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It is a new year… and it is time for change. As we contemplate what transpired in 2018, we must also think about what will happen in 2019. In many ways the dental industry is at a crossroads of sorts, the investment in analogue solutions has been a mainstay of our educational initiatives and daily clinical practices for more than a millennium. We are now closing in on all-digital solutions for most procedures in dentistry, including crown-and-bridge, orthodontics, porcelain laminate veneers, dentures, surgical placement of dental implants, and implant restorations. Of course, moving from analogue to digital requires a behavioural change. Can we exist in an all-digital world? Is this the future of dentistry? Thus, the crossroads of change.

Besides a behaviour change in order to adopt a digital workflow, we must first invest in new equipment and learn the new digital language that is necessary to move pixels and voxels around on our LCD computer monitors to design new smiles, diagnose pathology, or to place implants in the correct positions to support a new occlusion. The move from analogue is not easy because of the monetary investment and the time necessary to learn new ways to communicate our treatment plans and turn them into reality. Dentists are truly artists of the oral cavity; however, as I have stated many times, we are really the “architects and the engineers” of the oral cavity—and we now have some very powerful digital tools to create the blueprints necessary to achieve success. Clinicians used to using their well-trained hands to sculpt a beautiful functional and aesthetic result intraorally, are now using their hands to move a mouse around a screen to create a virtual restoration with the same outcome. It is a behavioural change for sure, but one that brings wonder and excitement to those who embrace the potential of the digital world.

Fortunately, many dental schools have made the change, and are now investing in the proper equipment (with thanks to the dedicated manufacturers who offer their assistance) to educate and train the next generation of clinicians to be proficient in the digital workflow that exists today, and that will continue to evolve for years to come. Therefore, change was necessary to the standard “analogue” dental curriculum to insure future progress. We are fortunate that Dental Tribune International is also a partner in this digital evolution—not only offering physical publications, but a strong online presence to help spread the world to our global community. Let’s see what change is in store for 2019.

Dr Scott D. Ganz
Editor-in-Chief
editorial
Change
Dr Scott D. Ganz

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Optical impression and provisional prosthesis: Proposal for a new approach

Drs Olivier Landwerlin & Michel Fages, France

Introduction

The widespread use of intraoral optical impressions and constant improvements in dental computer-aided design (CAD) software today allow the practitioner to manage various kinds of clinical situations, from the simplest to the most complicated, by using different types of dedicated equipment (camera software, processors and, more recently, 3D printers) as part of a completely digital workflow. Arch scanning methods using intraoral scanners yield impressions that are comparable to those obtained with traditional equipment in terms of clinical precision because they eliminate the variations caused by the user, reduce the readjustment processing time and costs, and improve patient satisfaction and comfort.

It is customary to distinguish direct computer-aided design/computer-aided manufacturing (CAD/CAM), in which all the stages (optical impression, CAD, CAM) are undertaken in the practice, from the semi-direct method, in which a digital impression is sent via the Internet to the dental technician for fabrication. When crowns and bridges are produced using semi-direct CAD/CAM, this usually includes the use of a temporary prosthesis. The temporary bridge is retained while the definitive prosthesis is fabricated in the laboratory. This helps in terms of maintaining aesthetic and functional factors, and in the event of adaptations to vital teeth, it protects pulp vitality and reduces inter-session sensitivity. The therapeutic goals of temporary CAD/CAM readjustments are similar to those of conventional fabrication techniques. The transitory fixed prosthesis is designed to enhance aesthetics, stabilisation, and/or function for a limited period, after which it is replaced by a definitive prosthesis.

Often, such prostheses are used to assist in the determination of the therapeutic effectiveness of a specific treatment plan or the form and function of the planned definitive prosthesis. The following requirements need to be met:

1. biological requirements: protect the dental pulp; maintain and contribute to periodontal health; provide a comfortable, functional occlusal relationship; maintain tooth position; and protect remaining tooth structure;
2. mechanical requirements: resist functional load and resist removal forces without fracturing;
3. aesthetic requirements: resemble natural teeth (chameleon effect) and achieve the stability of the shade at that time.

The materials used in CAD/CAM are more fracture-resistant than the resins used chairside; they are extremely aesthetic in aspect and afford repair or modification directly at chairside. The ability to produce temporary prostheses with optimal, more predictable adjustment margins is of the greatest interest from the aspects of plaque control, gingival health and protection of residual dental structures. The respect of limits, aesthetics and the choice of sufficiently resistant restorative materials are important factors to take into account, especially during mid- or long-term temporary aesthetic restoration.
In conventional techniques, a crown or a bridge can be prepared, that is, undertaken before the teeth are made, based on a wax-up or self-casting, using an impression taken prior to preparation. Transposed to CAD/CAM, this demands 3D digital recording of the initial clinical situation with the aid of an intraoral scanner. This article puts forward a modern, routine development in the management of CAD/CAM-produced temporary teeth based on three clinical case studies: one using a subtraction method (milling) and the others using an additive method (3D printing).

In the milling method (subtraction), the volume is reduced (block or disc) until the shape required is achieved. Three-dimensional printing is an additive method by the deposit of successive layers until the final shape is achieved. Stereolithography (SLA) was invented in the 1980s and involves the hardening of liquid light-cured resin placed in a tray by photopolymerisation, using a laser that builds the object up layer by layer. A similar 3D printing technology used for the fabrication of temporary dental crowns is known as digital light processing (DLP), which uses a projector instead of the laser. The digital projection of the 3D shape of the tooth on the liquid resin allows superposition of successive layers by light-curing the resin. It is one of the most precise 3D printing methods.

For the past few years, 3D printing has been used in various areas of dentistry:

- surgical guides,
- model manufacture, manufacturing of burn-out resin or wax pieces for the lost-wax method,
- anatomical models for the planning of surgery or for educational purposes,
- aesthetic prototypes (mock-up),
- removable prostheses.

Quite recently, the materials used in the 3D printing of temporary crowns and bridges have been marketed and are now being used successfully alongside intraoral scanners. The purpose of this article is to demonstrate the usefulness of rapid prototyping for the realisation of temporary dental restorations from preliminary optical
impressions gained using intra-oral scanners. We implemented this method using two scanners: a last-generation (2016) scanner (TRIOS 3 color, 3Shape) for Case 1, and a previous generation (2008) scanner (CEREC 3-D Redcam, Sirona) for Cases 2 and 3 (Fig. 1).

We describe the workflow to obtain an open STL file format of the final restorative design from proprietary format files, CDT for the CEREC 3-D scanner and DCM for the TRIOS scanner. We show that these files can be either milled or 3D printed to produce the final prosthesis.

After the presentation and comparison of the two fabrication techniques based on three clinical case studies, we will discuss which materials are available for 3D printing, in which type of printer they can be used, and the advantages we might draw from both case studies by manufacturing provisional prostheses prior to the preparation of the teeth.

Conventional methods for fabrication

Practitioners habitually use several methods to fabricate provisional prostheses:21

1. They preform custom crown shells (cellulose acetate or polycarbonate forms).
2. They customise resin restorations by different techniques:
   - direct technique assisted by a matrix (elastomeric or alginate impression or vacuum-formed plastic template) or by using a custom-carved technique (block temporary); or
   - indirect technique with the help of a laboratory that delivers an almost finished restoration (which will be relined and readapted in the mouth) from an impression of the clinical situation; this needs an impression preparation and antagonist arch and, often, a method for registering the occlusion.

Materials used for provisional restorations produced by conventional methods involve various polymers: polymethyl methacrylate (PMMA), poly(ethyl methacrylate) (PEMA), and bis-GMA light-polymerised urethane dimethacrylate (UDMA).

Direct methods are often very quick to implement, but a number of studies have shown better quality of restoration by indirect methods:

- It is known that fabricating provisional crowns by the indirect technique produces more acceptable marginal adaptation than do other techniques.22
- Chairside time is reduced because most of the procedures are completed before the patient’s visit.
- Less heat is generated in the mouth because the volume of the resin used is small. The amount of heat generated and transferred to the pulp chamber, however, may be sufficient to cause thermal damage to the pulp and odontoblasts. The temperature rises in the pulpal chamber during fabrication of provisional resin crowns.23
- Contact between the resin monomer and the soft tissue is minimised compared with the direct procedure.
- There are fewer final occlusal or aesthetic corrections. In the case of aesthetic or multi-unit restorations, the indirect fabrication of a provisional prosthesis becomes almost compulsory.

Case presentation

For 3D printing, the final CAD files of the restoration must be in open STL format to be printed. In our report, we describe that the workflow is similar regardless of the intraoral scanner used (new or old generation).

Case 1: Temporary 3D printed posterior crown (on a Perfactory Vida high-resolution printer, EnvisionTEC) based on a preliminary impression with a TRIOS 3 color intraoral scanner.

