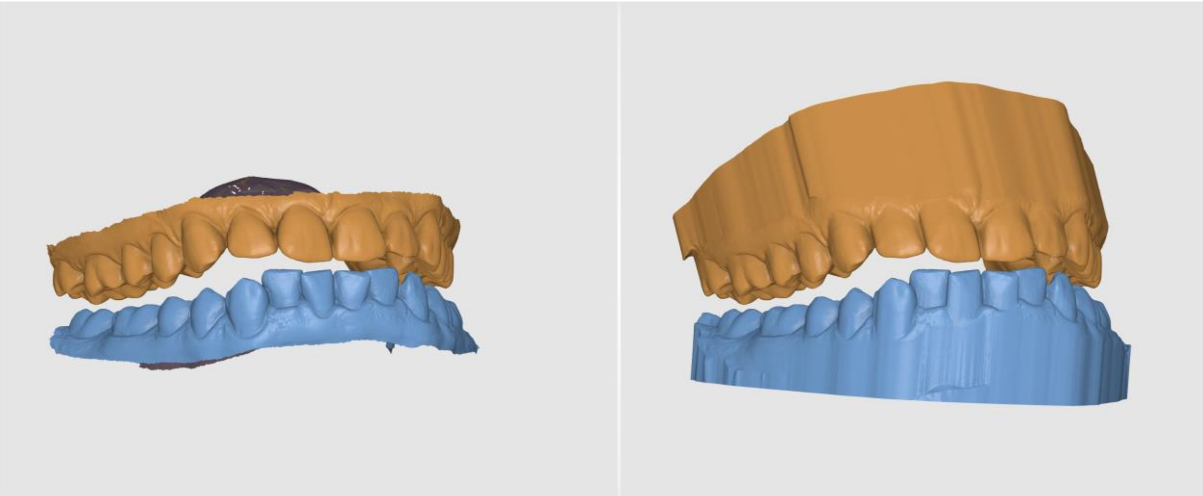

Figure 8.
Before and after blocking of the undercuts of the maxillary and mandibular models to define the path of insertion of the appliance.

An offset of 0.10 mm is then set to the outside surface of the blockout models. The 0.10 mm offset is chosen because the authors have found this value to be optimal for retention and patient convenience. Lower offset values offer better retention, but that often leads to difficulties for the patients in completely inserting the appliance, and if they succeed, they then cannot remove it. Higher offset values lead to a reduction in appliance retentiveness and a loose fit.

The last step for the inner surface preparation is using the Boolean Cut on the upper and lower USMs and the maxillary and mandibular blockout models with a 0.10 mm offset. This removes the excess on the inner surface of the appliances and provides a tight fit to the patient's tissues (Figure 9). With this step, the digital fabrication of the DPTB and DPRTB appliances is compete (Figure 10).

