

Virtual Orthodontic Treatment Planning

This article provides an overview of standard functionality and optional modules that can be used at the time of printing in the OnyxCeph^{3™} 3D imaging software for the purposes of virtual treatment planning in orthodontics basing on digital models.

Possibilities for the planning of fixed appliances, aligners, retainers, trays and surgical splints as well as various treatment aids are presented.

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Chemnitz, 03.10.2018

Preface

The recent years have shown a rapid development in the field of 3D-imaging systems. From the perspective of orthodontics, beside digital volume data and face scans - especially digital surface models are gaining importance. A major motivation behind this is most likely the multitude of emerging opportunities for improving workflows in the doctor's office - ranging from saving time, material, laboratory capacity, occupancy costs and others to the optimization of treatment progress and result.

For effective use of this potential in any given workflow a suitable infrastructure in regard to hardware, software and service providers is required.

As manufacturer of the dental imaging software OnyxCephTM with focus on its use in orthodontics, Image Instruments has continuously worked on development and implementation of a uniform concept for digital management, evaluation and comprehensive utilization of 2D and 3D image data.

OnyxCeph^{3TM} designed as dental imaging software represents a WindowsTM-based client/server host application with high performance local NexusDB SQL-database. By now, the software is used by more than 3,000 registered users in more than 70 countries for tasks relating to image based archiving, diagnostics, treatment planning, consultation and statistics.

Depending on the type and scope of the usage of patient-specific image records, the modular basic concept of the software, that is approved as medical product, offers different program versions and flexible licensing models.

In the following, the example of virtually planning an orthodontic treatment will be used to outline which possibilities exist for working with digital models in the current version of OnyxCeph^{3™}, even if the software provides a much larger framework to incorporate all other image-based findings for the patient into the planning and implementation of the treatment.

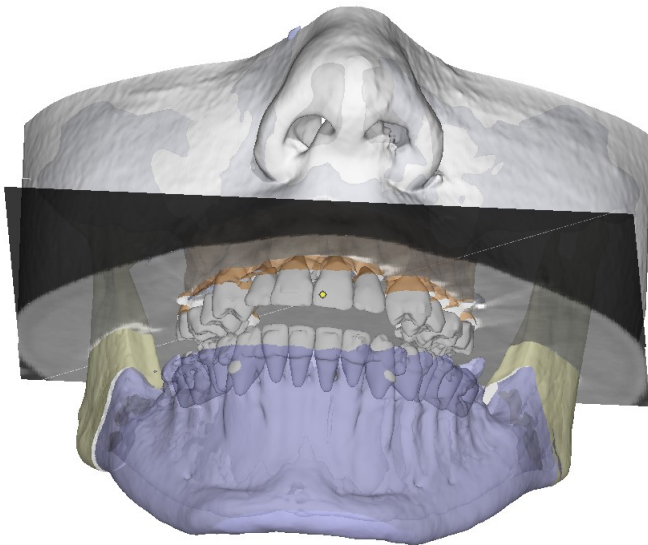


Figure 1: Fusion of CT and segmented model findings using registration in the Combine 3D module

Digital Models

In recent years, the utilization of digital models has become increasingly interesting in the field of orthodontics. This increase corresponds to a growing availability of affordable and practicable intra-oral and model 3D scanners, more powerful software applications and manufacturing technologies capable of producing the virtually planned treatment or transfer devices for an effective integration into the real-world treatment process.

However, a large number of orthodontic experts interested in digital models might lack detailed insight in how to employ the new technology in the daily workflow of their practice and which prerequisites have to be fulfilled for such an integration to be beneficial.

Therefore, this article aims at answering important questions concerning the software-related requirements and possibilities of digital models.

Virtual Workflow

Independent of the particular task at hand, the functions available in the software can be understood as a sequence of flexibly interchangeable processing and planning steps in between data import (scanning) and data export (manufacturing), see Figure 2.

While the software supports a distributed workflow between the doctor's office, own and other laboratories and further service providers, this is not the focus of this document. Please note that this support includes digitally aided ordering, communication, validation, correction and approval of treatment data as well as data management and the option to administer an arbitrary large number of clients

in parallel between which data can be exchanged and synchronized online and offline. This has led OnyxCeph^{3™} to become intensively used as frontend in the cooperation of offices, clinics, laboratories and health insurance companies.



Figure 2: Concept of virtual planning of orthodontic treatment
in OnyxCeph^{3™}

I. Scanning

A variety of both direct and indirect optical surface scanners and direct and indirect radiation methods with surface extraction can be employed for spatially capturing the dental arch.

At the present time, doctor's offices and laboratories primarily use the first group of methods where photogrammetry, laser scan or phase shift projection technologies help to determine the 3D position of surface points with an accuracy of about 10^{-2} mm which are then combined to a polygonal surface mesh. These methods are well established in fields such as prosthodontics and implantology and represent the current state of the art.

Specialized requirements for orthodontic applications arise because the complete dentition including gum and palate, possibly with complex malocclusions, needs to be captured and the occlusion must be registered in the correct bite relation optionally including information about the mandibular joint.

Nowadays, intraoral scanners for direct capturing on the patient are becoming increasingly important next to the model scanners which are used for plaster and polymer models.



Figure 3:
Structured-light projection scanner
scanBoxi by smartoptics

II. Planning virtually

The applicability of the virtual planning steps in OnyxCeph^{3TM} described here is not restricted to any particular scanner as long as the topology, resolution and size of the scanning datasets lies within a certain range and as long as the jaw relation is captured precisely.

Each scan is assigned to the correct patient and session using standardized and additional custom interfaces to practice management systems. For capturing data explicitly for a patient, a large number of image sources can be connected using extensively configurable interfaces.

OnyxCeph^{3TM} also supports the management of an arbitrarily large number of offices (clients), each with a separate trunk of patients which are backed by independent partitions of the underlying database. These client areas are created and synchronized by the concept of containers, where accepting a container imports all enclosed data into the correct client for that partner. Besides regular patient information, the container can contain 2D and 3D images, presentations, and (order) forms and can be transferred on- or offline.

This functionality is also used for synchronized data exchange between offices and/or laboratory locations, e.g. for sending planning data for bracket positions or aligner steps (on the basis of intraoral or model scans) online to dental laboratories for manufacturing of transfer or treatment trays. Another example is the ability to validate and optionally correct the steps implemented by the laboratory directly in the doctor's office.

- *Import, prepare and align scan data*

Importing scan data is integrated in the Add Image module and basically requires the same steps as recording any other 2D or 3D image data. The files resulting from the upper and lower jaw scans are presented in a preview area and can be moved to the according session panel using drag&drop.

All adjustments to the model orientation are saved as a coordinate transformation and can be undone if necessary.

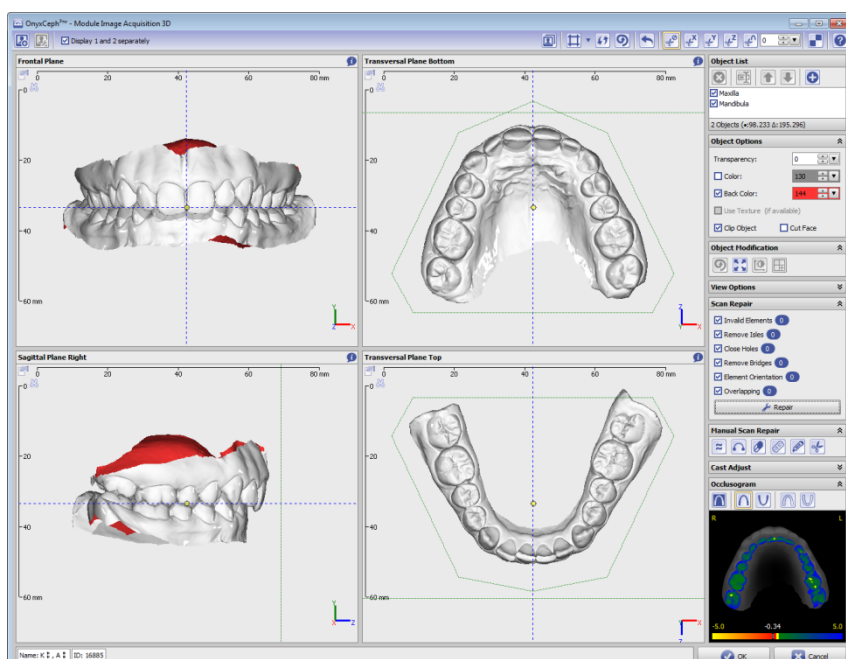


Figure 4: Importing, preparing and aligning scan data

The second part of the import procedure allows adjusting the virtual model to a patient-related reference system with respect to dental symmetry, incisor position and mean occlusion. If an articulated model was scanned, the axis of the articulator can be used if handed over by the scanner. Alternatively, an average axis position is assigned using clinical reference values.

At this point, the surface meshes retrieved from the scanner can be tested for topological errors, repaired, cropped and adjusted in their visualization properties.

- *Preprocessing of models*

Most of the diagnostics and planning options provided cannot be applied directly to the imported and adjusted scan data. Rather, they must first be converted by appropriate preprocessing steps into a working model.

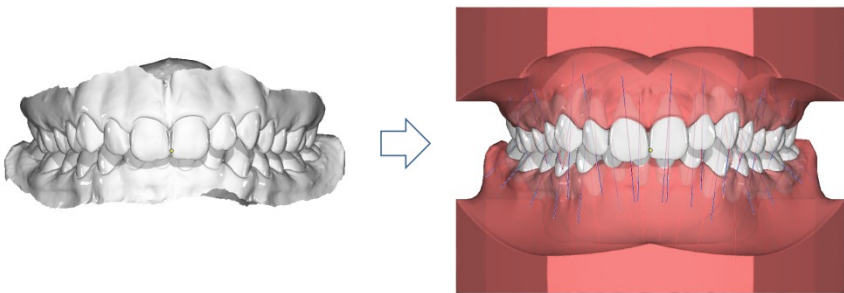


Figure 5: Initial and final situation of model preprocessing

- *Cutting, trimming and adding sockets to models*

The first step is done in the Cast Adjust module. This module allows the trimming of upper and lower jaw scans with the help of cutting lines or cutting planes and the attachment of virtual standard sockets of various shapes and sizes. Alternatively, an individual horseshoe socket can be selected and mounted with a defined base plane distance.