Initial situation and preliminary treatment
In a 37-year-old patient, necrosis under a composite led to loss of the vitality of tooth #45 owing to caries. The missing tooth structure did not affect the entire morphology of
the tooth, and we wanted to realise a zirconia core structure layered with aesthetic porcelain, a viable option for opacity in cases of stained, devitalised teeth. This restoration would be sealed just after the intervention and during the necessary laboratory phase.

We took a preoperative scan (pre-scan) of the initial situation with TRIOS 3 color to produce a temporary crown using a 3D printer (Fig. 2). The impression (in DCM format) was transferred to the cloud via 3Shape Communicate to be converted into STL format. The pre-prosthetic treatment involved a root canal therapy and the setting of a fibre-reinforced composite post under a rubber dam (Fig. 3).

Fabrication of the provisional prosthesis with a 3D printer
A provisional prosthesis was made according to the shape of the tooth in the pre-scan, using the provisional eggshell module of exocad software (exocad; Fig. 4). The temporary crown was fabricated with the Perfactory Vida printer (Fig. 5) and fixed in the mouth with temporary cement (Fig. 6). After the base had been removed, the temporary crown was relined and adapted in the mouth on the day of preparation.

Fabrication of the final restoration with CAD
An optical impression was taken on the day of measurement and positioning of the temporary impression. This enabled the fabrication of a zirconia coping and the stratification of the aesthetic ceramic on the printed model (Fig. 7a) and the coping was then set in the mouth (Fig. 7b).

Case 2: Temporary bridge milled in a fabrication centre from a CEREC 3-D Redcam optical impression
The aim of CEREC in the past-decade technology was to produce chairside ceramic restorations typically as single unit. The slowness of both the optical impression and the milling machine made it difficult to produce even a definitive three-unit fixed dental prosthesis (FDP) in a single appointment. The method of fabricating a provisional by pre-scan and eggshell CAD can help to temporise during the laboratory phase.

Initial situation
A 19-year-old patient came for a consultation after a fall of several meters on to a rock, which had caused fracture of the jaw and was followed by surgical implantation of an osteosynthesis titanium plate. Fractured tooth #31 had to be removed owing to this operation, causing unitary edentulism. Owing to the presence of the osteosynthesis plate, the option of an implant was rejected after a scan (Fig. 8). Six months later, the bone growth and maturation reached the terminal point and the bone became eligible for bridge application.

Manufacturing of a three-unit provisional bridge
A preliminary optical impression was taken with a CEREC 3D camera to record the initial situation and to create a dental morphological base for the manufacture of the FDP. The digital CDT file was then opened with the mainstream 3D open-source Blender software (Version 2.63.33; www.blender.org) equipped with the add-on Open Dental CAD developed by Patrick Moore for the export of the file in STL so that it can be read by exocad. The digital impression was optimised by free open-source CAD software (www.freecadweb.org) by trimming the edges to remove any artefacts created by the lower lip, which obstructs
visibility. The quality of the meshing and the automatic repair functions were implemented one by one if necessary. The file was then ready to be imported into the dental exocad dentalCAD software.

The client file with the patient’s name was completed, indicating the type of restoration (temporary bridge on teeth #41 to 32) and the type of materials chosen (resin). As the patient was satisfied with the aspect of the existing teeth, their morphology just had to be copied for the fabrication of the provisional prosthesis without having to present an aesthetic mock-up. The design software enabled the virtual replacement of the missing tooth. The margins of the future bridge were set out, represented on screen by movable yellow dots to create a black line. The intermediary bridge sat naturally between the two existing teeth. The bridge insertion angle was set according to the future dental preparation of teeth #41 and 32 (Fig. 9).

At this stage, the thickness of the walls of the temporary FDP, as well as the shape of the margin fit, could be programmed. The shape of the pontic and its connections were programmed to match durability and hygiene requirements.

The file was exported from exocad in STL format and then sent via the Internet to a milling centre for external fabrication (dentallgroup.eu). The shade, the type of composite resin material, and the date of delivery were selected directly on the client back office panel of the website. The fabrication and delivery time of the temporary FDP was 48 hours (Fig. 10), but it could have been reduced by in-office milling.

Figure 11a shows the clinical situation with abutment teeth. The bridge constructed using the files sent to the laboratory was delivered to the practice (Fig. 11). The prosthesis was tried and adapted in the patient’s mouth on the day of preparation. This stage demanded far fewer adjustments than with conventional construction methods. Refining was necessary, but the margins adapted well.

The intraoral optical impression of the preparations was taken with the 3D CEREC camera. The file was sent by the free-access website at www.wetransfer.com to the laboratory that was equipped with the Sirona inLab 4.3 software (Dentsply Sirona). The temporary FDP was then set in the mouth with temporary cement (DentoTemp, Itena; Fig. 12).

The thickness and shape of the intermediary bond guarantee the durability of the future prosthesis. The bridge was milled in a lithium disilicate CAD block (IPS e.max, Ivoclar Vivadent) in the laboratory and then made up according to

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Case 2—Figs. 11a & b: Preparation of vital teeth #31 to 42 bridge abutment (a). Digital impressions (CEREC 3.85) (b). Fig. 12: Trial of temporary bridge, milled with PMMA Tempomill Vario (ZMT).

Case 2—Figs. 13a & b: Anterior temporary crown printed using a preliminary CEREC 3-D Redcam impression. CAD of the IPS e.max FDP on CEREC inLab 4.3 (a). Bonded IPS e.max bridge (b).
the digital photograph sent by e-mail. The final bridge was fixed according to a conventional cementing protocol with an adhesive resin. The IPS e.max FDP was fixed with a resin cement (NX3 Nexus, Kerr) and made up; the total time taken for shading and construction was one week and was to the patient’s satisfaction (Figs. 13a & b).

The main limitation of the past decade in clinical so-called “chairside” CAD/CAM dentistry was the impossibility of producing an aesthetic zirconia crown, first because the proprietary format of the files could not be converted for milling at the laboratory; second, because most of the laboratories were not able to produce a 3D printed model; and third, because the optical impression files could not be transferred quickly and correctly to the laboratory. Currently, the new digital workflows at our disposal offer us these possibilities.

Case 3

Cases of aesthetic restoration of the smile are sometimes more difficult to comprehend when one is not reconstructing the entirety of the smile, but only one or two units. Communication with the patient is essential. Three-dimensional printing can help to better understand aesthetic desires by printing different tooth shapes.

A 32-year-old patient came to the practice because of an unsatisfactory restoration of her devitalised tooth #22 several years before using a composite material that now had taken on a dark, unattractive colour (Fig. 14). To optimise the aesthetic result, we decided to place a zirconia crown (made in the laboratory with the CAD/CAM method for the substructure and manual method for the stratification of the aesthetic ceramic) on a pressed corono-radicular restoration with a fibre-reinforced composite post.

A preliminary optical impression (CEREC) was taken to record the shape before preparation and to serve as a working base for the morphology of the provisional prosthesis. The CDT file was opened with the Blender software to be transformed into STL (Fig. 15a) and processed with FreeCAD (www.freecadweb.org) to eliminate any artefacts. Then, as previously, the provisional prosthesis was designed with exocad. The preparation of tooth #22 was done after cementing a fibre-reinforced composite post under rubber dam isolation.

**Fabrication of a 3D printed provisional prosthesis**

A provisional prosthesis was made by 3D printing on a PICO2 printer (Asiga; Fig. 15b) with NextDent Crown & Bridge A2 (Class Ila biocompatible; NextDent), validated for a 30-day in-use time frame in the mouth.

The CAD was made with exocad and several designs were made for the patient with the aim of closing, if possible, the diastema between teeth #22 and 23 in relation to the initial situation. Two provisional restorations were made for the patient (Fig. 16), and the preferred temporary tooth was polished and sealed (Figs. 17a & b).

**Fabrication of a definitive crown**

The final crown was made using an optical impression that enabled both the fabrication of the zirconia coping and the 3D printed models, which enabled the stratification of the ceramic in the laboratory (Figs. 18a & b).

**Discussion**

The pre-scan method can be useful in situations in which temporary restorations are required even if in some cases practitioners would prefer to make a temporary crown directly after preparation. We can ponder the question of which workflow to use (in the clinic or in the laboratory), and why it would be better to print than to mill. We can also enquire which printer and materials to use. Three-dimensional printing is currently in full development in the dental field, and the print speed is increasing steadily. Next, we will discuss what we can expect in the future for daily use in the dental clinic.
Advantages and disadvantages of the pre-scan method for temporary crowns

**Advantages**
The principal advantage of the pre-scan method to make temporary restorations is the principle of copy and paste for the shape of the tooth. Another advantage is that, after preparation, blood can mask the limits and make optical impressions difficult. It is appealing for a single optical impression and for only minor modification of the shape of the desired tooth without modification of the occlusion.