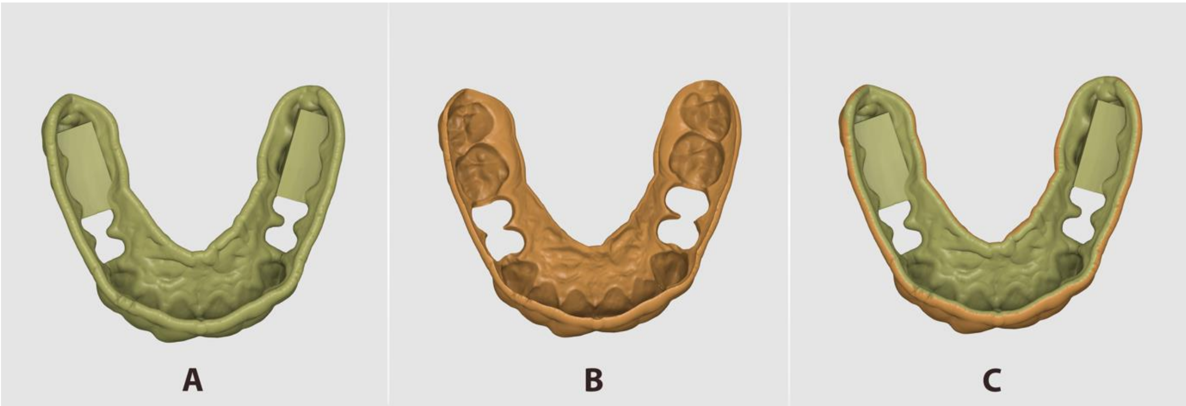

Figure 9.
Inner surface preparation: **(A)** the inner surface of the USM before the Boolean Cut with the blockout offset model; **(B)** the inner surface after the Boolean Cut; **(C)** a comparison between the initial and final inner surfaces.

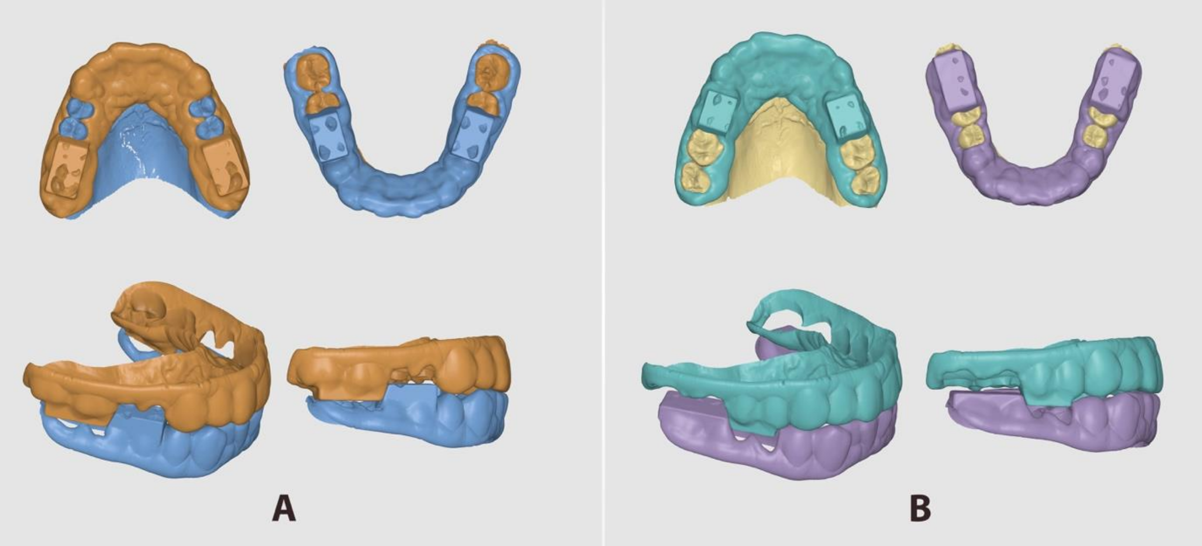

Figure 10.
The finished digital appliances ready for export to the 3D printer software: **(A)** the design of the DPTB; **(B)** the design of the DPRTB.

2.3. 3D Printing and Manufacturing

After the digital design of the DPTB or DPRTB appliance, the models are imported as STL files into PreForm, the 3D printer software. They are loaded onto a preset in the Dental Workspace of the software. This preset has established values for the type of resin, layer thickness, supports, printing settings, orientation of the models, and printer type.

The appliances are printed on an SLA 3D resin printer, Form 3B+ from Formlabs, using LT Clear V2 resin with a horizontal (flat) orientation for the models with standard layer thickness and default printer settings (Figure 11). The standard layer thickness for the resin is 100 microns. Supports are set on Basic Settings with Mini Raft type, Support density is 0.70, and Touchpoint size is 0.30 mm.

The outer surface of the appliance faces the printing platform; otherwise, the inner surface acts like a resin-holding vessel. The flat printing option is chosen because printing one to three sets of appliances is faster than using the vertical or tilted orientation. The layers are longitudinal and perpendicular to the forces created when removing the appliance from the mouth. This reduces the possibility of breakage and splitting of the appliance. There are fewer unsupported minima and cups when printing flat.

