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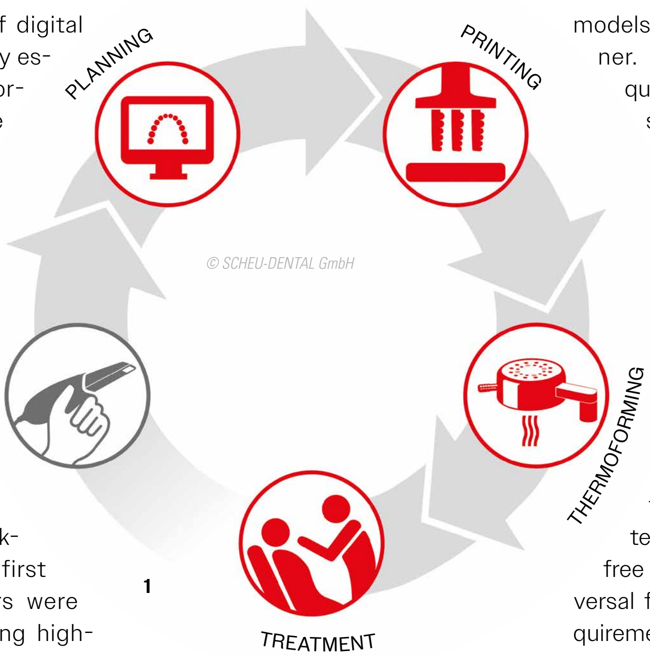
The simple way through the digital process chain in orthodontics

In this article, orthodontist Dr Stephan Peylo explains the use of digital models and 3D printing technologies for the production of attachment templates for the indirect bonding of brackets.

In recent years, a range of digital processes have increasingly established themselves in orthodontic practices, where they are steadily replacing traditional analogue processes. For example, there are likely no practices left where photographs are still taken with analogue negative or slide film. Patient files are also increasingly being kept in a purely digitalised form. In addition, digital impression taking has established itself in many areas of the daily workflows in the practice. The first generations of 3D scanners were already capable of generating high-quality scans for use in the digital production of treatment appliances (e.g. aligners) and for space-saving archiving. However, it often proved difficult to integrate the relatively long period of time required for a full-jaw scan into the normal daily routine of a dental practice. With the latest generations of intra-oral scanners, it is now possible to create digital jaw models in just a few minutes that are far superior to conventional alginate impressions from a precision perspective. However, as the digital scans are yet to be included in the catalogue of services covered by German public health insurance companies and a conventional plaster model represents a simple and inexpensive alternative for certain laboratory tasks (e.g. the production of removable braces), traditional impressions do not look set to become obsolete in certain areas of orthodontics at least in the near future. Of course, there is also the option of subsequently digitalising plaster models with the aid of a model scanner. Nevertheless, the increasing quality and speed of the intra-oral scanners makes them the better choice in the long term. At present, intra-oral scanners are currently employed in approximately 10% of dental practices; the figure is likely to be much higher in orthodontics.



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When deciding to purchase an intra-oral scanner, alongside the speed and price, it is also essential to make sure that you choose an open system that allows unrestricted and free export of the scan data for universal further use. As a minimum requirement, it should be possible to export the data in the universal STL format, although some colour information may not be conveyed with this option. For this reason, export in other formats preserving colour information is desirable. Some scanners only work without any issues in the corresponding manufacturer's workflow. Processing of the data with other software, which is often very practical and can open up a whole range of possibilities, may not be possible or may only be possible at considerable extra cost. This aspect should always be considered before making a