**Disadvantages**
The principal disadvantage of the pre-scan method is the necessity to keep the same occlusal schema (before/after) even if minor correction of the antagonist can be discussed and done before final restorations. Another problem is visualising and anticipating the position of the limits of the preparation, specifically in the proximal view. The curvature of the vestibulo-lingual edge in the interdental papillary zone can be difficult to anticipate when the limit is drawn on the software, especially in automatic mode. However, rebasing of the temporary restoration can correct it. We did not observe any problems of adhesion between the bis-acryl resin layer and the 3D printed resin. However, if the gingival finishing lines of the preparation are under the gingiva, rebasing becomes compulsory. The STL conversion (whether from CDT or DCM) yields a monochromatic model, and the limits of the gingiva and tooth can thus be difficult to visualise.

**Which workflow to use?**
The method of prototyping that we have described from a pre-scan offers several possibilities for producing temporary restorations, if they do not have to be made in the session:

- in-office milling or laboratory milling;
- in-office 3D printing or laboratory 3D printing.

It depends on the inter-session time and the investment to be made.

The import of digital scan files into open software such as exocad offers the possibility of using an older scanner such as the CEREC 3-D Redcam after conversion of a native CDT to STL format and overcomes the limited functions of the software whether for the realisation of a provisional prosthesis by pre-scan or a bridge.
The latest version of Sirona inLab CAD (SW 16.0) is (to our knowledge) not yet able to create temporaries from pre-scans. The add-On Open Dental CAD of Blender allows transformation to CDT (Sirona) format only into STL. The Datakit CrossManager software can transform not only CDT files but also DCM (3Shape) files into STL.

Now, TRIOS intraoral scanner users can export STL file digital impressions directly from their TRIOS Dental Desktop software. Digital provisional crown design can also be done in 3Shape Dental System but with annual licence fees. A free and original open-source method is to use STL files, as well as the Christian Brenes tooth library in Meshmixer (Autodesk, Fig. 19), which turns this free programme into dental CAD software able to perform after a few manipulations the same operation as described on a preoperative STL scan model. Other interesting manipulations on the initial numerical impression model, such as the Mirror function, can be performed for aesthetic simulation, numerical wax-up, mock-up or provisional restorations. A numerical dental model from an optical impression can be matched with high-quality 3D face scanning (Bellus3D) for good aesthetic integration.

Advantages of CAD/CAM provisional restorations and additive manufacturing
Temporary restorations can now be made in the dental practice by methods employing subtraction or addition; of course, we wonder which technique we should use. Is 3D printing the best solution?

At this time, no study has compared 3D printed resin material to CAM resin milling, but CAD/CAM-fabricated provisional crowns have demonstrated superior fit and better strength than have direct provisional crowns (Protemp, 3M ESPE). CAD-Temp (VITA Zahnfabrik) and Telio CAD (Ivoclar Vivadent) are more often used in-office for milling provisional restorations. CAD/CAM-milled polymers offer a wider range of translucency and chameleon effect than manually polymerised temporary materials do and have shown more favourable mechanical properties. CAD/CAM-fabricated FDPs exhibit a higher mechanical strength than directly fabricated FDPs do, when manufactured from the same material.

Advantages of additive manufacturing
There are many advantages to the techniques of addition compared with those of subtraction:

– no change of maintenance to the rotary instruments;
– noiseless during operation;
– possibility of creating highly precise, complicated shapes without being limited by the size of the drill for the completion of small details;
– once the cost of the printer has been covered, fabrication costs are much lower than when milling: no waste of materials after the milling of blocks;
– possibility of creating several prostheses simultaneously;
– good surface area by the spacing of polymer layers set in an optimal manner (25–50 µm);
– no waste of materials; only 5 per cent of additional material is used for the support, whereas with milling, around 70 per cent of the material remains unused—also it is possible to reuse any remaining material;
– for the most sophisticated printers, various materials can be used together during the same printing;
– possibility of integrating various shades.

Disadvantages of additive manufacturing
Disadvantages in comparison with the techniques of subtraction should be equally considered:

– The printed objects have to be hardened in a UV box after 3D printing, and then cleaned, dried, separated from the support, and finished (polishing, glossing). This post-UV treatment takes less than two minutes in the EnvisionTEC UV light-curing light-pulsing session of 2 × 5,000 flashes. The prosthesis is printed with the occlusal surface face down. The removal of any remaining print material from the support is undertaken on this side, which can lead to the need for adjustments.
– The total fabrication time of a unit can be close to or over an hour, against 15 minutes for a unit produced by milling.

Fig. 19: Virtual simulation on Meshmixer: mirror 3D duplication of initial situation of teeth #21, 22, 23 and 24 to replace teeth #11, 12, 13 and 14.
– Integration of the 3D printer with CAD/CAM software is an important factor to consider, ensuring that the fluidity of the digital workflow is not affected.

– The initial investment, for the software and the equipment, is still quite high, regardless of whether this is for laboratories or dental clinics.

– Experience in the use of these new materials is lacking, notably in terms of the temporary materials.

– The variety of available materials, particularly for permanent prostheses for dental purposes, is quite limited for the time being.

– The technological development of materials is much slower. The choice of these is limited to polymers at present. Materials must have the CE Class II marking if they are to be used in vivo.\(^{31-33}\)

– Machines require more maintenance and training in terms of their use and upkeep.

Three-dimensional printing and accuracy for temporary restorations

Resolution is one of the most important factors to take into account when considering different 3D printers to obtain satisfactory clinical results, particularly for fixed prostheses. The resolution of a 3D printer partly depends firstly on the technology used:

– laser SLA printer: the laser spot size (50 µm on the XFAB [DWS; Fig. 20a]; 140 µm on the printer [Formlabs; Fig. 20b])

– DLP printer: the quality of the screen (pixel size specification of the projector).

On fused deposition modelling (FDM) printers (the process of which entails melting plastic material and extruding it in a pattern, layer by layer, on a variable-height build platform), which is not described in our article, the machines are equipped with a nozzle measuring about 250 µm at its end.

When considering 3D printer resolution, we also have to take all three dimensions into consideration: resolution on the planar dimensions (x- and y-axes) and the vertical resolution (z-axis) determines the thickness of a layer. On FDM machines, the smallest practical layer height is generally 0.1 mm or 100 µm, and for DLP SLA machines, 0.025 mm or 25 µm.

Recent studies presented in the literature have shown the accuracy and quality of 3D printed temporary prostheses (Table I).\(^{34-37}\) However, accuracy must be placed in the context of our study, which entails producing only a preform intended to be rebased in the mouth.

Which materials for which printers?

Temporary materials must be used in the DLP (LED/UV) printers with a light spectrum of 378–388 µm. The factory-preset programmes included in the 3D printer to perform the polymerisation and the material tested and validated by the manufacturer must be respected. The post-treatment protocols must be scrupulously respected too.

At present, several manufacturers offer biocompatible resin materials that can be used in dentistry:

– E-Dent 100 and E-Dent 400 (A1, A2 and A3; EnvisionTEC), sold in bottles;

– NextDent Crown & Bridge (NextDent) in the form of a simple resin or a micro-particle resin;

– Temporis (DWS) as a liquid for XFAB (Fig. 20a) or in multicoloured cartridges for DFAB (DWS);

– Freeprint Temp (A1, A2 and A3; DETAX) sold in tubes of 500 g or 1,000 g;

– DWS (XFAB or DFAB) and Stratasys have launched their laboratory printers, whose products (Temporis and VeroGlaze MED 620) can be used in the mouth for up to 24 hours;

– VarseoSmile Temp for Varseo S (BEGO) 3-D printer (A2, A3 and C2 resin), for crowns, inlays, onlays and veneers, as well as bridges of up to seven elements and with a pontic of a maximum width of a molar and for temporary use in the posterior or anterior region short or long term;

– Planmeca has proposed a temporary material for its new DLP printer Creo;

– at the 2017 International Dental Show (IDS), Formlabs (Fig. 20b) announced the launch of Class Ila biocompatible materials for the direct 3D printing of dentures for bases (Fig. 21a) and teeth (Fig. 21b).

Each of these brands has developed printers for laboratories producing many components simultaneously and the fabrication of more voluminous objects requir-
ing greater precision (models and removable prosthetic frame). Dental practices can, as indicated in the table, use them less frequently or for the fabrication of provisional or aesthetic mock-ups of less voluminous and therefore less costly printers (Table II).