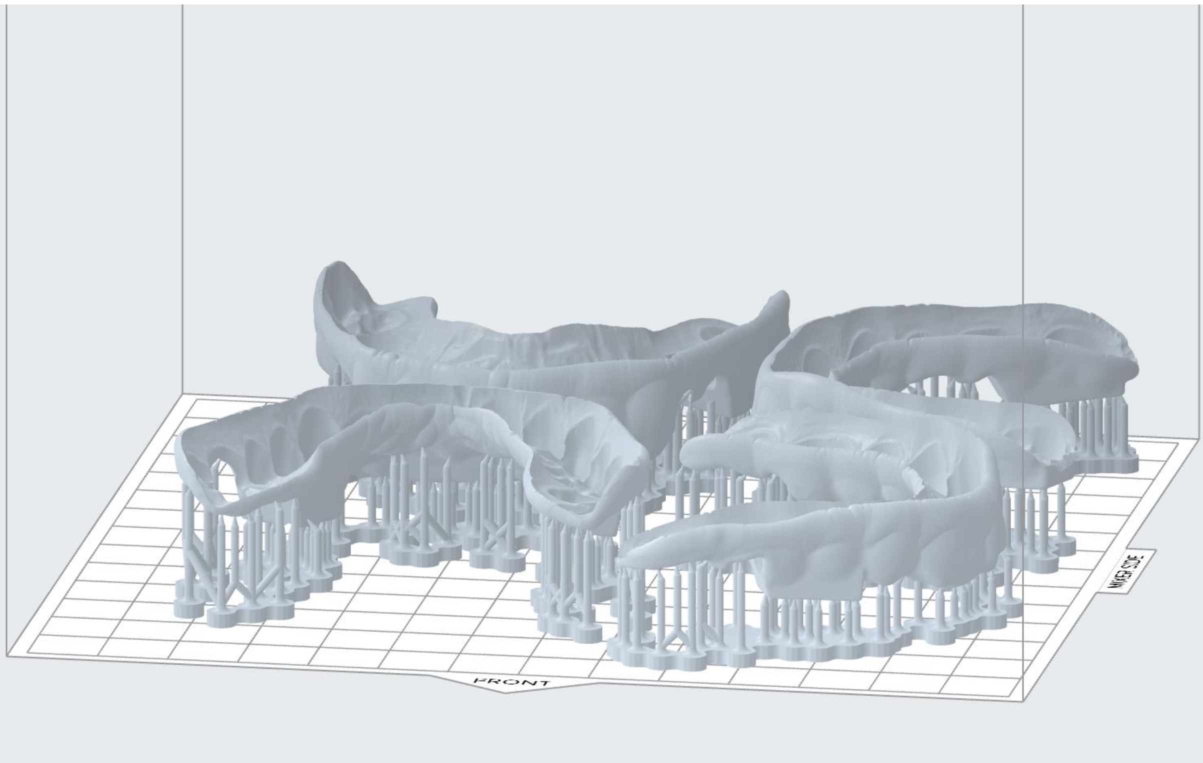

Figure 11.
The flat (horizontal) layout used for the in-house printing of the appliances. The models are positioned as close as possible to the mixer side of the printer to save printing time.

2.4. Post-Processing Procedures

The post-printing procedures are carried out according to the Formlabs application guidelines for 3D printing of splints with LT Clear V2 resin.

After the printing has finished, the models are released from the build platform and washed in ≥99% isopropyl alcohol (IPA) for 15 minutes. Then, they are removed from the washing machine and soaked in fresh ≥99% IPA for 5 minutes. At that time, the appliance parts are left to dry. The use of compressed air from the dental handpiece speeds up the drying and helps in removing excess resin.