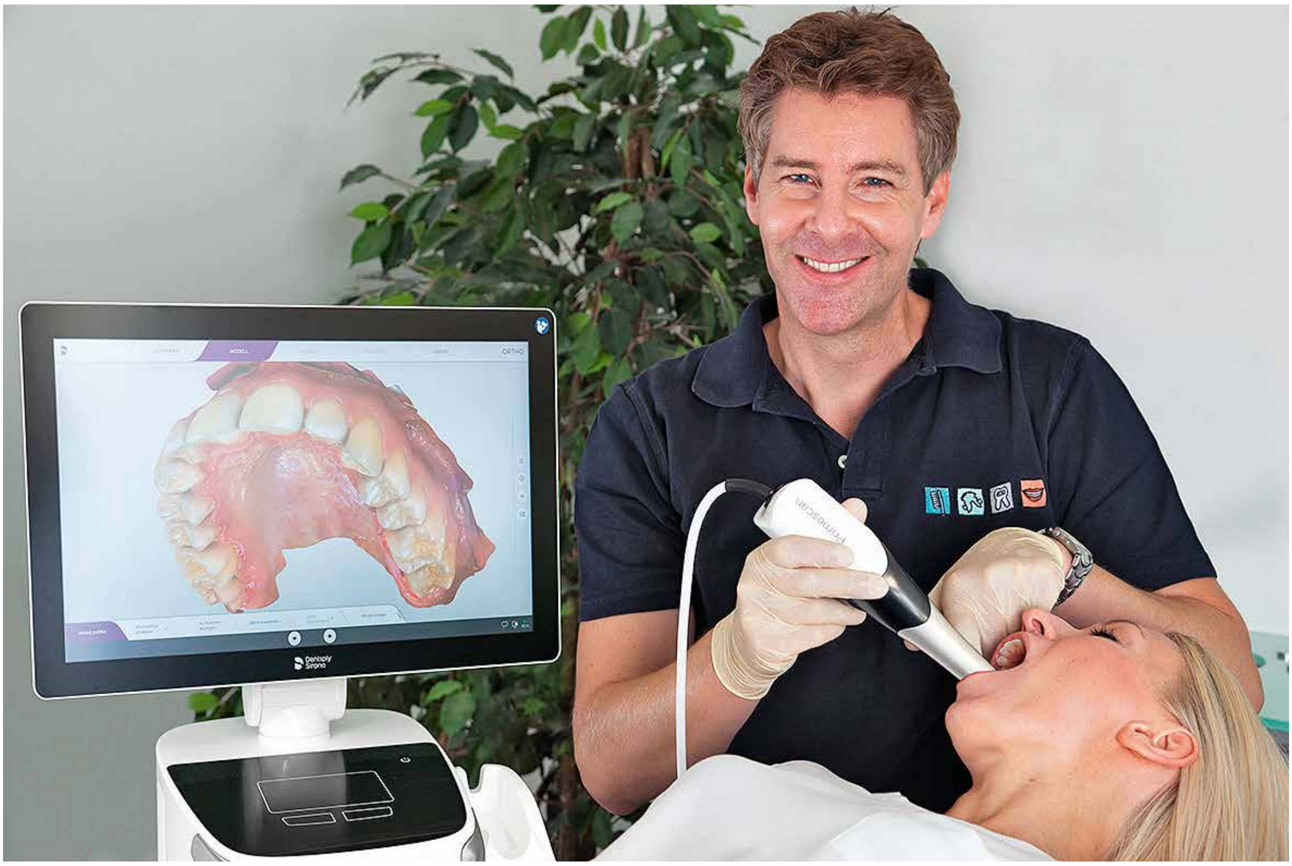
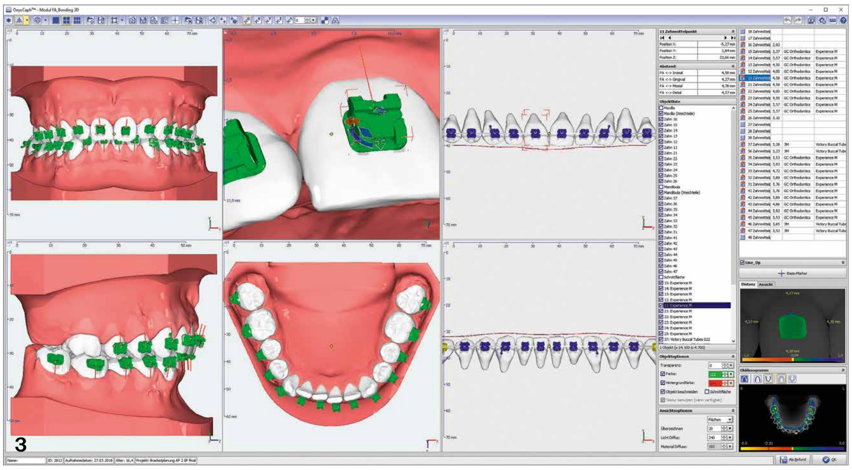