A welcome side effect of this step is the often significant reduction of data set size due to the replacement of areas not required but captured in high resolution by optimized geometry. One option in the context menu of the object list allows color-coding of original and scanned surfaces.

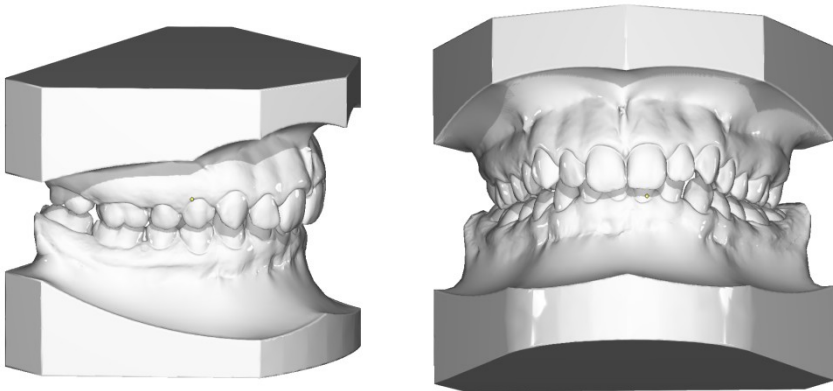


Figure 6: Virtual model after attaching standard base trays
e.g. EU (Hinz, left) | US (ABO, right)

- *Segmenting, separating, completing and landmarking models*

Module Segmentation allows to identify, to separate, to complete and to add landmarks and coordinates to single crowns in a model dataset. At the same time, the gingival area is prepared in such a way that its change during subsequent tooth movements can be realistically simulated.

Correspondingly, module Segmentation provides functions for independent but logically consecutive subtasks:

1. Segmentation of dental crowns
2. Separation of dental crowns
3. Completion of dental crowns
4. Add landmarks/coordinates to dental crowns

Step *segmentation of dental crowns* comprises the automatic recognition of all crown related areas of the surface mesh within a search area predefined per crown. If necessary, the automatically found gingival transition can be adjusted manually.

In step *separation*, the surface areas marked for each crown are created as separate 3D objects. The remaining soft tissue of the jaw surface is closed at the gingival margins, evaluating the surrounding jaw geometry. In addition, the initial objects upper jaw and lower jaw remain preserved in the dataset.

In step *completion of dental crowns*, the separated crown areas are completed by using a template tooth library to form closed single tooth objects. This process may be controlled with regard to the reconstruction of gaps and contacts via various parameter specifications.

Finally, the user can visually inspect the crown reference points and crown coordinates associated with the completed teeth and, if necessary, correct and complete them here or later in the Digitize module. The assigned crown coordinates form the basis for the specification and control of tooth movements in all evaluation and planning functions.

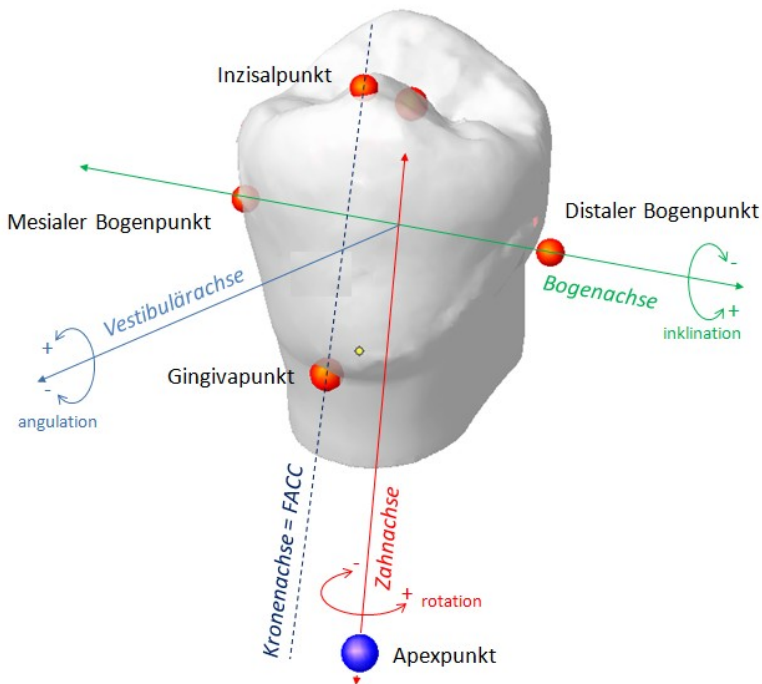


Figure 7: Assigned in module Segmentation and cross-module used crown coordinate system

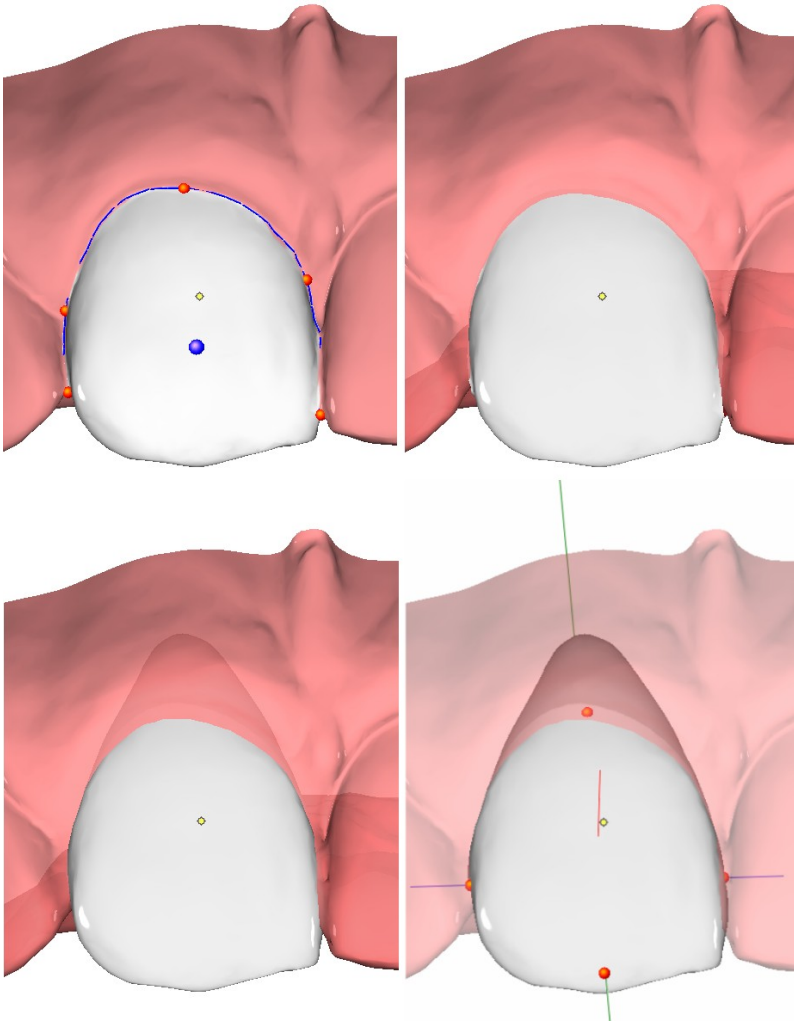


Figure 8: Intermediate results from the module Segmentation:
Segment crowns (top left), separate crowns (top right),
complete crowns (bottom left), check landmarks (bottom right)

- *Measuring the model: Module Digitize*

In the Digitize module, the user can apply preinstalled analyses for metric measurement and diagnostic assessment for the image types deciduous, permanent and mixed dentition. All reference points required for computing these analyses can be marked on the teeth or gingival surfaces or reference planes in the same manner as points are specified in other image findings.

About 50 different analyses are available as preinstalled evaluation methods. These analyses can be complemented by individually composed measurements.

Analyses can be selected individually or in groups, while, according to the concept of evaluation described above, a point placed once is available in any analysis. All results can be further used in print and presentations forms and other functions for evaluation, visualization or processing provided in OnyxCeph^{3TM}.

The Segmentation module does not only compute a completed geometry for each tooth but also executes automatic "Landmarking" (assignment of tooth-related reference points and coordinate axes) which provides most of the reference points needed in subsequent planning steps. These points can be checked and, if necessary, corrected in the Segmentation module. However, single, not directly tooth-related points (e. g. points for localizing the WALA-Ridge in the lower jaw or those for classifying the bite relation) have to be placed by the user before or after segmentation in the module Digitize.