The models are dried at room temperature for 30 minutes. After that, the parts are inspected, and if there is any residual resin, the models are rinsed with a squeeze bottle of IPA, and the drying process is repeated. The residual resin is easily detectable because it is sticky and makes the surface of the models shiny.

The post-curing is conducted in the Form Cure machine using the specific curing program for the LT Clear V2 resin. The curing process takes 60 minutes at 60 °C.

After the curing is finished, the supports are removed with the cutters from the tools included with the machines. The models are smoothed at the sites of the supports because, even when small touchpoints are used, there are always small positive features. Once the surface is finished, the outer edges of the appliance are smoothed for patient comfort. The finishing is completed with a handpiece using a carbide rotary burr and then a Scotch-Brite rotary.

A gloss shine is achieved with felt wheels and shine compound (Figure 12). After the polishing, the parts are cleaned using a delicate soft toothbrush with neutral soap and room-temperature water. The appliance is then ready to be given to the patient (Figure 13).

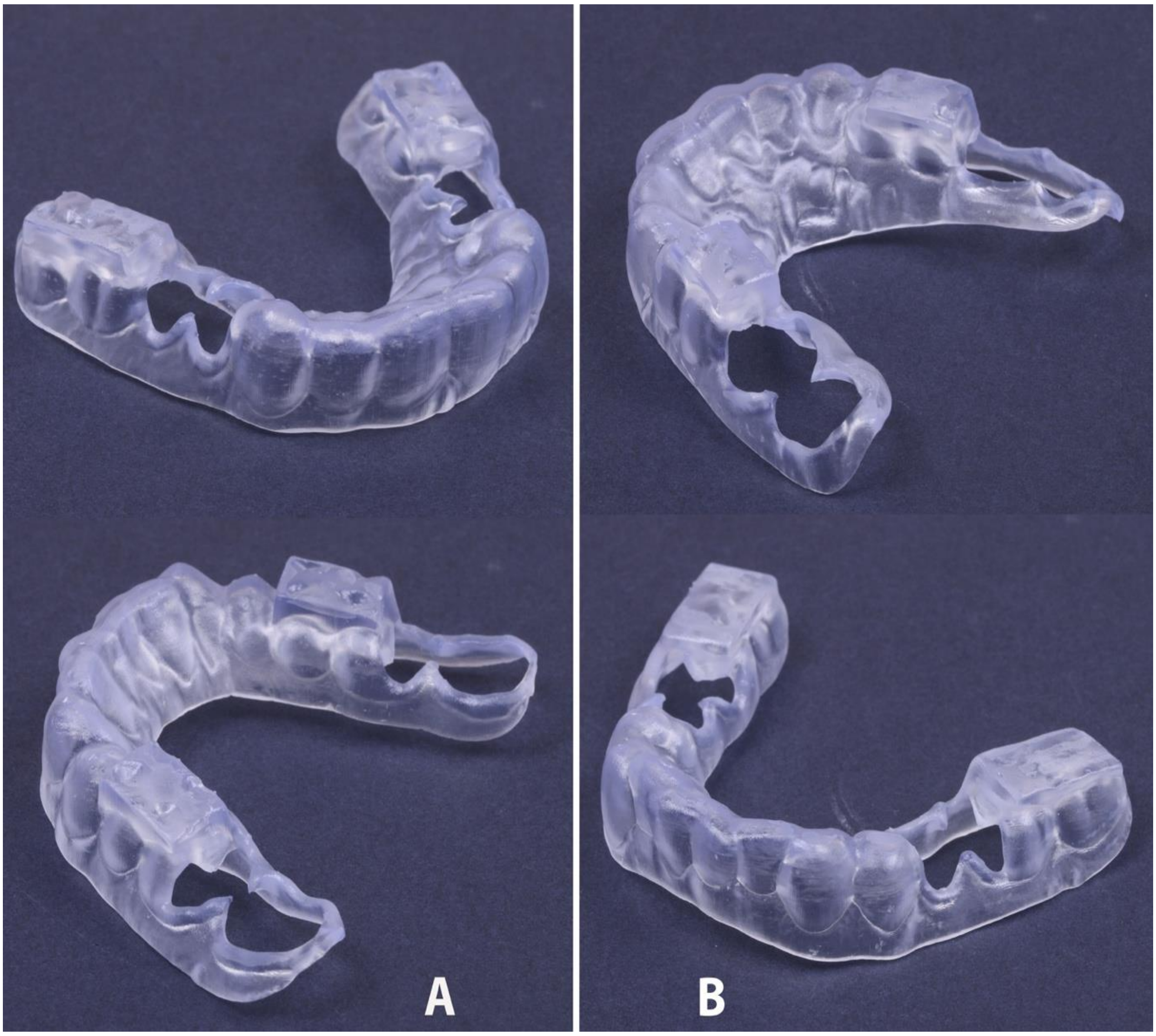

Figure 12.
The finished appliances ready for the patient; (A) the direct-printed TB; (B) the direct-printed reverse TB.

Figure 13.
Intraoral photos of the finished appliances: (A) the direct-printed TB; (B) the direct-printed reverse TB.

3. Results

The direct-printed TB and RTB appliances are made using a fully digital protocol and an in-house 3D printer. The results are reproducible, and the fully digital protocol is carried out without any additional expensive software. Only the software included in the intraoral scanner package is used, along with an open-source CAD program for designing and importing external forms (the bite blocks).

The appliances are accurate, and additional clinical adjustments are not necessary. They are easy to insert and remove, which reduces the clinical time for fitting and placement. The conventional TB requires adjustments to the labial bows and clasps, and sometimes articulation of the occlusal surfaces.

In comparison with the classic TB with an acrylic baseplate and orthodontic wire, the digitally designed appliance is not significantly bigger. In terms of comfort and adaptation time, patients find no difference between the two types of appliances. The direct-printed TB is better accepted and preferred by patients because it is transparent and does not resemble conventional removable appliances (e.g., Hawley appliance) (Table 1).