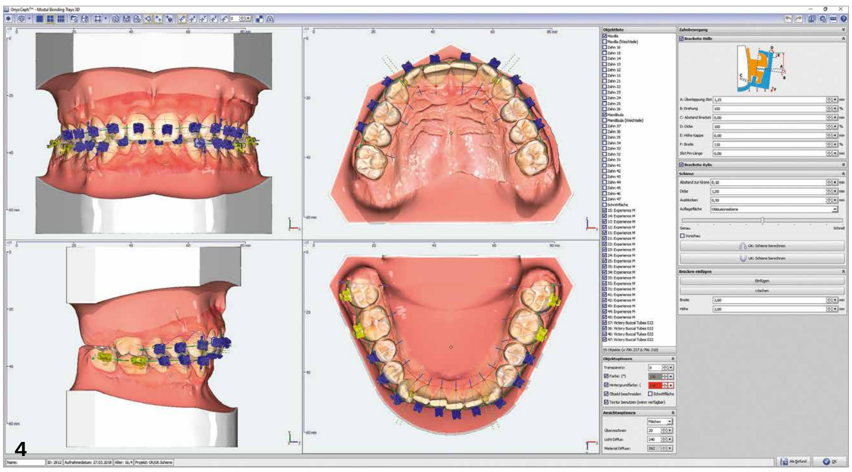
Fig. 2: An intra-oral scanner is the first step in digital orthodontics. **Fig. 3:** Selection and alignment of the brackets in OnyxCeph™. **Fig. 4:** The first step in the Bonding Tray module is the definition of the limits of the transfer tray.

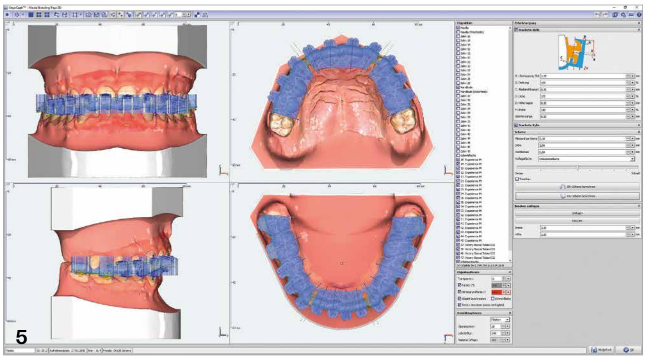
purchase. Once you have taken the first step into the digital world of orthodontics and the jaw models are available in the form of a digital dataset, there are a whole range of different options open to you depending on what should happen next with the dataset: archiving, 3D printing of a planning model, aligner production, bracket planning for indirect bonding and 3D printing of an attachment template, metal printing of treatment equipment (Herbst appliance, palatal expander, etc.), printing of CMD splints or drilling templates for the insertion of mini-screws, production of positioners, planning of retainers, etc.—the application possibilities are practically endless.

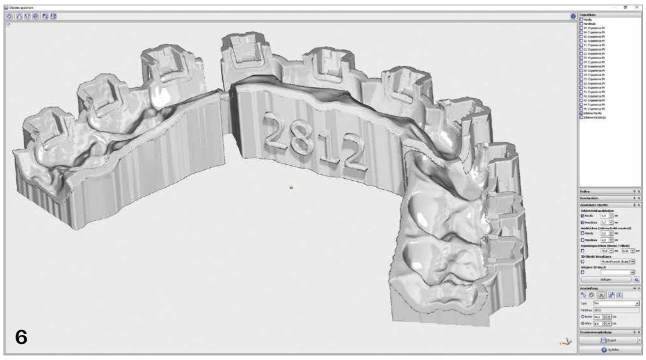
There are "stand-alone solutions" for many of these application possibilities, where one provider covers a subarea. These often require separate software and involve specific requirements on the format and transmission of the digital data. The wide variety of options available are now so numerous and confusing that in the end even computer-savvy practice owners feel overwhelmed.