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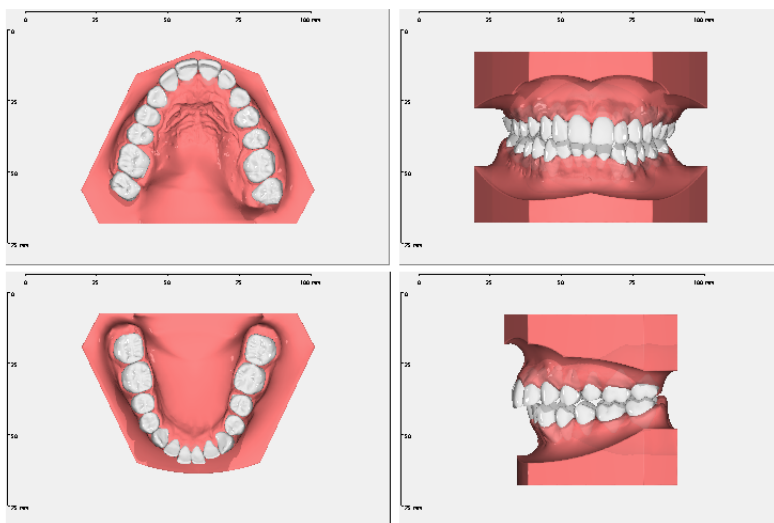


Orthodontic
Imaging
Software

OnyxCeph™

3D-Modellanalyse Bleibendes Gebiss

Demo, Modelle * 17.10.2008



Variable	Description	Value []	Variable	Description	Value []
A rMax	Available Space Right Maxilla	56,7mm	R antMax (3-3)	Sum of Maxillary Anterior Teeth	47,1mm
R rMax	Required Space Right Maxilla	56,5mm	R antMand (3-3)	Sum of Mandibular Anterior Teeth	36,4mm
D rMax	Discrepancy right Maxilla	+0,2mm	Ant. Ratio (3-3)	Ratio of the Anterior Teeth	77,2%
			R ovMax (6-6)	Sum of Maxillary Teeth	97,8mm
A lMax	Available Space Left Maxilla	59,5mm	R ovMand (6-6)	Sum of Mandibular Teeth	87,2mm
R lMax	Required Space Left Maxilla	57,9mm	Ov. Ratio (6-6)	Tooth Widths Ratio	89,1%
D lMax	Discrepancy left Maxilla	+1,6mm			
			Ratio A rMand / rMax	Ratio of the Right Arch Lengths	96,9%
A lMand	Available Space Left Mandible	52,6mm	Ratio A lMand / lMax	Ratio of the Left Arch Lengths	88,5%
R lMand	Required Space Left Mandible	54,7mm	Ratio A rMand / Max	Ratio of the Arch Lengths	92,6%
D lMand	Discrepancy left Mandible	-2,1mm			
			Symmetry	None (Standard)	
A rMand	Available Space Right Mandible	54,9mm	Incl. Method	MBT	
R rMand	Required Space Right Mandible	54,0mm	Modify Max. Ant. Teeth		
D rMand	Discrepancy right Mandible	+1,0mm	Modify Mand. Ant. Teeth		

Figure 9: Print out model analysis 3D (example)

When opened with a segmented model, the user can, in addition to traditional model analyses, also carry out quantitative assessments of misalignment and treatment need (e. g. PAR- and IOTN-Index).

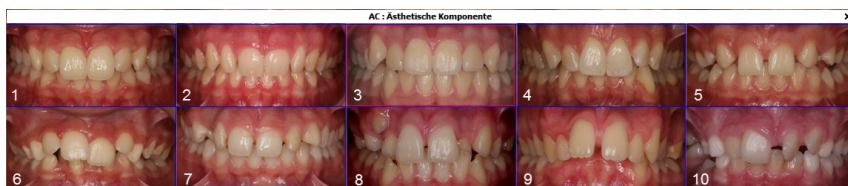
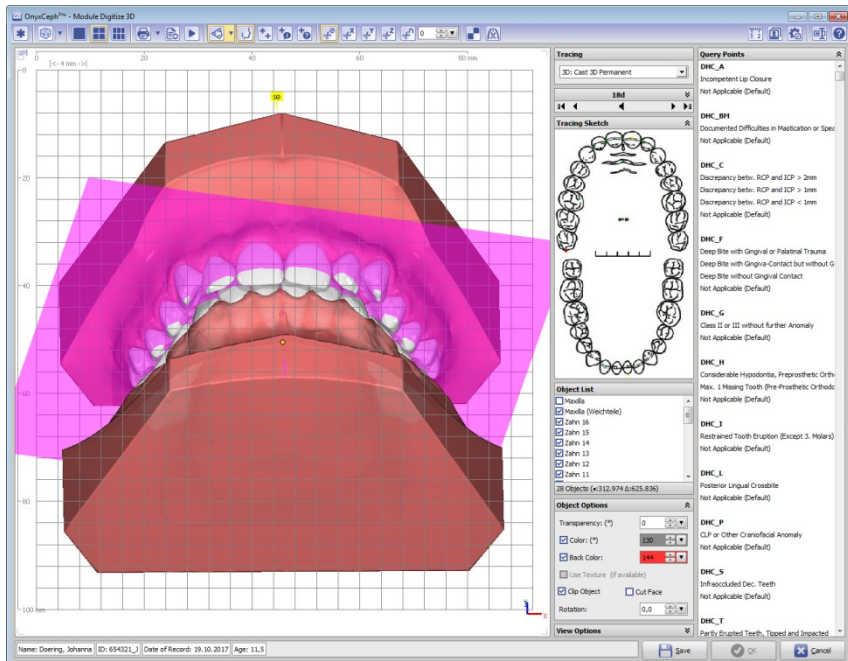


Figure 10: IOTN- Assessment in the Digitize module

The Onyx-Model Analysis™ 3D represents another evaluation option and can be applied for mixed and permanent dentition. It calculates the space discrepancy for each quadrant on the basis of a mathematical dental arch model pre-aligned to the current situation acc. to specific criteria and on the evaluation of the effective crown contacts.

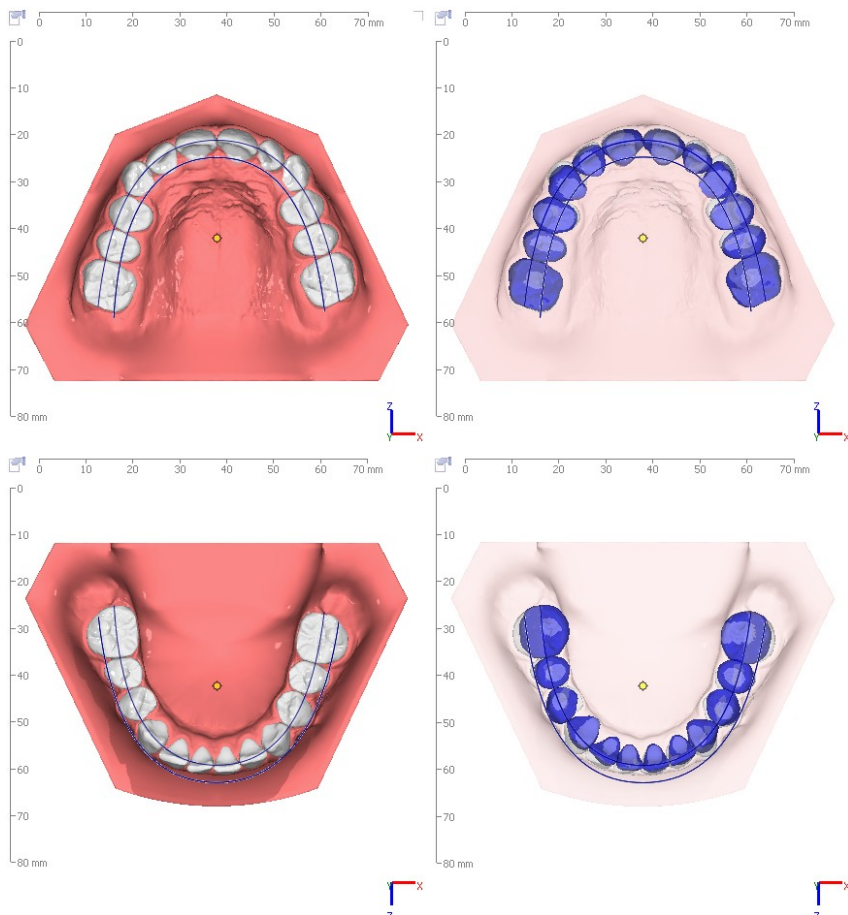


Figure 11: Space discrepancy calculation by the Onyx-Model 3D analysis

- *Orthodontic planning modules*

On the basis of a finding exported from the module Segmentation, which was optionally verified and extended by more landmarks in the Digitize module, various orthodontic treatment options can be planned virtually. Depending on the program version, different modules are available whose functions can be applied separately or in combination with each other to the images of the specific patient case. In the following this will be illustrated by means of some examples:

- Bracket positioning on malocclusion:
Module FA_Bonding 3D
- Defining the virtual treatment objective:
Module V.T.O.3D
- Bracket positioning on treatment goal:
Module Wire_Bonding
- Transferring planned bracket positions:
Modules Kylix, Bonding Trays, Bonding Jigs, Bracket Adapt
- Removing Brackets virtually:
Module Bracket Erase
- Virtual aligner treatment planning:
Module Aligner 3D
- Virtual retainer planning:
Module Retainer 3D
- Surgical treatment planning:
Modules Sim 3D, Waefel Creation 3D

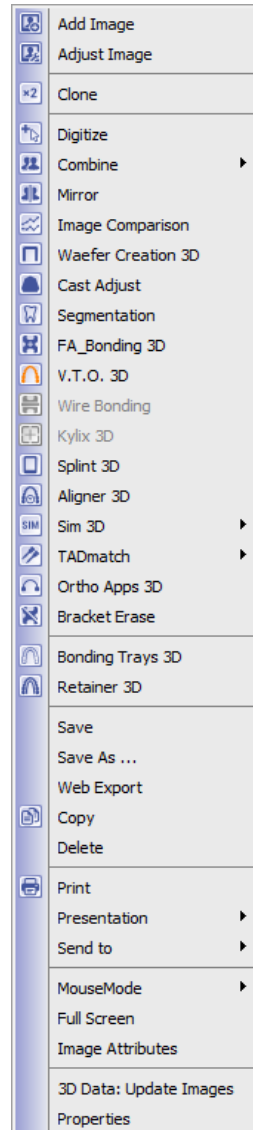


Figure 12: 3D thumbnail context menu

▪ *Bracket positioning on malocclusion: Module FA_Bonding*

In the FA_Bonding module, brackets can be assigned to the tooth crowns individually or in pre-configurable groups from the local and online updatable onyx bracket library.