Less time is needed for designing and manufacturing the digital appliance than for the conventional laboratory method. The digital workflow is a same-day chairside procedure. The whole manufacturing process takes a few hours.

Table 1.
Comparison between the digitally designed DPTB and the conventional TB.

DPTB	**Conventional TB**
Cost investments in new technology	No cost investment
Initial time investment for software learning	No initial time investment
Chairside procedure	Laboratory stage
Cost-effective—only pay for the resin used	Laboratory fee
Simple and quick to replace (can be directly printed without additional visits)	Additional visits for impressions and clinical time
No need for additional adjustments	Adjustments of the clasps and bows
More aesthetic*	Less aesthetic*
Potentially less vestibular incisor tipping	Vestibular incisor tipping when teeth are excluded from baseplate coverage
No possibilities for bending of the structure	The metal clasps and bows can be dislodged by the patients
More difficult to incorporate mechanical elements	Direct incorporation of the metal elements while fabricating the baseplate
Cannot correct teeth positions	Basic correction of rotations
Design options may be limited by software	Design is limited by the technician's dexterity
Less material waste	More leftover materials
Similar sizes	
*Patient-specific issues	

With the direct-printed appliances, there is less material waste. The only leftover material is the support structure resin, while for the conventional laboratory method, there is waste impression material, dental cast models, orthodontic wire, and bite registration material.

The digital workflow of the appliance allows for a fast replacement if the TB is lost or broken. There is no need for an additional appointment for impressions. The appliance can be printed directly, and the patient only needs to pick it up. With the conventional TB, at least two clinical appointments are required.

The digital designing and planning of the appliances allow customization for individual cases. This can be performed by modifying the splint base or the bite blocks, or by the incorporation and precise positioning of custom elements such as extensions of the baseplate; metal arms, expansion screws, etc.