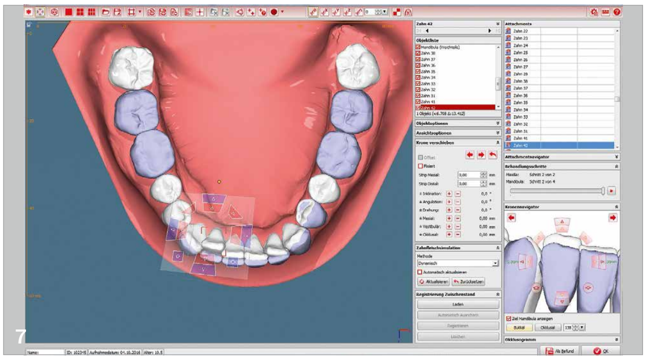
In order to offer a structured solution in this situation, SCHEU-DENTAL GmbH











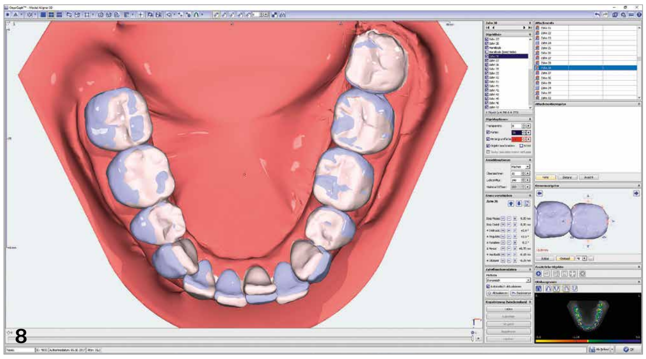


Fig. 5: The tray is calculated and saved. **Fig. 6:** The tray can be labelled with a unique number and exported as an STL file. **Fig. 7:** The customised target setup is generated in the Aligner 3D module. **Fig. 8:** The extent of the planned tooth movement can be visualised by superimposing the final finding over the initial finding.

has now developed a workflow. Continuing on from the scanning process, it offers a consistent solution concept for every step, from the data processing and the digital tooth repositioning to the 3D printing and thermoforming right through to the patient treatment. The result is an integrated process chain optimised for orthodontic practices and laboratories. With the corresponding modules, users can enter the digital workflow at any time and receive the customised range of products and services from a single source.

> "With the latest generations of intra-oral scanners, it is now possible to create digital jaw models in just a few minutes that are far superior to conventional alginate impressions from a precision perspective."

STEP 1—Planning

Following a successful scan, the first step in the digital world of orthodontics, the manufacture of a digital model, is complete. The next task is to process the digital data, as the scan still contains gaps and other artefacts that have to be digitally closed and corrected. First, the scan file is sensibly stored on the server and then transferred to the OnyxCeph3TM soft-

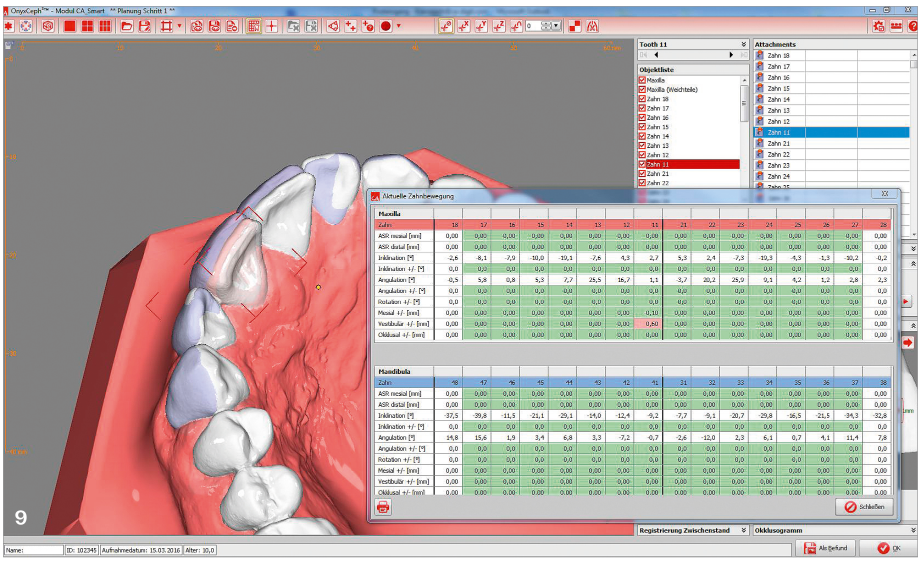


Fig. 9: It is also possible to enter the measurements in a table and specify the limit values. **Fig. 10:** The DLP 3D printer Asiga MAXTM.