Actual and future developments

Speed is a parameter that has greatly improved recently for 3D printers. During the 2017 IDS, 3D Systems with NextDent presented a printer prototype that can produce 20 crowns in nine minutes. A dedicated printer for dental practices (DFAB), also presented at the 2017 IDS, allows one to define the shade to be printed (Photoshade technology) and the position of the different graduated shades (Fig. 22) to be printed and could guarantee a relatively fast, 20-minute, building time for a five-element bridge compared with a similar task in a milling machine. According to the manufacturer, the new EnvisionTEC Micro Plus cDLM printer can print eight to ten crowns in 15 minutes. With DLP technology, print time is not affected by the number of crowns printed.

All shades presented on screen are included in a single cartridge (Temporis). With this material, we can produce temporary bridges of up to five components.

Conclusion

The method for prefabrication of bridges is a new alternative using CAD/CAM and provides an answer to the demand for total dematerialisation of the digital chain and predictability of the aesthetic result, because it circumvents the need to take physical impressions. This technique also reduces adjustments if the initial project matches the preparation and simply requires temporary cementing without the use of a relining resin.

The transformation of the proprietary format to an open format means that the file can be used in the software of one’s choice (in this case, exocad) by allowing the design of a temporary bridge, as well as its transfer to a milling centre. Hence, we can benefit from all the progress made in the dental industry in terms of milling precision and the choice of materials.

Table I: Accuracy of 3D printed temporary restorations according to recent literature.\textsuperscript{34–37}

<table>
<thead>
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<td>2017</td>
<td>PolyJet</td>
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<td>Improvement of the precision at the marginal and internal level compared with milling</td>
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<tr>
<td>Lee et al.</td>
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<td>(ZENITH)</td>
<td>(ZENITH)</td>
<td></td>
</tr>
<tr>
<td>Molinero-</td>
<td>2018</td>
<td>Witbox 2</td>
<td>Poly(lactic acid)</td>
<td>3D printed provisionals in poly(lactic acid) are clinically acceptable</td>
</tr>
<tr>
<td>Mourelle et al.</td>
<td></td>
<td>(BQ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tahayeri et al.</td>
<td>2018</td>
<td>Formlabs1+</td>
<td>NextDent C&amp;B Vertex</td>
<td>Sufficient mechanical properties for intraoral use of 3D printed crowns and bridges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Formlabs)</td>
<td>Dental</td>
<td></td>
</tr>
</tbody>
</table>

The transformation of the proprietary format to an open format means that the file can be used in the software of one’s choice (in this case, exocad) by allowing the design of a temporary bridge, as well as its transfer to a milling centre. Hence, we can benefit from all the progress made in the dental industry in terms of milling precision and the choice of materials.

Figs. 21a & b: 3D printing with Form 2 resin for a complete removable prosthesis (denture base and denture teeth). Denture tooth resin is used for both prosthetic teeth for removable prostheses and temporary teeth.
### Table II: Comparison of 3D printing resin materials for temporary prostheses according to Tollefors and Meland

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flexural strength</strong></td>
<td>&gt; 100 MPa EN ISO 4049</td>
<td>85–100 MPa EN ISO 10477.2003</td>
<td>100–130 MPa EN ISO 10477.2003</td>
<td>93MPa</td>
</tr>
<tr>
<td><strong>Tensile strength</strong></td>
<td>30 N/mm² EN ISO 4049</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
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<tr>
<td><strong>Compression resistance</strong></td>
<td>&gt; 250 N/mm²</td>
<td>No data</td>
<td>No data</td>
<td>&gt; 290 N/mm²</td>
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<tr>
<td><strong>Water absorption</strong></td>
<td>18.1 µg/mm³ EN ISO 10477</td>
<td>&lt; 30 µg/mm³ EN ISO 10477.2004</td>
<td>&lt; 30 µg/mm³ EN ISO 10477.2004</td>
<td>22µg/mm³</td>
</tr>
<tr>
<td><strong>Water solubility</strong></td>
<td>EN ISO 10477</td>
<td>&lt; 5 µg/mm³ EN ISO 10477.2004</td>
<td>&lt; 5 µg/mm³ EN ISO 10477.2004</td>
<td>&lt; 1.2 µg/mm³</td>
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<tr>
<td><strong>Modulus of elasticity</strong></td>
<td>&gt; 4,500 MPa EN ISO 4049</td>
<td>&gt; 2,300–2,500 MPa EN ISO 10477.2003</td>
<td>&gt; 2,400–2,600 MPa EN ISO 10477.2003</td>
<td>2,700MPa</td>
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<tr>
<td><strong>Maximum stress intensity factor</strong></td>
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<td>No data</td>
<td>0.8–2.0 MPa EN ISO 20795-1:2013</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Total fracture work</strong></td>
<td>No data</td>
<td>No data</td>
<td>7–10 kJ/m² EN ISO 20795-1:2013</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Resistance to fracture via impact (without cracking)</strong></td>
<td>No data</td>
<td>12–15 kJ/m² ISO 179:2010</td>
<td>16–18 kJ/m² EN ISO 179:2010</td>
<td>No data</td>
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<tr>
<td><strong>Hardness</strong></td>
<td>25 HV (Vickers in kgf/mm²)</td>
<td>D 80–90 (Shore) EN ISO 868:2003</td>
<td>No data</td>
<td>D 92 (Shore) 129 MPa (Ball)</td>
</tr>
<tr>
<td><strong>Filler weight%</strong></td>
<td>49.8</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Filler volume%</strong></td>
<td>30</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Filler size</strong></td>
<td>0.04–0.70 µ</td>
<td>No data</td>
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<td>No data</td>
</tr>
<tr>
<td><strong>Shades available</strong></td>
<td>A1, A2, A3</td>
<td>Not specified, Staining and glazing possible</td>
<td>Not specified, Staining and glazing possible</td>
<td>BL3, A1, A2, A3, A3.5, B1</td>
</tr>
<tr>
<td><strong>Pontic number possible</strong></td>
<td>1</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Max. number of components allowed</strong></td>
<td>4</td>
<td>Not specified</td>
<td>Not specified</td>
<td>4</td>
</tr>
<tr>
<td><strong>Area of connectors</strong></td>
<td>A: 12 mm² P: 14 mm²</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Minimum thickness of sides</strong></td>
<td>0: 1.5 mm C: 1.0 mm</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td><strong>Medical devices directive</strong></td>
<td>No data</td>
<td>93/42/ECB-NC-B:2015-01-UK</td>
<td>93/42/ECB-NCB-C:2015-01-UK</td>
<td>93/42/EEC</td>
</tr>
<tr>
<td><strong>Certification</strong></td>
<td>FDA approved Biocompatible Class Ila CE</td>
<td>Biocompatible Class Ila CE (mid term)</td>
<td>Biocompatible Class Ila CE</td>
<td>Biocompatible Class Ila CE</td>
</tr>
<tr>
<td><strong>Max. time validated in mouth</strong></td>
<td>1 year</td>
<td>30 days</td>
<td>1 year</td>
<td>Long-term provisional</td>
</tr>
</tbody>
</table>
The pre-management of temporary prostheses is recommended especially in simple cases (unitary restoration, small bridges without any change in the morphology or the vertical dimension between the initial and final situation). Moreover, the initial impression can be kept and reimported into the CAD software and be used as a digital base to undertake restoration. Because 3D printing will soon be readily available, it will be possible to produce temporary bridges in-session while the practitioner prepares the teeth, thereby significantly reducing the number of sessions or the time in the chair (Fig. 23).

Hence, we suppose that 3D printing will substitute milling for permanent prostheses in some cases and especially for the fabrication of mock-ups. A digital wax-up from an initial impression of photographs or a 3D scan of the face and then a mock-up is much more predictable and faster to achieve, but before the technique can be used efficiently in-chair, particularly in a single session, the time required for printing and post-treatment of the prosthesis must still be reduced.

For the time being, the interest in prefabrication of CAD temporary crowns and bridges makes complete sense in terms of reducing the time taken in-session by optimising precision, relining and adjustments. To further the subject of this study, a comparison of the properties of the different temporary resin materials available for the 3D printer should be performed in an in vitro study. Future studies will be necessary to evaluate better whether this material fulfills the stated objectives for restorations (biological, mechanical and aesthetic).

It would also be interesting to compare the mechanical and optical properties of 3D printing materials and CAD/CAM materials available for temporary restoration. The utility of either a 3D DLP printer or a 3D SLA printer for fabrication of temporary restorations (comparison at the level of printing time and accuracy) may also be considered in another study.

Editorial note: A list of references is available from the publisher.

**Dr Olivier Landwerlin** (DDS) is a practitioner in Cannes in France. He graduated from the University of Nice Sophia Antipolis (France) and is a lecturer in the dental CAD/CAM postgraduate diploma at the University of Montpellier’s Faculty of Dentistry in France. He is the author of the book *L’empreinte optique intra-buccale et ses applications au cabinet dentaire* (Éditions universitaires européennes) and has been webmaster of the Dentisfuturis.com website since 2003. He has been interested, since entering practice, in the innovations and technologies in dentistry, optimising the workflow in daily practice, particularly with optical impressions and dental CAD/CAM. He is CEO of the French start-up company Tooty VR (www.tootyvr.com), which has developed the first application for visualisation of numerical 3D intraoral impressions and dental models in virtual reality.