The DPTB and DPRTB appliances can be applied to both mixed dentition and permanent dentition and are used for active treatment as well as in post-treatment after the bracket or aligner phase to maintain the occlusal relationships and tooth positions.

4. Discussion

Because the market is flooded with dental software, different appliance designs, digital workflows, and approaches are appearing in the literature.

Cousley proposed a semi-digital workflow for the fabrication of thermoformed baseplate modification of the TB. The appliance has all the advantages of digital appliance design while minimizing the aesthetic impact and patient discomfort [22].

In implementing a defined digital workflow in their appliance manufacturing, Nucera, et al. [26] proposed a digitally designed, bonded Twin Block. This is the first and only digital bonded TB described in the literature [26]. They utilized the advantages of software planning—the accurate reproduction of planned mandibular advancement, integral fit of the blocks on the teeth, and optimal fit between the blocks.

Graf, et al. [25] described a fully digital protocol for an in-house printed TB [25]. The proposed design is shell (splint)-based. Our digital design and workflow are consistent with Graf's limitations, owing to the similarity in the basic design of the appliances.

For our fully digital protocol, basic user-friendly and accessible software (Medit Link) is used. The software comes in a package with an intraoral scanner (Medit i700). The software can be downloaded even if the clinician does not have the intraoral scanner.

Medit Link software has limited usage in the orthodontic field. Other than the Ortho Simulation App, there is no specific orthodontic application. The Simulation App has limited tooth positioning options and cannot be used properly for aligner staging.

Another limitation is its lack of a true CAD design program. There is a beta version with limited options, but it is developed only in the field of prosthetic and restorative dentistry. Therefore, the digital workflow limitations arise from the software limitations. The workflow requires additional CAD software for the bite block design. This is a minor deterrent because once the blocks are created, they can be imported into Medit Design and saved as templates.

For the basic digital design of the TB and RTB, a single external CAD program is enough. However, if the appliance requires additional parts such as an expansion screw or other mechanical elements, the proposed digital workflow using the Medit Apps cannot be applied.

The DPTB and DPRTB appliances use Clark's principle to promote forced mandibular repositioning to achieve the same orthopedic results as the conventional ones. In addition to the mandibular repositioning in the sagittal direction, they also allow vertical correction of a deep bite by selective grinding of the blocks. The selective grinding can be used to ensure space in the biteplate for the erupting teeth. In the transversal direction, they can maintain the transversal position of the mandible and the achieved transversal changes in the dental arches.

The direct-printed appliances cannot completely correct tooth position. The DPTB and DPRTB have no active parts (such as labial bowls, springs, or a combination of both to move and rotate teeth). They are based on a splint, meaning that only occlusal relationship correction, with no tooth movement, can be achieved. This limitation requires additional phases (with fixed techniques or aligners) for tooth position correction or selecting patients with relatively good tooth alignment.

A possible future solution is to incorporate aligner-like staging to correct the tooth positions while maintaining the mandible position. This modification of the design could work if a suitable resin is developed. The best market option for direct printing and tooth aligning is the Graphy Inc. TC-85DAC resin. Further research is needed to assess the possibilities of this modification.

This tooth positioning limitation occurs during active treatment, but it is an advantage when using the DPTB and DPRTB for retention in post-treatment after using a fixed technique or aligners while there is still growth. The splint base serves as a retainer for the teeth (similar to a thicker thermoformed retainer), and the bite blocks help maintain the occlusion. The insertion and removal of the appliances are comparable to the thermoformed retainers regarding the path of insertion, which is incorporated into the design of the appliance.

Another advantage of using them as retainers is the absence of metal wire elements. This saves clinical time because there is no need to adjust the clasps and labial bowl for adequate retention of the appliance, which minimizes the possibility of dislodgment. In addition, patients cannot bend, deform, or dislocate the wire elements, meaning they will not need unscheduled or extra appointments, which take up their time and the clinician's time.