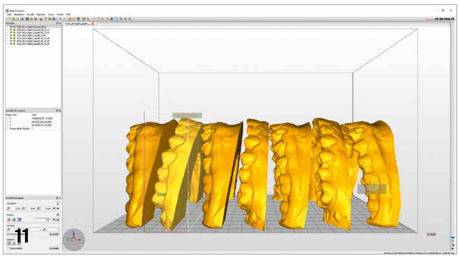


Fig. 11: Arrangement of the IDB trays in the Asiga Composer software. **Fig. 12:** The printed trays suspended from the build platform of the Asiga MAX™. **Fig. 13:** A glass scraper or similar tool can be used to detach the trays and printed models from the build platform. **Fig. 14:** The cleaning and light-curing device from rapidshape.

ware. Direct transmission of the patient data from the administration software via a VDDS interface is also possible. OnyxCeph³™ from Image Instruments is a software for planning, conversion and controls in the context of digital data processing and aligner therapy. It can be employed for the processing of datasets, the performance of cephalometric analysis if applicable, the virtual segmentation of the teeth, the repositioning of the teeth, the generation and export of print data, the creation of 3D reports and direct data export to the Asiga Composer software. In other words, all the steps of the further model processing and planning are performed using this software. Once any gaps have been closed, the model is virtually mounted to give a digital planning model. The patient name, patient number and date can be added if required. If the model is intended for archiving purposes only, the digital workflow is now complete.

Indirect Bonding Trays (IDB)

For indirect bonding (IDB) or aligner production, however, the model must be further processed. The first step is "informing" the computer which area of the dataset corresponds to the teeth and which to the gingiva. This is also done in OnyxCeph³™. Once the teeth have been clicked on, the separation process proceeds largely automatically; corrections may sometimes be required in certain areas, but these can be performed with ease and conveniently.

Following this processing step, we have a digital model where the teeth can be moved independently of each other and the actual planning can take place.

If a digital transfer tray for the indirect bonding of brackets (IDB) is to be produced, the first step is to open the corresponding module in OnyxCeph³™. The required system is then chosen from a comprehensive library in which the digital bracket data is stored. Almost any bracket of your choosing can be imported into this database, as long as the manufacturer has made the corresponding data available. The virtual brackets are positioned on the 3D model in accordance with specific preset or individually defined criteria, for example on the facial axis (FA) point, which is automatically calculated after the separation (Fig. 4).

A variety of views can now be selected to check the precision of this alignment and make any corrections if necessary. With this method—as in direct bonding—an optimal treatment result depends on the brackets being aligned as precisely as possible with the teeth. The bonding of the brackets is described as the first finishing step for good reason. Once the brackets have been positioned, these findings can be saved to allow subsequent changes to be made if necessary. The digital attachment template for the brackets is now designed in the Bonding Tray module (Figs. 5 and 6). Depending on the

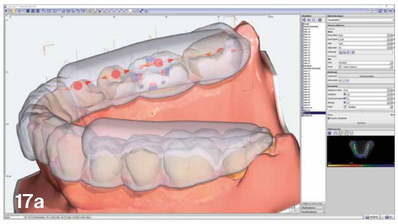


Fig. 15: The tray fitted with brackets (Experience™ Metal from GC Orthodontics). **Fig. 16:** Production of a haptic jaw model can help the patient to visualise the treatment planning. **Figs. 17a–c:** (a) The CAD/CAM planning of a CMD splint. (b) Printed splint made of IMPRIMO® LC Splint. (c) Blocking out of the undercuts is performed directly in the software.

type of bracket used, various parameters can be adjusted here to ensure an optimal fit of the brackets in the template. The finished tray is saved as a finding once again and exported as an STL file to permit sending of the data to the 3D printer in this format (Fig. 7).

Aligner planning

The Aligner 3D module is opened in OnyxCeph³™ for the aligner production. A customised target setup can now be created and each tooth positioned as desired (Fig. 8). In this step, it is also possible to display the occlusal contacts and the space conditions with gaps and crowding. The orthodontist can then decide whether and to what extent interproximal reduction (IPR) is required or whether other options for creating space (distalisation, expansion, protrusion) should be employed. The planning and configuration of attachments are also possible here. Dr Pablo Echarri's CA® CLEAR ALIGNER treatment philosophy, which is stored in the software, can be used for an automatic repositioning check during creation of the setup (Figs. 9 and 10). The next step after creation of the target setup is the definition of the "staging", in other words how much each tooth should move per treatment step or aligner. Once the treatment goal has been saved as a project file, it is possible to generate the number of 3D model datasets corresponding to the staging using the series export function. These are once again saved in STL format so that they can be sent to the 3D printer.