Placement relative to the crown is accomplished according to the selected empirical rule using the crown coordinate system assigned in the Segmentation module and the respective bracket parameters. In addition, the user can also store his own rule sets of incisal bonding heights. Pre-installed rules are:

- OnyxCeph³™
- MBT
- Muchitsch
- Creekmore
- Andrews
- Alexander

Option LineUp allows previewing and modifying the bracket-crown relation slot-aligned on a pre-selected virtual wire.

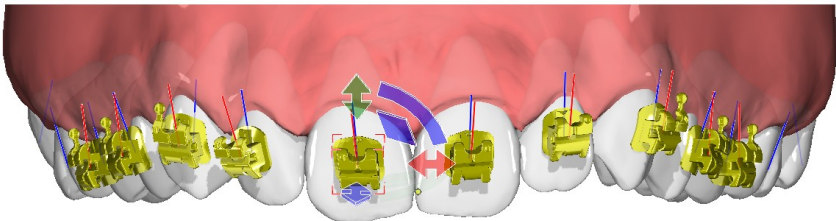


Figure 13: Bracket placement by rule set OnyxCeph³ and manual correction via in-view navigator

- *Defining the virtual treatment objective: Module V.T.O.3D*

For planning methods requiring a target setup of the teeth, the module V.T.O. 3D provides a rich functionality for automatic and interactive positional corrections of the teeth on a segmented digital model.

With the focus on professionally recognized ortho- and prosthodontic criteria for occlusion and mandibular joint, different steps can be applied in a logical order of a proposed workflow. At the same time, a multitude of interaction tools allows the user to individualize the planning in order to meet the requirements of even highly complex cases.

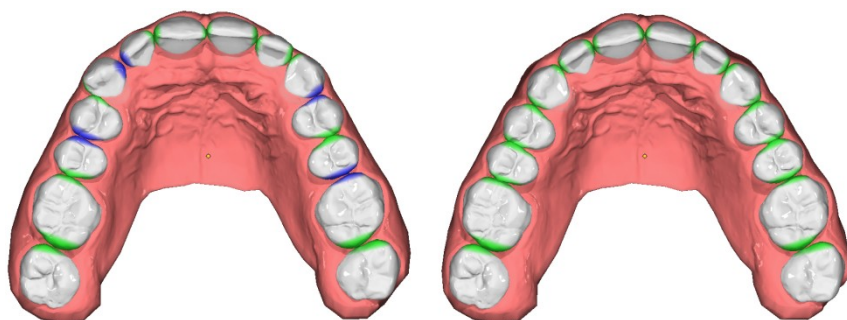


Figure 14: Definition of a treatment objective in module V.T.O. 3D

The basic idea of planning a treatment objective is the alignment of the single segmented teeth along their mesial-distal orientation on a Monson-curve ("Core Line") which is defined by the mesial center of the central incisors and the most distal points of the posterior teeth on the surface of a Monson-sphere with a case specific radius.

In order to adjust the teeth to an optimal constellation in the treatment objective, each tooth can be offset to this curve individually in position and orientation. Extracting teeth and enamel reduction can be incorporated as well as fixed teeth (e. g. implants).

When starting the module, the parametrically described core line curve is best fitted to the tooth arch given in the malocclusion while preserving the mid- and most distal points. Simultaneously, the crown inclinations are set to the values the user selected from the inclination table. These parameters unambiguously define the initial position and orientation of each virtual tooth.

Procedural steps that build upon each other are available in the form of a wizard. They can subsequently applied separately or en-bloc and, if necessary, customized by parameters. Examples are setting up a vertical arch symmetry, adjusting dental and skeletal centers and harmonizing angulations and crown height relative to the arch before or after the arch is fitted to the skeletal mandibular shape using a guide value for the transversal FA-WALA-distances.

For compensating the space discrepancy in a single jaw by applying crown offsets, IPR, extraction or by adjusting the radial bow curvature (Curve of Spee), various numerical and visual controls and interactive algorithms are available.

The maxillary curve is adjusted to the mandibular curve by setting overjet, overbite and the centric relation contact position of the posterior teeth as specified individually by the user followed by a correction of the autorotation. Afterwards, the remaining space discrepancy in the upper jaw can be resolved with regard to the occlusion, where a mandibular displacement is also available as option.

In any planning step, the user can choose to simulate the gingival deformation resulting from the tooth displacements with different models.

The transformations necessary for each tooth movement are recorded so that the feasibility of the planning can be assessed and logged at any time using thresholds and the selected analysis which is updated in real time.

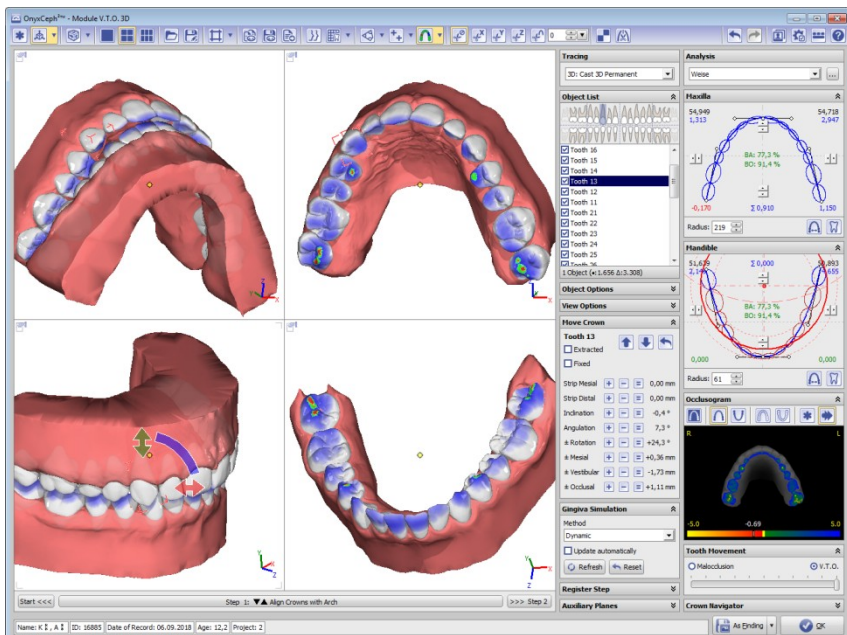


Figure 15: V.T.O. 3D module window (virtual setup)

Note:

The V.T.O. 3D module allows setting up a virtual treatment objective in respect to a geometrically optimized teeth arrangement under predefined constraints. While any virtual adjustment of single teeth is carried out on the basis of empirical rules and is under permanent control of user-defined thresholds for all movements, the physical movement in the actual rearrangement is influenced by forces of skeletal anchorage, gingiva, neighboring teeth and treatment equipment, which cannot be measured or computed explicitly. Assessing whether a simulated tooth movement is feasible and can be achieved with a given treatment device is in all cases the duty of the professionally qualified user.

In the same manner, the gingival deformation resulting from the tooth arrangement is based on empirically adjusted simulation models.

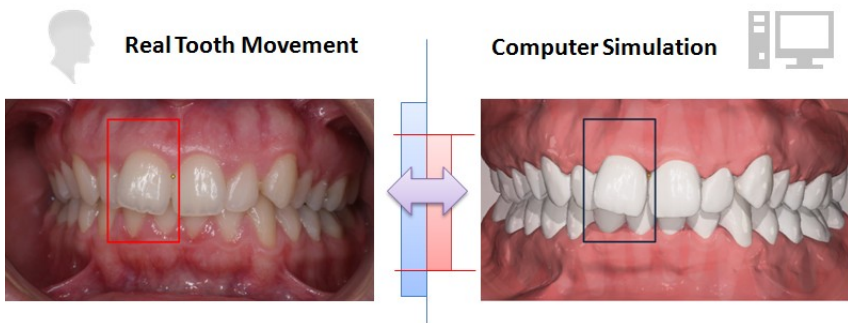


Figure 16: Real (left) and simulated tooth movement (right)

In the current implementation, the V.T.O. 3D module allows a virtual representation of all steps during an orthodontic treatment aiming at a purposeful correction of misaligned teeth.

The variety and recombination of those single steps allows a high flexibility for various treatment concepts and desired treatment objectives. However, this diversity of options indeed places considerable demands on the user with regard to expedient use of the module

For this reason, we especially point out that the planning module V.T.O.3D, just as other modules, is subject to ongoing development. The primary objective is to simplify the use and reduce the time spent on virtual planning by further automation of substeps that require no or rare user input.

Similar to all other 2D and 3D planning modules, intermediate steps as well as final results of a setup planning can be saved as project, sent online for validation and approval, or saved as separate finding in the database for further utilization in other modules. An animation can be created for the findings exported from the module, so that they can be reviewed separately in full screen mode.

- *Bracket positioning on treatment goal: Module Wire_Bonding*

In the Wire_Bonding module, the user is allowed to specify the course of the arch wire in relation to the target tooth arch. For this purpose, the two wire planes are automatically prepositioned using the FA-points of both jaws. The user can correct this positioning right at the start or at any other time, whereupon all data depending on these planes is updated immediately.