When treating Class II Division 2 patients with the DPTB, an additional treatment phase for correcting the retroclined upper central incisors is needed. This phase aims to convert the incisor relationship to Class II Division 1. This is most commonly done using appliances for the proclination of the incisors. With conventional TB modifications, this can be accomplished in one phase, saving treatment time [30]. With the evolution of dental software, adding different elements such as protrusion screws and their precise positioning is becoming easier, which will eliminate the need for additional phases and shorten the treatment.

The digitalization of orthodontic practices leads to the optimization of protocols, workflows, and clinical time, as well as a reduction in manual labor and waste. The time needed to design and manufacture digital appliances is less than that of the conventional laboratory method [31-35]. In their systematic review, Mahato, et al. [32] analyzed 22 articles and found that digital workflows reduce working time, minimize material consumption, and enhance patient comfort and acceptance. Mahato, et al. [32]. Yu, et al. [31] described a fully digital workflow for developing orthodontic appliances and concluded that this workflow decreases labor and labor costs, increases productivity, and avoids environmental pollution [31].

The manufacturing process is cost-effective. With the in-house provision and rapid workflow, the appliances can be completed on the same day or the next, in contrast to dental laboratories that require several days or even a week due to their scheduled workload [31].

With the digital workflow and direct-printed appliances, waste materials are reduced. The only waste material is the support structure resin, while for the conventional laboratory method, there are waste impression materials, dental cast models, orthodontic wire, and bite registration material. The digital method reduces the risk of human or technological errors that can accompany the many successive manipulations (dental cast pouring, occlusion adaptation, and mounting in the articulator, metal wire bending of different elements, plastic baseplate fabrication, etc.) in the classic method.

Using a flat (horizontal) orientation in the SLA resin printer ensures high accuracy without the accumulation of errors ElShebiny, et al. [36] and Perlea, et al. [37]. Subbaiah, et al. [38] conducted a study of over 50 models printed vertically and horizontally. They concluded that the horizontal orientation was more cost-effective in terms of the amount of material (resin) utilized and the printing time [38].

The advantage of the digital method is that the working files are saved in the patient's digital file. We observed that patients of average treatment age often lose or break the appliances. In these cases, reprinting the appliances is immediate, and no re-taking of impressions, construction bites, or other laboratory stages are necessary.

A disadvantage of the fully digital workflow is that it requires a high initial investment for the intraoral scanner, dental software, and 3D resin printer. Another disadvantage is the initial time invested in learning the software and developing the appliances. Both of these disadvantages are only temporary because if one converts to the digitalization of the practice, the investment soon pays off both financially and clinically. Additionally, the expenses for the 3D in-house printer can be recouped by not exporting the designs to an external orthodontic laboratory. The use of an external orthodontic laboratory lowers the starting investment but increases the fabrication-to-chairside time.

With the growing choices of dental CAD software, 3D printer manufacturers, and printable materials, more possibilities for designing and customizing appliances are emerging. Fully digital workflows and in-house printing of appliances are becoming integral to the everyday work of orthodontists. The DPTB and DPRTB provide fast, cost-effective production and save clinical time, optimizing work schedules.

5. Conclusions

The proposed fully digital design and workflow are easily reproducible using basic software and allow for the production of accurate appliances. They can be used for both treatment and retention phases in mixed and permanent dentition.

Digital design allows for the optimization of appliance retention with efficient use of undercuts and ease of anatomical adaptation. It offers an accurate reproduction of mandibular advancement and an integral fit between the bite blocks and the occlusal surfaces. This is a chairside workflow that is cost-effective, saves clinical time, reduces waste, and provides fast production (same-day) when a replacement is needed.

The limitations of the digital workflow arise from the constraints of the software, indicating that further incorporation of active components is necessary. Future studies will be conducted to establish the possibilities for correcting tooth positions.

To the best of the authors' knowledge, this is the only digital workflow utilizing Medit Link and Medit Apps, and one of the first digitally designed and direct-printed RTBs. This indicates that further modifications and clinical studies will enhance their clinical application.

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