STEP 2—Printing

To bring the results of the virtual planning back into the real world, a 3D printer is required to print the generated STL data of the models. With just one click, the OnyxCeph³™ software can generate the STL data in the Export module and send it directly to the network-compatible DLP 3D printer Asiga MAX™ (Figs. 11 and 12). The Asiga MAX™ 3D printer is a UV HD LED projector with which particularly precise printing results can be achieved in a very high quality and just a short printing time. Alongside the interactive operation via touchscreen, it also offers the option of web-based control and monitoring. A light sensor ensures consistent projector performance and uniform resin curing. Numerous coordinated materials also contribute to particularly high user-friendliness.

The imported model files are positioned on the build platform in the build space using Asiga Composer, which is a purely nesting software designed for the positioning of data and creation of support structures to stabilise the objects during 3D printing. It is not possible to process the data with the print software. Horizontal arrangement is recommended for the IDB trays (Fig. 13). If preferred, print models can also be arranged vertically to allow simultaneous printing of a larger number of models, which translates to further time savings. As the Asiga MAX™ is network-compatible, the data can be sent directly to the printer from the PC. The 3D printer can process a wide variety of materials and thus be employed in different areas of application. Depending on the task, a tray is then filled with different resins. Following the final object alignment in Asiga Composer, the corresponding material is selected, e.g. IMPRIMO® LC Model for models. Definition of the layer thickness is the final step before printing starts. The print object is sliced into layers using the slicing function, and the images for the projection are calculated. The material parameters stored in the software ensure that the resin is cured correctly in the corresponding layer thickness. During the printing process, the object is built up layer by layer, with the print platform being dipped into the container full of resin and the complete print surface being cured from below as if with a projector. The print platform is then raised a little and the next layer of the print resin is cured. In this way, the print model is built up layer by layer. The exposure of the entire surface of the print platform to light enables a considerably higher printing speed than is possible with other laser printers where the resin is spot cured. When the dental arches are arranged horizontally, printing takes only approx. 35 minutes (Fig. 14). With vertical positioning, where seven to eight arches can be printed simultaneously, the process takes around two hours. The speed also depends on the print resolution. In our practice, we have had good experiences with a resolution of 100 µm, as it offers a good balance between high print quality and a short time.

Once the printing is complete, the print models are detached from the build platform (Fig. 15) and cleaned in a special cleaning fluid or isopropyl alcohol for three minutes. This step is particularly convenient with a special cleaning device, as

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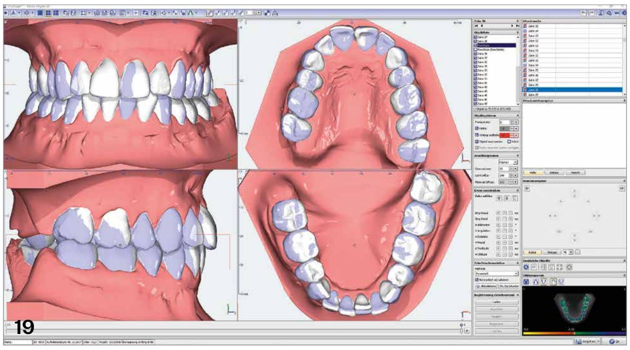

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Figs. 18a and b: Producing the aligners in your practice's own laboratory is very easy with the BIOSTAR® thermoforming device from SCHEU-DENTAL. **Fig. 19:** Starting and target situation of a treatment with CA® CLEAR ALIGNER.

Figs. 20a–e: Clinical situation before treatment. **Figs. 21a–e:** Clinical situation after treatment.

the applied parameters are also saved for an integrated workflow. Alternatively, cleaning can also be carried out in an ultrasound bath as a cost-effective option. Following the cleaning, curing is performed for ten minutes in a light oven with a wavelength of 385 nm (Fig. 16). A light-curing device with a vacuum or nitrogen purge function is particularly recommended to avoid an inhibition layer and for complete curing.