**Dr Michel Fages** (DDS, MS, PhD) began using CAD/CAM in 2005 and currently teaches it as a lecturer at the University of Montpellier’s Faculty of Dentistry in France. He is also a lecturer in the dental CAD/CAM postgraduate diploma at Toulouse and the postgraduate diploma in aesthetic dentistry at the Université Nice Sophia Antipolis in France. He is a hospital practitioner at the dental centre of Montpellier CHRU and head of the CAD/CAM prosthetic medical application unit. Dr Fages is co-author of the books *Guide de CFAO clinique* (Éditions CDP), *Les préparations assistées par guidage* (Éditions EDP Sciences), *Guide de Prothèse fixée* (Éditions CDP) and *La CFAO appliquée* (Éditions Espace ID).
Comparison of guided and non-guided implant placement accuracy

In vitro study with 3D printing (Part 1)

Dr Łukasz Zadrozny, Marta Czajkowska & Dr Leopold Wagner, Poland

Introduction

The procedure of implantation is becoming an increasingly popular method for replacing teeth. The critical factor in the achievement of a therapeutic and aesthetic long-term effect is the accuracy and precision of implant placement, being the support for the future prosthetic work. Thanks to modern digital technologies, it is possible to plan the implantation virtually. Evaluation of this plan by 3D printing in a subsequent step allows the creation of implant guides. Using the guides, which provide precise information on implant placement and insertion depth and angle, allows the maintenance of all the parameters included in the planning stage, lowering the risk of a mistake during implantation. Using 3D printing allows the fabrication of both implant guides and study models that accurately represent patients’ true clinical conditions. This makes it possible to compare the precision of procedures under the in vitro conditions, which are safe and representative of actual requirements. During the implantation, clinical conditions very often hinder precise orientation in the operating field, thus the precision of implant positioning is lower. According to the literature, both more and less experienced clinicians face this problem. Introducing virtual planning based on CBCT is highly useful while preparing for the procedure; however, what allows the fully controlled preparation of the implantation site is the transfer of its result to the guide imposing the positioning. The virtually created implant guide can be printed using a 3D printer, sterilised and then used in the procedure. The use of the guide affects the precision of the procedure and shortens its time.

Aim of the study

The aim of the study is to prepare 3D models for the analysis of the precision of implant procedures performed on the basis of digital planning, conducted with and without the use of implant guides.

Methodology

Based on the CBCT examination of the patient, who underwent implantation in the mandible, a 3D model corresponding to the actual bone and mucosal conditions before implantation was created in DDS-Pro software.
It was then reprinted 20 times. The print was produced with selective laser sintering technology using polyamide powder in the TPM Elite P3600 SLS System printer (Solveere). It yielded ten identical pairs of mandibular models. Virtual planning (DDS-Pro; Fig. 1) of implant positioning and placement (TSIII, OSSTEM IMPLANT) and the implant guide, printed in 3D with Jet technology (ProJet MP 3000 printer, 3D Systems), with stock sleeves for three implants with regular platforms previously used clinically (sterilised), were used to intro-

![Fig. 2: Exemplary pair of models before the procedure: on the left, without the guide, and on the right, with the guide.](image2)

![Fig. 3: A model with the guide and implants after the implantation. The guide was stabilised with two posts.](image3)

![Fig. 4: The material was deposited on the drill attached to the extension.](image4)
duce implants into every second printed model, using the OsstemGuide KIT(Taper). The drilling speed was set at 1,200 rpm. Water cooling was not used. Osteotomies were performed according to the manufacturer’s instructions. Other models were used for implantation based on the planning performed, but without additional help (no guide), using the same implant kit and under the same conditions. As the test was conducted in vitro, TSIII training implants with dimensions of 4 × 10 mm were used. It was assumed that all ten procedures performed would yield the same results.

Findings

The use of 3D printed models allows implantation under conditions spatially corresponding to those of a clinical situation. However, the models printed in this study were hard. The material cut during osteotomy preparation was deposited on the drill and the implant thread, making it difficult to perform full-depth insertion. More torque was required to insert the implant than is clinically used. It was observed that, when an osteotomy was prepared in the vicinity of a preserved tooth, there was a need to use the drill extension in order to avoid leaning the contra-angle handpiece on the guide or tooth. Because this tool is missing in the OsstemGuide KIT(Taper), one must have an additional implant kit when using it clinically. The use of the guide shortens the implantation time, compared with the same procedure performed with no help of a guide.

In the following stage of the project, the models will be optically scanned and undergo comparative analysis in terms of repeatability, accuracy and compliance with the planned virtual goal.

Editorial note: The study is being carried out as a part of a project in the field of scientific developmental research aimed at the development of young scientists and students enrolled in PhD studies, financed as part of the scientific activity of the Medical University of Warsaw in Poland.
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Full-guided treatment for the edentulous mandible: A proof-of-principle report and technical note

Drs Christos Alamanos & Reinhold Lang, Germany

Since 2015, the Straumann Pro Arch portfolio, in synergy with the Bone Level Tapered Implant, has provided an accelerated and comprehensive solution for the rehabilitation of the terminal dentition and edentulism with fixed, full-arch tooth replacement. In this clinical case report we demonstrate the feasibility and accuracy of a full-guided Pro Arch treatment in a patient with partial edentulism in the lower jaw. For this purpose, we combined the Straumann guided surgery workflow supported by the coDiagnostiX software (Dental Wings, Straumann Group) with the conventional Pro Arch surgical and prosthetic protocols.

Initial situation

A 65-year-old, non-smoking male patient presented at the Department of Prosthodontics, University Medical Center Regensburg with an ill-fitting double-crown-retained overdenture on tooth #33 in the lower jaw, and fixed dental prostheses in the opposing arch. The patient asked for his lower dentition to be restored with a fixed dental prosthesis. His past medical history was unremarkable. The clinical and radiological examination revealed a peri-radicular infection and secondary caries on tooth #33, which was therefore considered as irrational to treat (Figs. 1–6). The fixed dental prostheses were evaluated as insufficient but, in view of the patient’s financial constraints, it was decided to remake these at a later date. The occlusion was insufficient and showed heavy anterior contacts and non-occlusion on the posterior sites, but the occlusal plane was considered acceptable (Figs. 1–3).

Treatment planning

To meet the patient’s expectations, it was decided to place four interforaminal implants at teeth #32, #34, #42 and #44 following the Straumann Pro Arch protocol.
for delivering a screw-retained fixed restoration, thereby avoiding the need for expensive and time-consuming alternative treatments involving demanding surgical procedures in the posterior segments. To facilitate a more efficient conversion of the available denture into an immediate temporary fixed restoration in the lab, it was decided to follow a full-guided surgical workflow, which was supported by the coDiagnostiX software (Dental Wings, Straumann Group). This workflow improves the precision of implant placement and increases the AP spread by tilting the distal implants either at 17° or at 30°, still without interfering with the mental nerves. The preliminary records needed to deliver this treatment included a radiographic template, by means of a duplicate denture with radiopaque teeth and a CT scan of the lower jaw with the template (Figs. 7 & 8). The integration of the tooth set-up in the treatment planning facilitated a prosthetic-driven implant placement. Due to the tilted posterior implants, it was important to use 30° angled screw-retained abutments to place the access channels on the occlusal surface of the temporary restoration (Fig. 9). Tooth #33 was planned to be extracted prior to implant placement because its root would impinge on the distally tilted implant #34. In the absence of any other anterior tooth support, the surgical guide was designed with anterior lateral anchoring to avoid any movement during implant bed preparation. The lateral preparations for the anchoring elements were realised by means of a first (or pilot) guide which was mucosa-tooth-borne and included an incisal window to check the seating (Figs. 10 & 11). For the implant bed preparation, we used a second (or main) drill guide, but this also kept the lateral sleeves in the same position (Neodent, Straumann Group; Figs. 10–14).

Surgical procedure

The pilot surgical guide was used before the main surgical guide to facilitate a full-guided placement. The pilot guide was used for a flapless preparation of the sites to anchor the fixation pins. This guide was tooth-mucosa-supported. After checking the patency of the lateral preparations, the tooth was removed and the main drill guide was tried in. As the pin positions were copied, the pin sleeves of the second guide retrieved the same positions obtained with the first guide. Before proceeding to the implant site development, a midcrestal incision with a midline release was performed, and a full-thickness flap was reflected. Since the guide allowed for some mucosal clearance at the sites of flap reflection, it was only bone-supported in the anterior segments (Fig. 15). Tooth #44 revealed a bony defect, which, after copious debridement, was reconstructed with a guided bone regeneration procedure (Fig. 16). The lateral anchoring secured the drill guide against tilting during the whole implant site preparation. Finally, four Straumann Bone Level Tapered SLActive implants (diameter 4.1 mm, length 12 mm)
were inserted with the fully guided protocol at teeth #32, #34, #42 and #44 and torqued to a minimum of 35 Ncm. Non-engaging temporary titanium cylinders were attached on the screw-retained abutments and the flap was sutured with 4/0 multifilament polyamide (Fig. 17).