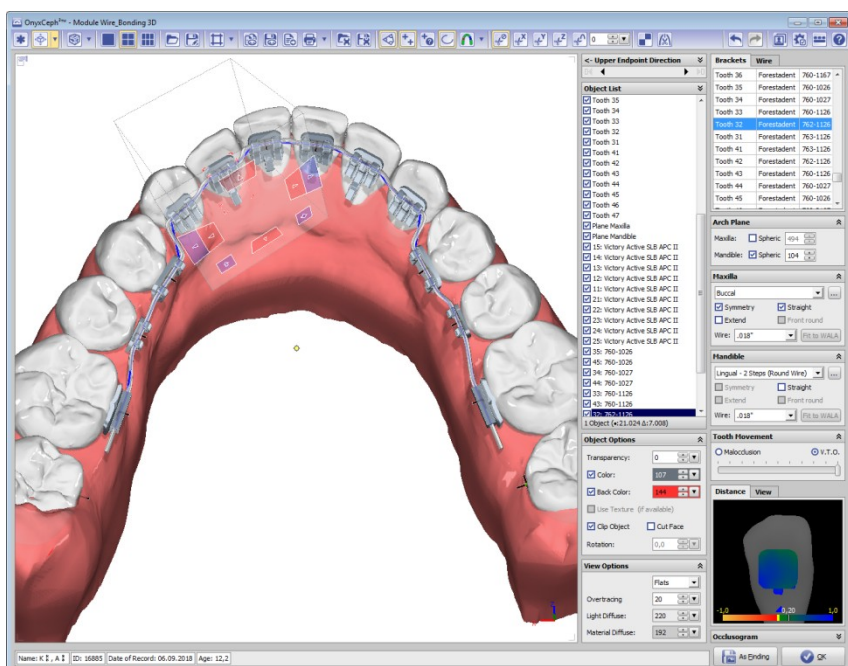


Figure 17: Wire_Bonding module window

The buccal or lingual arches with different profiles, dimensions and shapes are selected using the respective pull down and selection elements and can be adjusted to the target tooth arch by translation or virtual bending.

In analogy to the FA_Bonding module, the brackets designated for a treatment can be assigned to the respective crowns separately or in groups. With this information, the course and profile of the wire as well as the center of each crown define the initial position of each slot and bracket.

Following the concept described so far, individualization of the treatment device maintaining the mostly straight prefabricated target wire shape has to be put into practice by an individual bonding base for each bracket on the respective crown. As an alternative, the brackets can be moved in the wire plane towards the crown as far as possible while keeping the correct slot orientation. This leads to an optimized thickness of the bonding base from a mechanical point of view and transfers the individualization mainly into the wire itself.

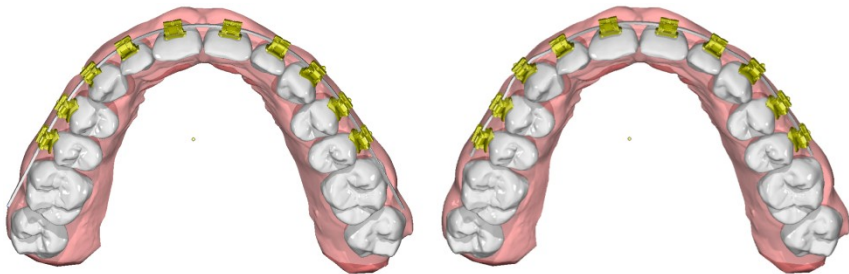


Figure 18: Alternative individualization: left: straight target wire and individual bracket base distance, right: individual target wire and minimized bracket base distance

Depending on the wire profile, in both cases the bracket navigator can be used for further modifications to the bracket position in the degrees of freedom remaining in adherence to the straight wire concept in consideration of collisions of neighboring teeth in the malocclusion setting.

At any planning stage, the transformation of each single tooth computed in the virtual setup can be applied in reverse to the crowns and bracket groups to visualize the planned straight wire position of the brackets in the initial treatment stage.

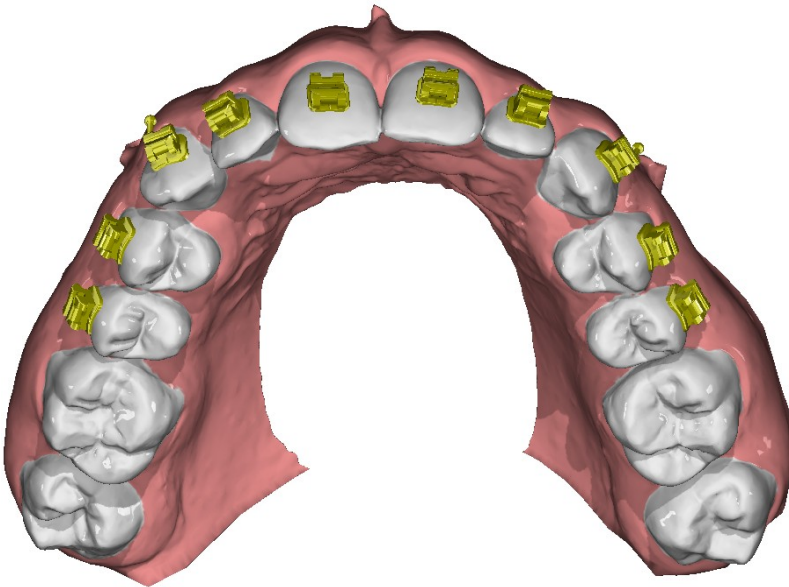


Figure 19: Bracket positions planned on the treatment objective and transformed to the initial stage

The treatment planning from the module Wire_Bonding can again be saved as project and accessed using the project management in the card file of the patient.

In addition, the individualized wire geometry in intermediate or the final stage can be printed in true scale or exported as a coordinate file in CSV format for driving bending machinery.

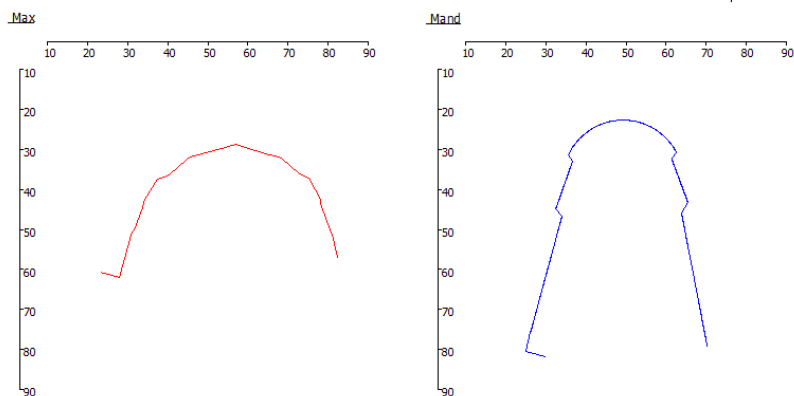


Figure 20: Scaled print results of individualized wires

The planning of bracket positioning relative to the malocclusion model is stored as separate finding in the database so that it can be used for manufacturing transfer trays.

For the sake of completeness, it should be mentioned that the module Wire_Bonding already allows planning and simulating a wire geometry of higher dimension but in practical use it is largely impeded by limitations of manufacturing of spatially completely individualized wire shapes.

- *Transferring planned bracket positions*

Once the desired positions of the virtual brackets on the virtual malocclusion model have been determined using the FA_Bonding or V.T.O.3D / Wire_Bonding planning modules, the task remains to transfer this placement to the patient as simple, fast and accurate as possible. For such purpose, several indirect bonding techniques can be applied in OnyxCeph^{3™} with separate modules:

- Module Kylix
- Module Bonding Trays
- Module Bonding Jigs
- Module Bracket Adapt

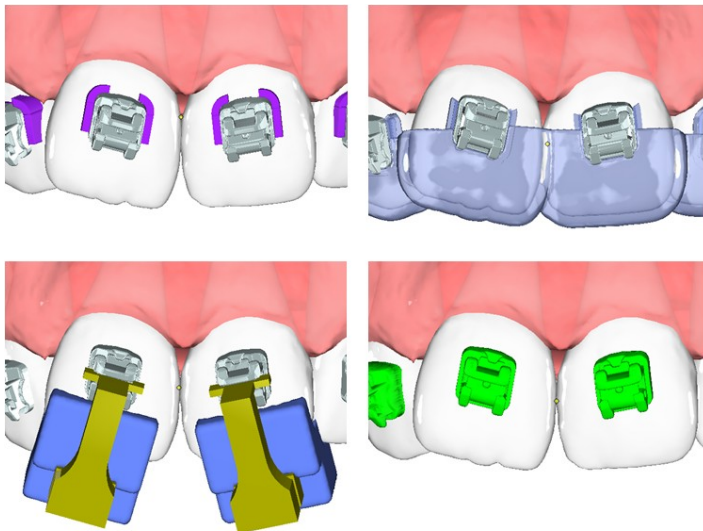


Figure 21: Methods for transferring planned bracket positions

With the Kylix 3D module, the bracket position on the printed dental arch can be pre-defined by means of flexible markers around and underneath of the bracket base for the manufacturing of transfer trays by means of thermoforming technology.

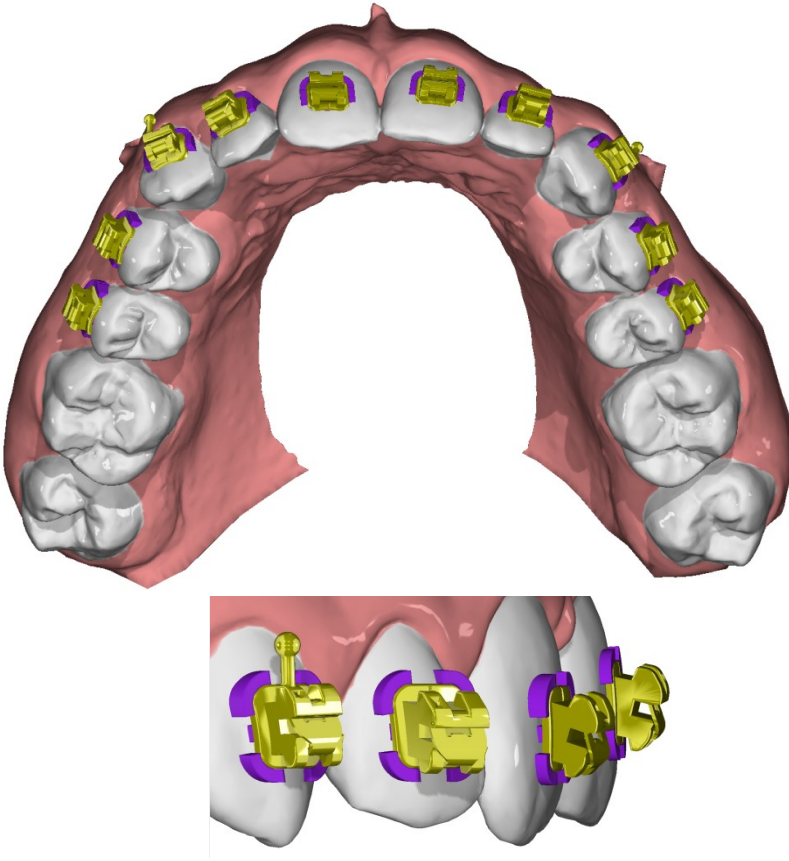


Figure 22: Definition of bracket position and alignment by means of base markers

In the Bonding Trays module, different types of bracket transfer trays can be designed over virtual arches with brackets by the help of various parameters in order to subsequently be manufactured by milling or 3D printing.