If the printed objects are IDB trays, they are now fitted with the brackets and can be inserted in the patient (Fig. 17a). If aligner therapy is to be performed, the next step is thermoforming of the splints with a thermoforming device. Even printing of high-quality planning models—which can also be printed hollow to save printing material—is possible with the Asiga MAX™ without any problems.

Orthodontists can also save a significant amount of time by manufacturing CAD/CAM-produced CMD splints in their own lab. Following the 3D scan, which is performed in the desired therapeutic target position, the software can be used to plan the splint. Depending on the requirements of the respective treatment concept, the splint can be produced in the upper or lower jaw and with or without canine guidance. IMPRIMO® LC Splint for rigid splints is available as a print material. It is also possible to produce flexible splints with IMPRIMO® LC Splint flex. If the CMD splint should be lost or broken, the fact that the STL planning data is stored means a new splint can be produced to replace it quickly and without great expense (Figs. 17b and d).

STEP 3—Thermoforming

While we initially used the MINISTAR S® device for occasional thermoforming in our practice, it makes complete sense to purchase the larger BIOSTAR® device if you will be using it more frequently or to produce aligners. Both devices feature a patented thermostatic heating control and convenient scan technology for simple programming for different thermoforming materials and reach their working temperature in just one second. Both devices are also integrated in the digital workflow. The MINISTAR S® employs a working pressure of 4 bar, while the BIOSTAR® uses 6 bar and also offers a database with information on scanned foils and indications along with illustrated application hints and animated videos (Figs. 18 and 19).

As per the classic CA® CLEAR ALIGNER philosophy, we use three thermoforming materials for each printed model, which corresponds to one treatment step respectively. They are supplied in the thicknesses 0.5, 0.625 and 0.75 mm and labelled “soft”, “medium” and “hard”. For the production of the splints, the printed dental arch is placed on the model platform and the CA® foils in the corresponding material thickness (soft, medium, hard) consecutively thermoformed. When doing so, it is important to cover the model with an ISOFOLAN® foil for insulation prior to the first thermoforming procedure. The exact process is stored in the BIOSTAR® library and can also be found on the SCHEU-DENTAL website (Figs. 20a–e). A new splint material called CA PRO® has also been available for some time now. The special feature of this material is that each foil is composed of three layers fused together. This compound material demonstrates considerably improved mechanical properties. For example, the initial force when inserting the aligner is lower, which increases wearing comfort for the patient. However, the splint’s force loss over time is also lower and thus the force more consistent, meaning the effect lasts for longer and tooth movement

Fig. 22: Inserting the IDB tray in the patient. **Figs. 23a and b:** The design of the tray makes it easy to remove any excess adhesive. **Fig. 24:** The final situation following insertion of the archwires (Initialloy™ 014 from GC Orthodontics).

is even more predictable. In our experience, the new CA PRO® splints allow a greater degree of tooth movement per splint, meaning fewer splints are required per treatment. Splints already containing an ISOFOLAN® foil are also available under the name CA PRO®+, thus eliminating the additional step of the insulating foil. All CA® foils are labelled with a barcode that can be read by the MINISTAR S® and BIOSTAR® thermoforming devices and transmits all the necessary parameters to them automatically. After thermoforming, the splints are cut out and the edges smoothed and polished, leaving them ready for insertion in the patient.

STEP 4—Treatment

As outlined, this covers the individual steps of the digital workflow. From the initial processing of the 3D model data, planning, printing and thermoforming to the insertion of the respective treatment appliance in the chair, a functioning, perfectly coordinated solution concept is offered for each sub-step. The various individual steps to be carried out dovetail seamlessly, providing orthodontists with an easy-to-follow and reliable guide. Integration of the digital process chain into the practice can reduce external laboratory costs significantly, thus resulting in a very rapid return on investment. As there are no shipping and production times by external companies involved, the production speed depends solely on the practice's internal specifications. In summary, it is safe to say that the digital workflow offers a simple and functional solution for every step and is thus set to simplify routine work in orthodontic practices in the long term. Of course, each individual step of the digital workflow can also be carried out with other software and equipment.

To make your start in digital orthodontics and in particular the production of aligners in your own practice even simpler, I have developed an online course in cooperation with Dr Oliver Liebl where the individual steps are presented in detail in an easy-to-follow manner (www.digital-ortho-academy.de).

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