**Prosthetic procedure**

**Provisional restoration**

In the lab, the dental technician retrofitted the main surgical guide on a preliminary cast to index the position and angulation of the future screw-retained abutments. The prosthesis was modified with perforations, to pick up the titanium copings chairside. The copings and their screw access channels were blocked-out respectively with rubber dam and Fit Checker (Fig. 18). The copings were secured intraorally with a self-curing composite (Quick Up, VOCO). The cylinders were disconnected from the screw-retained abutments, and the prosthesis was transferred to the lab for modification. During the lab procedure, PEEK copings were attached to the screw-retained abutments to counteract a tissue collapse and retain the access to the abutments (Fig. 19). A postoperative panoramic radiograph was taken at this stage (Fig. 20). The temporary restoration was configured with a “high water” design to allow for effective home care. Specifically, the tissue surface was given a convex contour and a high luster. Additionally, the arch was shortened to minimise the occlusal load on the implants during the initial healing period. The 11-unit screw-retained provisional was attached on the screw-retained abutments and the occlusal screws were torqued down to 15 Ncm, as required. The screw channels were sealed and the patient was rescheduled in one week and thereafter at four-weekly intervals (Figs. 21 & 22). The postoperative healing period was uneventful, and the patient was able to perform optimal oral hygiene as observed at the first month recall (Figs. 23 & 24).
Final restoration
An open-tray impression was performed at abutment level after a healing period of four months (Fig. 25). After assembling scanbodies on the NC/RC analogues for screw-retained abutments, the lab technician performed an optical scan and designed a 12-unit fixed dental prosthesis framework (Fig. 26). Modifications regarding the connectors’ dimensions and the space for the veneering materials were performed with the Modellier software module. The final layout was exported to the CAM software module for production. A five-axis precision milling machine was used to fabricate a 12-unit non-precious-alloy bridge framework (Figs. 27–30). The framework showed an exceptional marginal adaptation and passive fit (Figs. 31 & 32). The veneering procedure included surface conditioning (120 µm sandblasting), layering (Duceram ceramics, DeguDent) and several firing cycles. Pink ceramics were also layered to imitate the gingival structure. The final restoration was delivered and torqued to 15 Ncm. Screw access channels were sealed with Teflon tape and a light-curing, nano-hybrid composite (Tetric EvoCeram; Figs. 33–35).

Treatment outcome
This case report demonstrates that the concept of immediate fixed full-arch tooth replacement assisted by guided surgery can provide exceptional accuracy and confidence to the surgeon. The potential of this workflow can be further enhanced, e.g. by means of a flapless approach or a CAD/CAM immediate temporisation.

Acknowledgements
Laboratory procedures
- Framework: Peter Brune, Brune und Fleischmann, Regenstauf, Germany
- Porcelain Veneering: Olga Nosikowa, University Medical Center Regensburg, Germany

Dr Christos Alamanos graduated with a degree in dental surgery from the University of Athens, Greece, in 2005. Diplomate oral surgeon, 2010 (German boards for Oral Surgery). Thesis (Dr. med. dent.) University Medical Center Freiburg, Germany, 2013. MSc in Periodontology and Implant Dentistry, Dresden International University, Germany, 2014. Resident and research associate, Department of Prosthodontics, University Medical Center Regensburg, Germany, 2013–2018. His interests include guided implant dentistry, immediate implant loading and advanced reconstructive oral surgery.

Dr Reinhold Lang is an associate professor and research associate, Department of Prosthodontics at the University Medical Center Regensburg, Germany. His research focuses on implantology, synthetic materials and aesthetic dentistry.
Planmeca is known for high-tech innovations and continuous product development. The company’s powerful Planmeca Romexis software platform allows all stages of the dental implant and aesthetic prosthodontic treatment to be completed using one piece of software, from the computer-assisted design of patients’ smiles to the fabrication of surgical guides.

The following clinical case, which I performed together with my colleagues Dr Ponomarev, Dr Kozhevin and Dr Yarokhin, illustrates how digital solutions can be used in prosthodontic treatment, implant placement and restoration design. According to our experiences, digital CAD/CAM technologies enable maximal functional and aesthetic results compared to traditional methods.

Clinical case report

The clinical case illustrates the advantages of using Planmeca CAD/CAM solutions in the digital planning of an implant placement and surgical guide, as well as in the fabrication of a ceramic restoration. This article presents a clinical case in which the treatment was completed using the Planmeca Romexis 3D Implant Guide software, Planmeca PlanCAD Premium software and Planmeca PlanMill 40 milling unit.

The clinical case features a female patient, who complained about missing tooth #22, as well as the shield-like shape of tooth #12 (Figs. 1 & 2). During the initial examination, the area around the missing tooth was estimated to be quite narrow for an implant. However, the patient declined orthodontic preparation, as she had already previously had orthodontic treatment with orthodontic surgery.

In this particular case, we started with an aesthetic analysis of the patient’s CBCT data and concluded that a Straumann implant with a 2.9 mm diameter would fit in the area of tooth 22, if we used a surgical guide...
for maximum precision (Figs. 3–5). For tooth #12, we decided to fabricate a thin-walled IPS e.max ceramic restoration (Ivoclar Vivadent).

Thanks to digital planning and a carefully fabricated surgical guide, the implant was placed successfully, even though the anatomical conditions appeared to be less than advantageous. We achieved a torque of 30 Ncm and attached a healing abutment to the implant (Figs. 6 & 7).

Three months after the implant placement operation, the osseointegration of the implant fixture was completed. A temporary crown was fabricated on the implant from a VITA ENAMIC multiColor block to support the formation of soft tissues (Figs. 8–10). We improved the original design on the Straumann superstructure with gum contouring. On tooth #12, crown lengthening was performed with an electrocoagulator (Figs. 11–13).

Once the formation of the soft tissues was complete, tooth #12 was minimally prepared for the ceramic crown with the help of a surgical microscope. After the preparation, the teeth were scanned in order to digitally design a custom abutment and crowns (Figs. 14–19).

The final smile design was planned digitally together with the patient. For the implant structure, we chose an individual zirconium abutment screw with a ceramic facing and a fully anatomical Empress crown (Figs. 20 & 21).

The ceramic facing concealed the excessive brightness of the zirconium, and we were able to achieve the desired colour. Thanks to the digital workflow, we managed to fulfil the wishes of the patient. (Figs. 22–24).

**Conclusion**

With digital technologies, the entire implant workflow can be completed in the dental clinic, from planning to fabrication of the restorations. Digital planning increases the reliability of the implant treatment and helps the dentist to succeed in the operation. Digital tools allow achieving the maximum functional and aesthetic result even in combined operations in which an implant placement and ceramic restoration are performed simultaneously.
Thanks to the development of modern technologies, a 3D model of a patient’s set of teeth can now be acquired in only a few minutes, without infringing on the comfort of the patient. At the same time, combining a CBCT image with an intraoral scan enables the dentist to plan the implant placement and surgical guide accurately and with just a few mouse clicks.

Finally, digital technologies also enable visualising the treatment outcome for the patient. Clear visualisations of the end result facilitate communication with the patient, which, in turn, can increase case acceptance.

Dr Kirill Kostin graduated from Saint Petersburg State Medical University in Russia in 2004. He became the co-founder of the PerfectSmile dental clinic and dental study centre in 2014. At his clinic in Saint Petersburg, Dr Kostin runs a private practice concentrating on the aesthetic and functional rehabilitation of natural dentition and implants, applying various digital instruments as part of restorative procedures (digital smile design, intraoral scanning, CAD/CAM milling, 3D printing, and guided surgical procedures).

Using a dental microscope on a daily basis, Dr Kostin focuses on minimally invasive restorative procedures with direct and indirect restorations. This particular case Kostin performed together with his colleagues Drs Mikhail Erohin, Oleg Ponomarev and Maxim Kozhevin.
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Matching of CBCT and virtual wax-up for single-tooth replacement of a central incisor

Dr Jakob Zwaan, Netherlands

Although many smile design programmes offer us solutions for rendering of multiple-tooth replacements, very often in our daily practice we encounter major challenges when just a single tooth needs to be substituted. In order to estimate the risk of an unacceptable aesthetic final result of our treatment and to determine the most effective and predictable treatment plan, it is necessary, also in these cases, to perform an analysis of the desired tooth shape, the soft tissue architecture and the bone volume necessary to stabilise an implant in the optimal position and support the soft tissue. This analysis can be done using several means. In the traditional workflows, we asked our dental technician, after taking impressions of the dental arches and registering the occlusion, to perform a wax-up to obtain information about tissue volume available and needed. It was difficult to get from this hard model information about the lip line and gingival exposure, and before the era of 3D scanning, it was impossible to interface the teeth with the deeper anatomy. With the arrival of digital photography, video, intraoral scanners and CBCT scanners, our possibilities have grown enormously, thus raising the accuracy and predictability of our treatments.