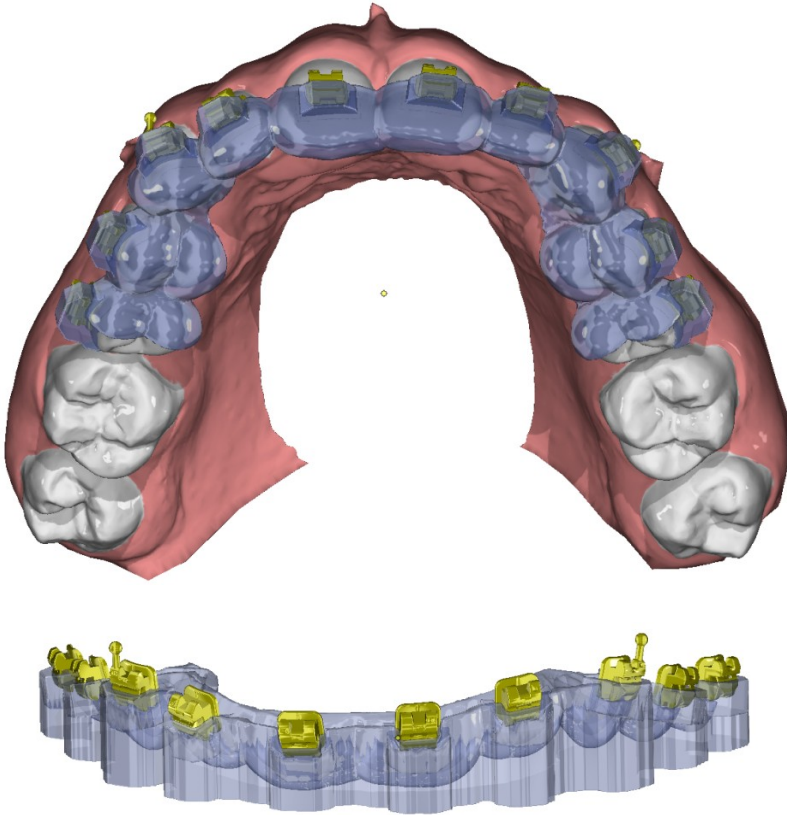


Figure 23: Bracket transfer tray designed over virtual model and brackets

In Module Bonding Jigs 3D, the position and alignment of the brackets are transferred by jigs with movable bracket adapters that can be attached to the crown or which are connected to one another and are adjustable by design parameters.

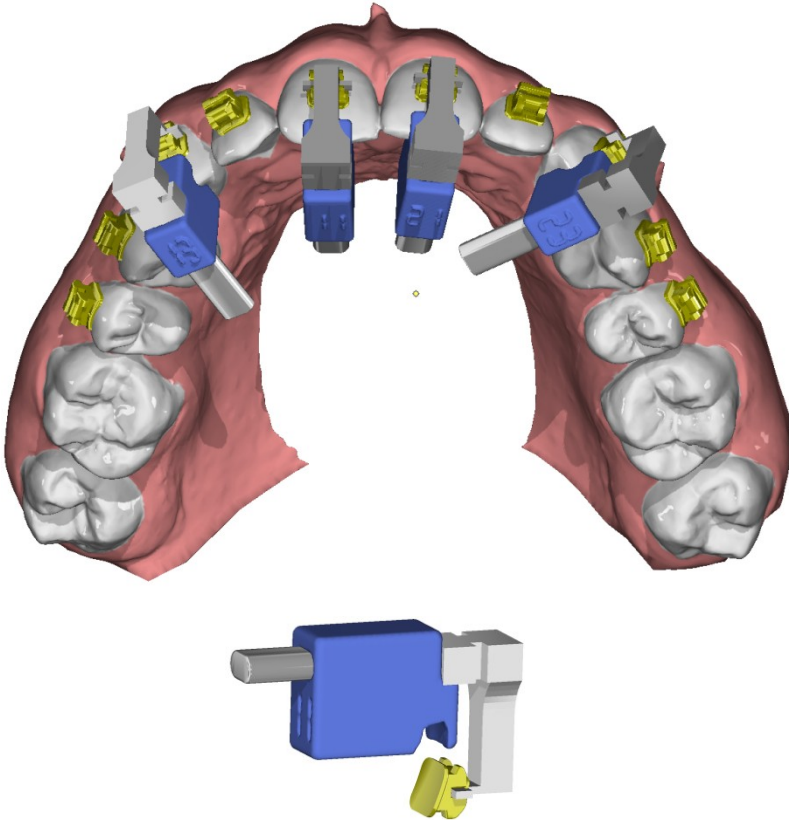


Figure 24: Transfer of bracket positions by means of single or interconnected Jigs with sliding bracket adapter

Module Bracket Adapt 3D allows a customization of the bracket base. With this technique, e.g. individual ceramic brackets are planned and fabricated by means of selective light-curing of a photosensitive plastic mixture in 3D printing.

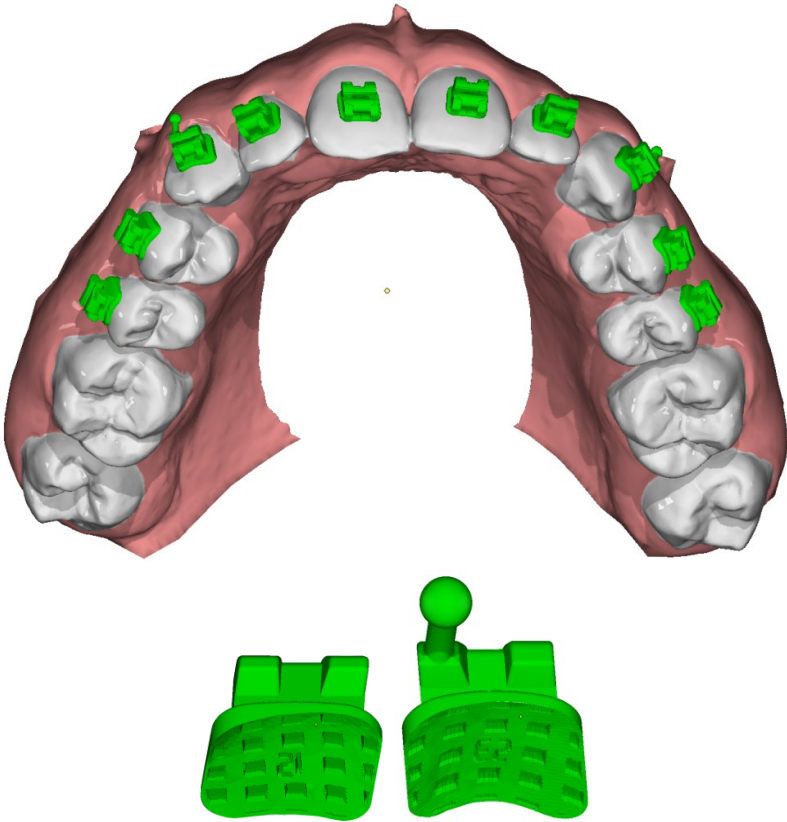


Figure 25: Planning and tailoring individualized brackets

- *Removing Brackets virtually: Module Bracket Erase*

For final tooth corrections with aligner trays at the end of a multi-band treatment, it may be helpful to virtually remove the brackets contained in a scan. This can be done with the Bracket Erase module by replacing the automatically or manually marked bracket area with the geometry of the segmented crown from the initial scan.

Based on such an adjusted result, a series with a few finishing trays (FinAligner™) can subsequently be calculated and exported for production with little planning effort in the Aligner 3D module.