In the following case report, the author will describe how he and his team approach cases in which a single tooth needs to be replaced by an implant-supported crown. Most of the procedures can be applied to more extensive cases, since the basic rules of implant dentistry are universal. After an anamnestic interview in which patient
expectations play a fundamental role, we proceed with the intraoral examination. Hygiene and periodontal health are checked, and if required, a session for calculus debridement, motivation and instruction is scheduled. Normally, the first radiographic examination performed is an intraoral radiograph for a single tooth (Fig. 1) or a dental panoramic tomogram if the need for a more extensive treatment is suspected. In the same session, both dental arches are scanned with an intraoral scanner and the bite is registered. A simple photographic sequence is followed:

1. Full frontal view intraoral photograph (Fig. 2).
2. Detailed photograph of the single arch, possibly with a black mirror to contrast the teeth (Fig. 3).
3. Photograph of laterolateral detail of the tooth and ginvival profile (Fig. 4).
4. Full-face photograph with maximum gingival exposure (Fig. 5).
5. Full-face photograph of a spontaneous smile (Fig. 6).
6. Photograph of the full face at rest.

This sequence allows one to view immediately the presence of orthognathic and periodontal issues (Figs. 1 & 2), to evaluate the biotype (Figs. 2 & 3) and to estimate aesthetic challenges, like tooth colour, tooth texture, soft tissue/lip exposure and position of the incisal edge/lip (Figs. 2 & 4–6). The 3D intraoral scan is extremely helpful for determining orthodontic alignment of the teeth and in our protocol replaces an occlusal and/or 12 o’clock photograph in most cases.

“There can be different ways of treating a disease, but there can be only one correct diagnosis.” Dr Morton Amsterdam, 1974. When anamnesis, intraoral examination and preliminary radiographs are sufficient to conclude that the tooth in question cannot be preserved, it needs to be decided what the optimal timing for extraction and a CBCT scan is and how to provide for a temporary tooth replacement. Also, the timing of implant placement is essential and the operator must choose between immediate, early or delayed placement in the fresh extraction socket. Will there be a (potential) need for bone augmentation and/or a soft tissue graft? In short, our policy is the following: in case of acute inflammation that cannot be effectively treated in a way that an infection of the future implant site will be prevented, we will proceed with extraction. A temporary fixed etch and bond or removable prosthesis can be used to guarantee acceptable aesthetic comfort to the patient. In these cases, a CBCT scan will be taken after extraction so that the most detailed image of the socket anatomy can be obtained. Since a provisional solution has been provided for, there is no need for very early implant placement. Timing is now based on the expected period needed for the infection to be eliminated and the risk of loss of volume by the collapse of tissue. Normally, the implant is placed four to six weeks after the extraction. Another reason for delayed implant placement can be the need for healed soft tissue in order to facilitate proper wound closure to protect, for example, bone substitutes and membranes when bone augmentation is necessary. Additionally, if the patient is suffering...
owing to the tooth that is to be extracted, it can be a reason to proceed quickly with the extraction, thus gaining time for adequate treatment planning and preparing for surgery and eventual immediate temporary crowns. If the anatomy and biological conditions are favourable, one can decide to proceed with implant surgery at an early stage after extraction, such as one week. Only in those cases in which there is no acute inflammation or infection, and sufficient bone and soft tissue quantity and quality are present is it recommendable to place the implant in the fresh extraction socket. Obviously, in such a case, the CBCT scan would be performed before proceeding. Minor bone augmentation and/or connective tissue grafting can be performed contemporaneously. The decision to place an immediate provisional crown on the implant is strongly related to the expected primary stability of the implant, as well as the opportunity to manage the position of biomaterials in such way that undisturbed and uncontaminated healing is guaranteed. After healing, good aesthetics and sufficient protection of the underlying implant and implant–prosthesis connection are requisite if we wish to treat our patients in the best possible way and earn their long-term trust.

Risk evaluation

First aesthetic risk evaluation
A very simple tool to start with can be a render of a 2D photograph. We use the macro intraoral shot with the black background behind the teeth (Fig. 3). With Adobe Photoshop, GIMP, Microsoft PowerPoint or Keynote, for example, it is possible, with little time invested and no expense, to cut out the shape of the contralateral tooth that will not be extracted, copy it, flip it horizontally and paste it in the position of the tooth that needs replacement. It will be clear immediately whether this shape, which provides for symmetry, supports the papillae sufficiently or whether there is a lack of volume that needs to be compensated for (Fig. 7). Another trick is to use this image with the flipped contralateral tooth and align it with the original photograph and then draw a horizontal line across both images that coincides with the same gingival reference points. This will demonstrate whether there is a vertical component that indicates a lack or abundance of soft tissue (Fig. 8). This can be easily quantified in a metric system if an intraoral reference is measured with a calliper. We can now inform the patient whether an additional procedure like guided bone regeneration (GBR) or a connective tissue graft will be needed, which can be helpful for informed consent and financial planning.

Second risk evaluation
The intraoral scan is imported into CAD software and transformed into a virtual master model without the tooth to be extracted and a separate STL shape of the ideal CAD-designed tooth (Fig. 9). Now there is the opportunity for 3D evaluation of the dimensional relation between the new tooth and the soft tissue before extraction. In the current case, the tooth involved had not been extracted and a CBCT scan was performed (X-Mind trium, ACTEON; 110 x 80 mm field of view; 0.15 mm voxel size) for further investigation and treatment planning. In the AIS 3D App...
software that comes with the CBCT X-Mind trium device, STL files can be matched and aligned with the 3D bone volume, thus giving the opportunity to plan the future implant position taking into account the shape and position of the future crown (Figs. 10a & b). In accordance with the prosthetic procedure preferred, cemented versus screw-retained, CAD/CAM-fabricated versus manual layering and the type of material to be used, all the information for the final treatment plan is available, on which decisions can be made regarding GBR, connective tissue graft and timing of implant loading.

Case report

The female patient, aged 47 and a non-smoker, was in good general health. She performed regular oral hygiene and had good periodontal health. The patient experienced increasing mobility of the maxillary left central incisor and complained about compromised aesthetics due to the extrusion and progressive migration of the tooth in a buccal direction. The incisor had been treated with a crown at a preadolescent age after a violent trauma. The intraoral radiograph showed incomplete root development and evidence of a root canal therapy suggesting a strip perforation though no signs of periapical lesions were present. The shape of the crown was not symmetrical in relation to the triangular shape of the maxillary right central incisor, but had a wider and rectangular profile. Minor general gingival recession had led to the presence of a tiny inter-dental space. The marginal gingiva was reddened, and the central papilla was not symmetrical. Probing depths were within 2 mm for both the right and left central incisors and the radiographic mesial and distal bone peaks were of a regular height.

The photographic aesthetic evaluation showed that it would be very difficult to obtain symmetry in tooth shape and have good-looking and healthy soft tissue support at the same time. The patient's maximum smile exposed the gingival contours. In such cases, it may be wise to consider also the possibility of altering the anatomy of the contralateral tooth with, for example, a ceramic veneer and discuss outcomes with the patient before finalising...
the treatment plan. This can be evaluated by performing the cut/copy/flip/paste sequence in reverse (Fig. 7). Together with the patient, it was decided to start performing the best possible replacement of the maxillary left central incisor and evaluate at an advanced stage with a temporary crown on the implant and mature, conditioned tissue whether to add a veneer to the maxillary right central incisor.