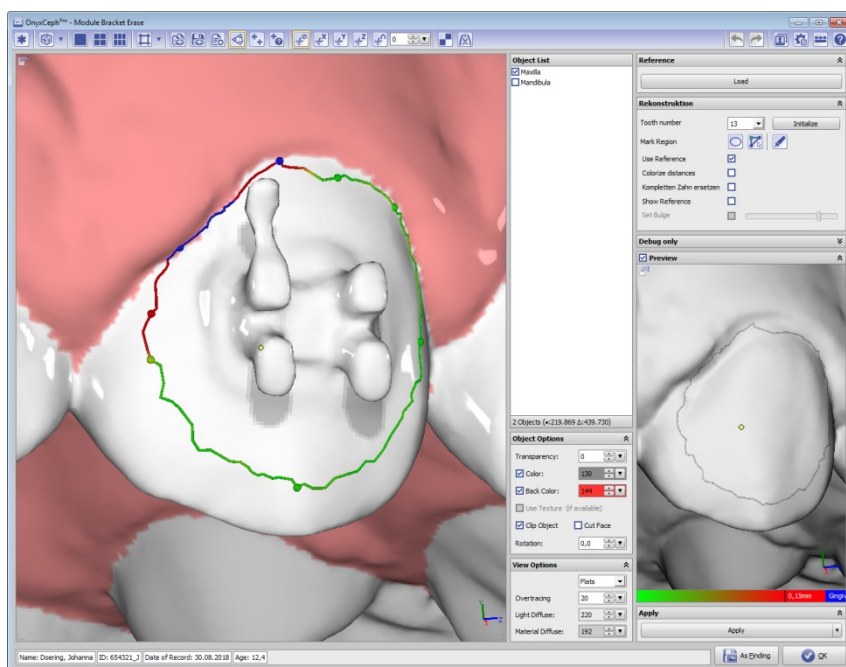


Figure 26: Bracket Erase module window

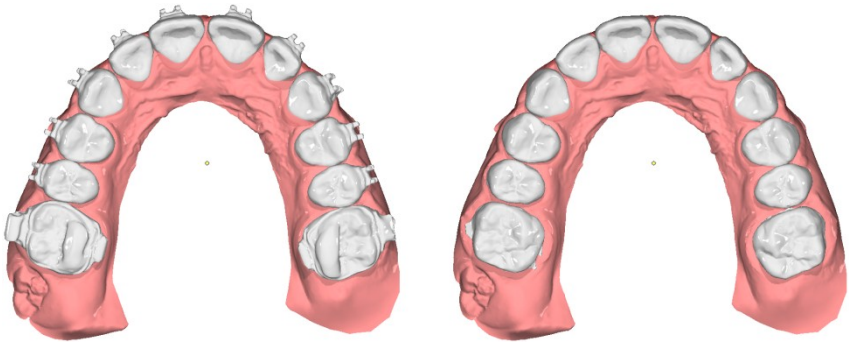


Figure 27: Finishing scan before and after virtual removal of brackets and bands

If the finishing is performed instead of Aligners using a series of 3D target wires, can be dispensed with the virtual removal of brackets and bands. The target planning, including the subdivision into the required number of steps, can then be performed after realignment of the initial scan with brackets.

However, the manufacturing capabilities of 3D target wires are currently limited to a few technologies, so practical use of the methodology is currently only in research projects.



Bild 28: 3D wire sequence

- *Virtual aligner treatment planning: Module Aligner 3D*

The Aligner 3D module can be used for planning aligner treatments. It is launched with a segmented initial or goal finding and allows the subdivision of the planned tooth movements in a series of individual steps. Tooth movements can be controlled separately or grouped and monitored and adjusted using limits.

If attachments are to be applied, they can be selected, positioned and, if desired, replaced or removed by help of the internal attachment library. Also the design and use of own attachments is possible.

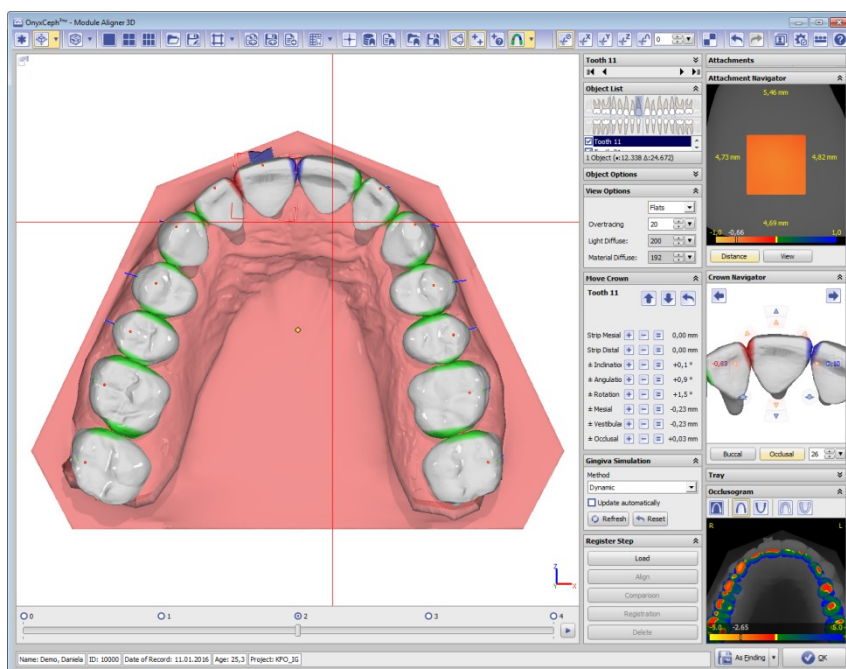


Figure 29: Aligner 3D module window

A helpful feature of the module Aligner 3D is the so-called progress-refinement option, in which an intermediate scan of the real treatment progress can be loaded into the initial aligner planning in order to control the tooth movement achieved and to update the virtual planning while retaining the initial treatment objective. For that purpose, the scan is loaded into the planning and different methods of registering it to the existing model are offered so that the remaining steps can be corrected using the actual tooth movement.

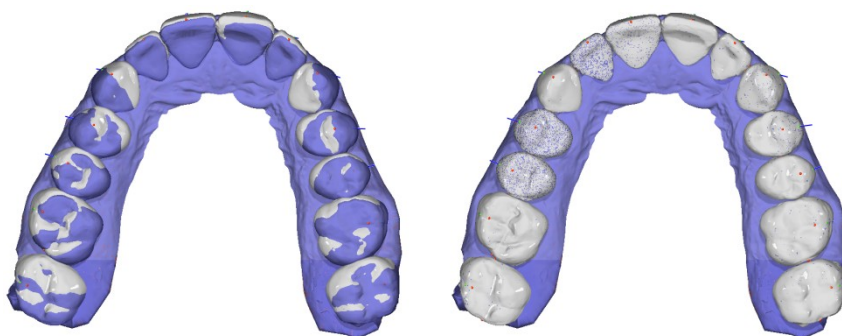


Figure 30: Matching the planning (in white) to the actually achieved treatment progress (in blue) using progress-refinement

The entire planning can be saved as project and restored. Step models with the option of additional trimming, blocking, labeling and re-meshing can be exported from the project without generating and saving a separate finding for each step.

- *Virtual retainer planning: Module Retainer 3D*

Also planning and manufacturing of retainers is another example how orthodontic planning workflows can be aided and optimized by using modern 3D-based methods. Module Retainer 3D provides intuitive design tools for creating such appliances, which can be exported in a suitable data format for different manufacturing approaches.

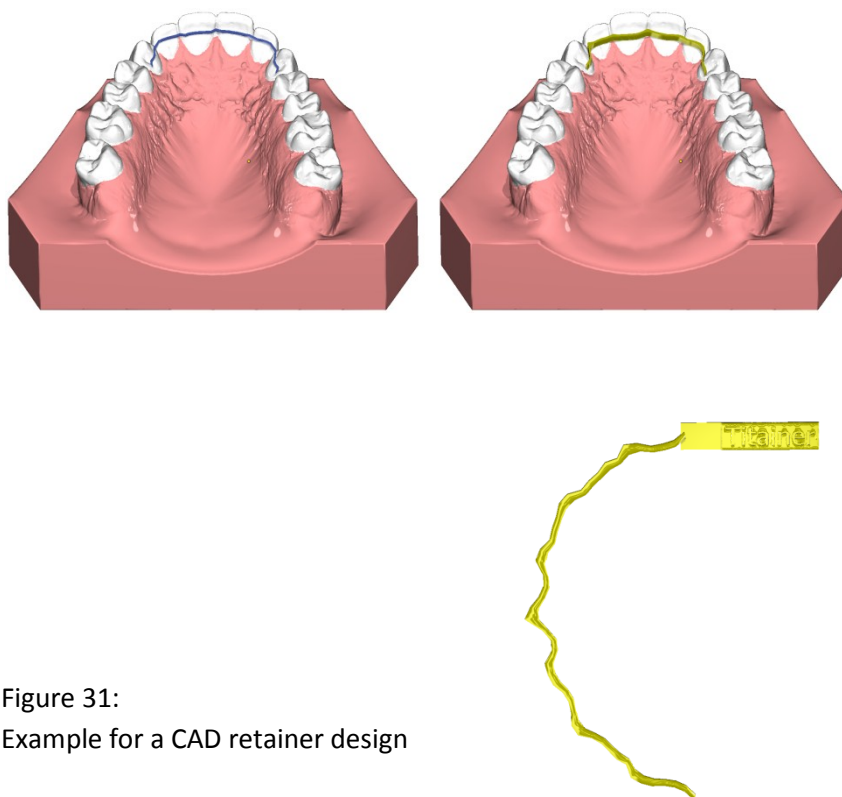


Figure 31:
Example for a CAD retainer design

- *Placement of mini implants: Module TADmatch™*

The TADmatch™ module allows virtual placement of the mini-implants available in the internal screw library using a fusion of intraoral or model scan and lateral ceph xray or CT/CBCT volume data. As a result, an assembly model or a position model, usable for the production of the desired appliance can be created and exported in 3D data format.

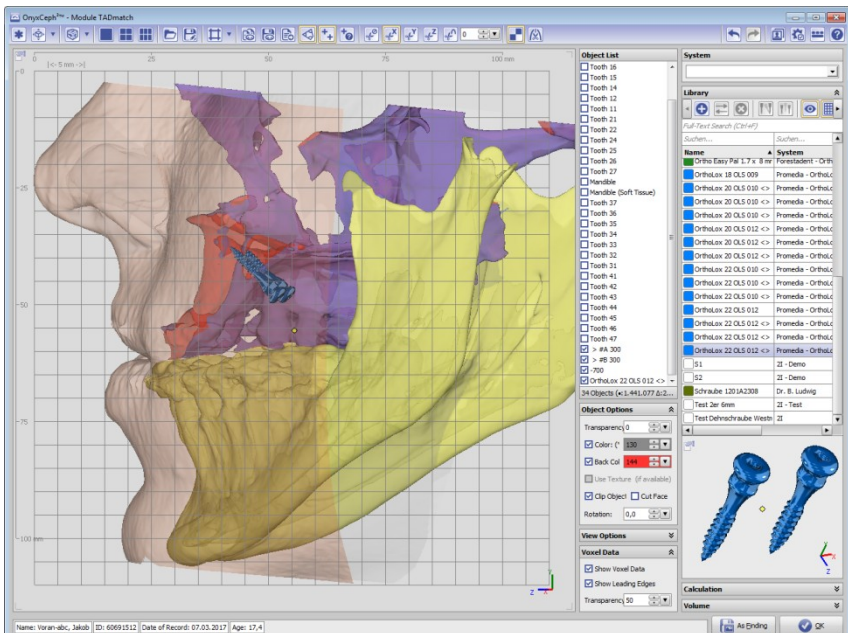


Figure 32: TADmatch™ module window

- *Surgical treatment planning: Module Sim 3D*

Tasks in connection with the preparation and execution of combined orthodontic - oral-maxillofacial treatment can be performed in the module Treatment Simulation 3D. After registration of the individual data provided by different image sources, skeletal segments can be defined and repositioned. A variety of planning tools are available for this purpose. The change in the visual appearance between the initial and final situation can also be simulated.

Intermediate situations and target planning can be exported as occlusal jaw relations for the splint construction.

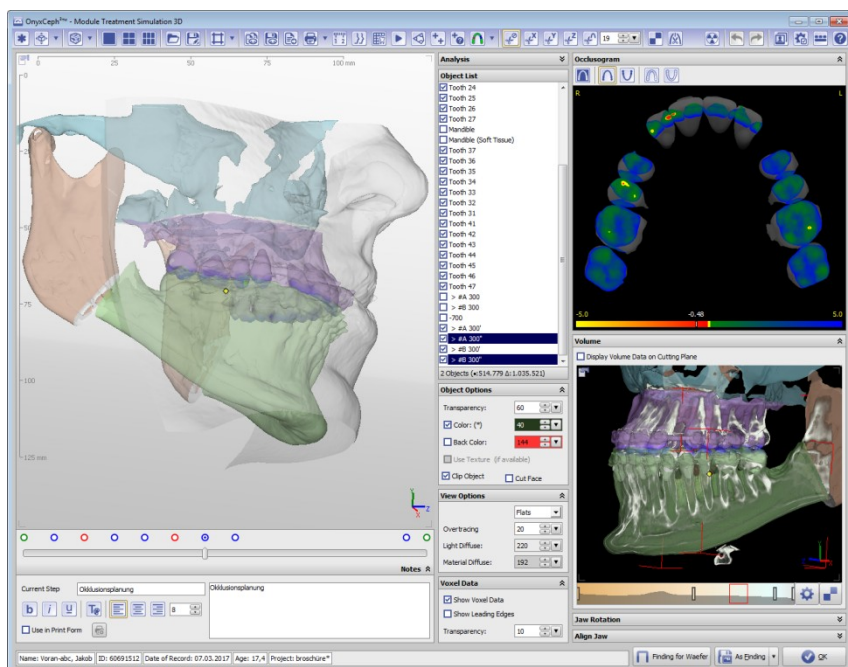


Figure 33: Sim 3D module window

- *Designing surgical splints: Module Waefer Creation 3D*

The creation of splint designs for the mutual fixation of upper and lower jaw segments during maxillofacial surgery can be done with the help of the module Waefer Creation 3D. It enables the user to create case-specific constructions with the help of intuitive design tools and to provide them with desired features (holes, labels, registration markers).

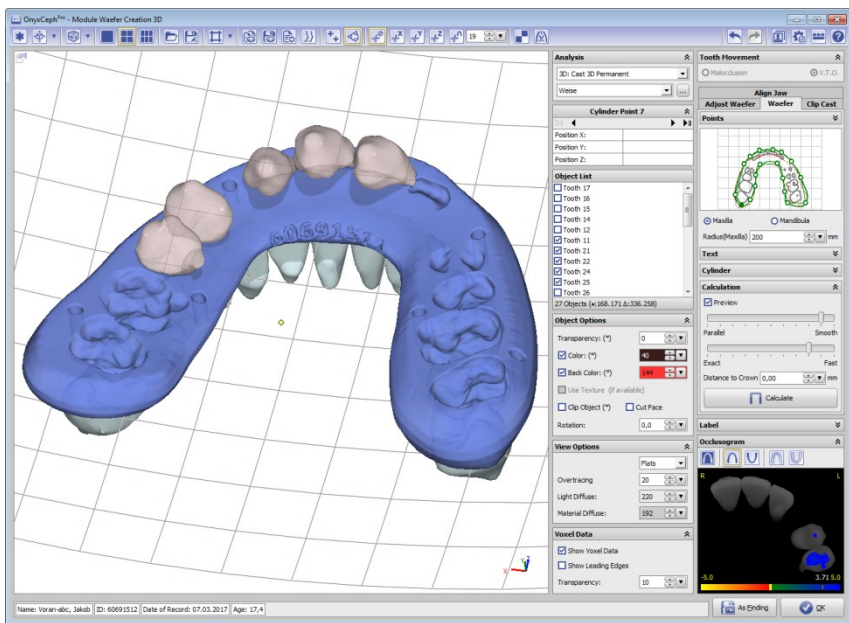


Figure 34: Waefer Creation 3D module window

The adjustment of the jaw segments to be fixed may be e.g. be done in advance in the planning of orthodontic treatment in the module Sim 3D.

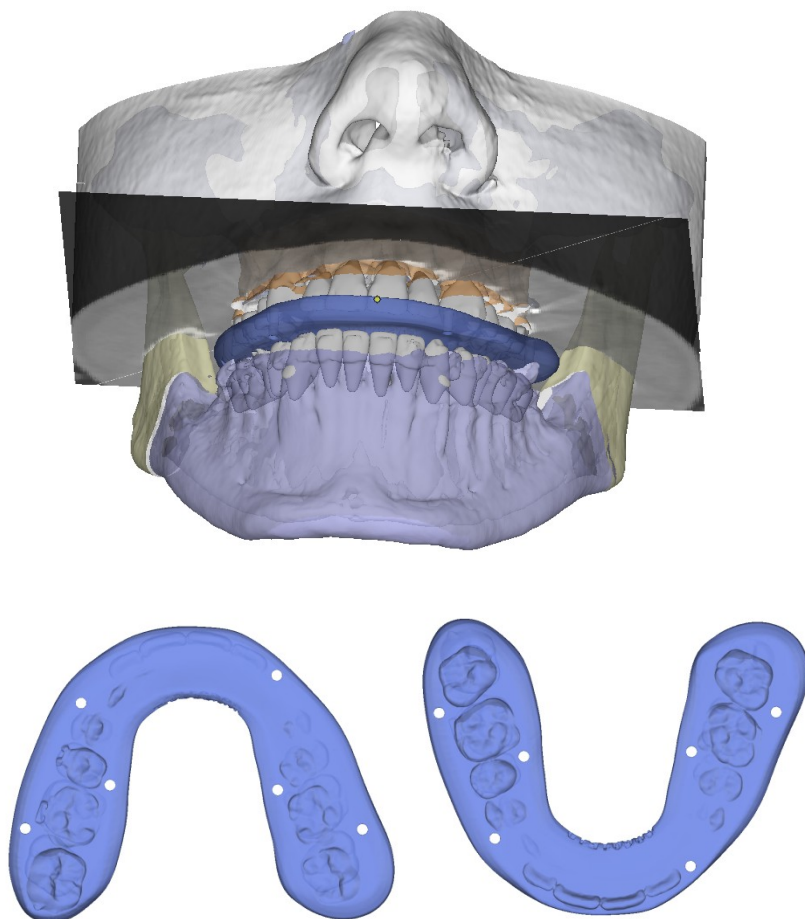


Figure 35: Virtual design of surgical splints

III. Manufacturing

This article is based on the concept that the orthodontic imaging software OnyxCeph^{3™} also serves as connector between the imaging sources on the one and the appropriate manufacturing techniques on the other side in the portion of virtual planning covered by the software.

For this setting, the user is provided with a number of planning options aiming at optimizing treatment planning steps in orthodontics. Due to the highly varying quality of scan data analysis and revision of this data is often required. The module Image Adjust offers suitable tools for this task.

Similar to importing images, exporting of virtual planning results for manufacturing processes with the respective technologies often exhibits high data quality requirements. These processes are often generative manufacturing technologies, but also traditional techniques such as milling, cutting, eroding or bending are common.

Which manufacturing method is most suitable for the specific device, has to be analyzed and decided for by the user for each individual case in consideration of recent advances in technology and materials.

Program version OnyxCeph^{3™} 3D Lab allows 3D data export in various formats (STL, OBJ, PLY, OFF, DXF, ZPR). Similar to data preparation on image import, particular post-processing options can be applied to exported records, e. g. combining of multiple objects, such as single teeth or brackets, into a record with closed ("watertight") surface in order to prevent manufacturing problems at an early stage.

In addition to saving 3D data as files in the export, sending this data including placing of orders to suitable 3D print service providers is possible.

Other data, such as virtually constructed wire arches and retainers can be exported as 1:1 print template for the purpose of manual bending as CSV file with all needed coordinates for a bending machine or robot or also as 3D geometry.



Figure 36: 3D DLP printer Asiga MAX
for use in orthodontic practice and laboratory

Conclusion and Prospect

The aim of this document is to describe the 3d planning functions available at time of printing in the dental software OnyxCeph^{3™} by Image Instruments in order to give interested users an idea of requirements, effort and benefit of working with 3D image data in general and with digital models in particular. Other tools for different treatment methods that are under development or already available are deliberately excluded.

To various extents and based on different integration concepts several basic functions of the software OnyxCeph^{3™} are also available in applications of partners and cooperating companies.

In addition, we provide specially configured program versions which they deploy and distribute within the scope of assuring their range of services.

At this point, it should be emphasized that we, being non-physicians who develop a software application for orthodontists in general and implement issues of virtual treatment planning in particular, depend on expert collaboration with professionals from private practices, laboratories, universities and also from industry and highly appreciate appropriate offers.

From our point of view, the great interest shown in our concepts underlines that there is still a great need for alternative and, above all, practicable solutions, irrespective of many offers already available on the market and that the potential for treatment improvement by means of suitable software applications is far from being exploited.

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