**Analysing the CBCT scan**

It became evident that the short-rooted tooth could be extracted without compromising the buccal bone, and that there was sufficient bone volume and quality to obtain good primary stability of the implant. Thanks to the AIS 3D App software, this information can be visualised using the bone density tool and linear measures tool (Fig. 10c) and represented in a graphic or according to a coloured scale. The presence of the nasopalatine duct prohibited ideal palatal positioning of the implant, and if the implant were to be placed flush with the palatal alveolar bone, this would have resulted in a 1.5–2.0 mm high exposure of the implant collar on the buccal aspect (Fig. 11a). This information, combined with the aesthetic analysis, led to the decision to place the implant in that position and to augment the buccal bone volume with a contemporaneous GBR procedure, thus also providing for major soft tissue support. As often described in the literature, it is to be expected that in some measure the implant will deviate buccally from the original planning because of the major mechanical resistance of the palatal plate. The author’s team prefers whenever possible screw-retained solutions. Several production centres are capable of milling angulated screw access holes in cobalt-chromium abutments of up to 25°, which is a range that covers most cases in daily practice. It can be easily checked in the implant planning software whether the future access hole will exit on the palatal aspect of the tooth, either by angulating the implant extension tool or by choosing a virtual abutment from the library. Confirming being in the safety range from this point of view allowed for an approach that foresaw the implant in native bone without the necessity for major GBR on the apical aspect of the implant. Knowing that a flap needed to be raised to facilitate the marginal tissue augmentation, it was decided to use a surgical guide (Figs. 11a & b) for only the first drill to determine with precision the position and angulation of the osteotomy that would be performed freehand thereafter. In order to limit
surgery time and eliminate unpredictable factors inherent in immediate loading, a removable temporary prosthetic tooth was produced in advance.

**Surgery**

Local anaesthesia was performed with 2% mepivacaine with 1:100,000 adrenaline. Preventative antibiotic therapy with amoxicillin (1 g, b.d. for five days) was prescribed, aided by use of a 0.2% chlorhexidine mouthrinse three times a day for one minute. The tooth was extracted and the sulcular epithelium removed with diamond burs. The milled surgical template (Figs. 12 & 13) served as a guide for the first 2 mm diameter pilot drill (Fig. 14). Thus, the planned depth, position and angulation of the osteotomy were obtained. The drill sequence was completed free-hand, using tapered 3.0 and 3.4 mm drills. A Neoss Pro-Active Tapered Implant of 4 mm in diameter and 13 mm in length was inserted flush with the mesial/palatal/distal bone, motor driven up to a torque of 50 Ncm and then with a manual wrench (Fig. 15). The correct position of the internal hex was verified by checking the references on the implant driver, which ideally points in the buccal direction. Resonance frequency analysis with Penguin-RFA (Integration Diagnostics Sweden) determined an ISQ value of 73/76. At this stage, a Neoss Esthetic Healing Abutment with a ScanPeg was connected to the implant (Fig. 16). A flap was then raised after a vertical incision of the frenulum and the expected buccal exposure of the implant neck was evident. Autogenous bone harvested from the drills was positioned directly on the implant surface (Fig. 17), followed by a bone substitute on top of it and on the buccal cortical bone (Fig. 18). This material was covered with a resorbable membrane (Fig. 19). The mobilised flap was then repositioned by rotating it coronally and fixed with single sutures (Fig. 20). An immediate postoperative CBCT scan of 60 x 60 mm was performed, and it confirmed a perfectly centered implant position (Figs. 22 & 23).

**Intraoral scan**

Eight days after surgery, the patient reported that healing was uneventful and the prosthodontist removed the stitches. It has become the author’s standard protocol to perform an intraoral scan for implant position in this same session (Figs. 24 & 25). The specific and
unique PEEK healing abutment used has an internal circular channel and on one side, normally positioned on the buccal aspect, a vertical rectangular slot (Fig. 26). After removing the PTFE tape used to plug this area during surgery, a ScanPeg can be positioned inside the healing abutment. This allows for a unique scanning procedure without removing the healing abutment, thus avoiding disturbing healing tissue or dislocating recently placed biomaterials. The producer provides libraries for STL files of the five different anatomical shapes—wide incisor, narrow incisor, canine, premolar and molar—that determine the basic profile of the gingival tunnel during healing.

Temporary crown

The surgeon indicated that the healing abutment may be removed after four weeks. By then, the temporary screw-retained crown had already been fabricated by the technician, who had prepared a CAD/CAM-milled acrylic tooth glued on to a Neoss NeoLink abutment (Figs. 27–30).

As a result of the decision to place the implant entirely in native bone, the angulation was such as to locate the screw access hole of the provisional on the buccal aspect. This can be easily camouflaged by a simple composite filling after plugging the channel with PTFE tape. The gingival profile copies in this first stage of loading the central incisor anatomy of the Neoss Esthetic Healing Abutment (Fig. 31).

Tissue conditioning

As evidenced by the aesthetic analysis before treatment, it was clear that symmetry with the contralateral incisor would be impossible. The implant was placed slightly distal because the distal papilla normally has a narrower mesiodistal basis than the central papilla. The tissue volume augmentation helped to obtain the necessary quantity of gingiva to shape nice papillae, leaving a minimal gap. The soft tissue architecture was conditioned (Fig. 32) by adding composite to the temporary crown and grinding ma-
material where necessary until the prosthodontist and the patient felt an optimal result had been achieved.

Transfer of the profile

A new intraoral scan sequence was performed. First was the scan of the full arch with the temporary crown in place. The provisional was then removed from the mouth and screwed on to an implant replica fixed to a stable support with wax. The second scan revealed in 360° the modified shape of the temporary crown, including the gingival profile (Fig. 33). These files can be easily matched in the CAD software when the technician designs the definitive crown (Figs. 34–36). If a monolithic material is used, the technician may copy the entire shape of the temporary. When a support is needed that will be layered with ceramic afterwards, at least the gingival profile can be duplicated in a reliable way.
Definitive crown

The author strongly prefers screw-retained devices. Owing to the angulation of the implant, it was necessary to relocate the screw access hole. In CAD, the design for a cobalt-chromium support that copied the gingival profile of the temporary was prepared, and the screw access was brought to the palatal aspect (Fig. 37). The file was sent to the Arc solutions milling centre in Helsingborg in Sweden. High-quality material and CAM production guarantee an excellent outcome in terms of connection and smooth surfaces (Figs. 38–40). The technician layered feldspathic ceramics to obtain the final anatomy and texture. The patient was totally satisfied with the result and did not wish for intervention for the maxillary right central incisor. Minor gingival asymmetries, though evident at high magnification in photography, are not really disturbing when viewed at social distance if all other parameters, like colour, incisal edge, tooth texture, correct proportion of the incisal two-thirds of the tooth and transitions, are respected (Figs. 41–43).

Conclusion

Innovative technologies enable extremely accurate diagnosis and treatment planning. Affordable high-quality CBCT has profoundly changed our profession. In the current case, the detailed X-Mind trium 3D images allowed for planning and performing implant placement in the optimal mesiodistal position. Correct distances to the lateral incisor and the nasopalatine duct were obtained. Final choices will always remain related to the experience, skills and equipment of the performing team. After collecting all of the necessary information and knowing what technology can provide, it is possible that one team will opt for GBR and monolithic crowns, where another might try to minimise the invasiveness of surgery and employ innovative milling strategies to deliver a predictable, beautiful solution. In the actual challenging buccopalatal dimension, the implant was perfectly planned and guided into the centre of the native bone. Guided bone regeneration was limited to the minimum and minor buccal exposure of the implant was predicted. Reviewing the case described above, the fact that bone volume could be matched with the dental preoperative situation and the CAD virtual wax-up made the whole procedure, from extraction to final restoration, highly predictable. Bone volume, bone quality, extent of GBR indicated and the type of prostodontic solution were all known before starting treatment thanks to the implant planning with the AIS 3D App software. Both the clinician and patient were well informed and prepared, avoiding surprises, improvisations and unnecessary stress. New developments like smart, scannable healing abutments will help to continue creating treatment outcome and comfort improvements.

Editorial note: A list of references is available from the author.

contact

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CBCT is an advanced diagnostic used in modern dentistry. However, many clinicians still have not mastered CT systems, as this requires good awareness of viewer software, image preparation skills and knowledge of radiographic anatomy. It takes a dentist over 20 minutes to properly analyse a CBCT image. In a real-world setting, a dentist has only a few minutes for image interpretation during a patient visit. As a result, the region of interest is narrowed down to several teeth, while the majority of other medical conditions remain off record. Additionally, when a patient shows a dentist images obtained with different CT systems, the dentist needs some time to adapt to the new software, even if it is much like the others. In other words, image interpretation is subjective and depends exclusively on the clinician’s experience and skills. This may lead to diagnostic discrepancies and cause difficulties affecting the accuracy of dental diagnosis and control of diagnosis and treatment plans. Diagnocat is a powerful tool in which computer vision assists human in the detection and characterisation of the anatomy and most often pathologies affecting the jaws.

At the core of Diagnocat is a system of 3D neural nets. The nets are designed and taught to function collaboratively. For example, one net finds an approximate position of a tooth, another one precisely defines the tooth boundaries and the next one predicts its conditions and pathologies. Datasets have been assembled for each of the nets, specific to their type and function. In addition to this system of neural nets, Diagnocat uses multiple algorithms and heuristics, which turn raw outputs from the neural nets into reports and imagery that are easy for dentists to understand. Diagnocat’s artificial intelligence analyses 3D dental studies in DICOM format. The innovative solutions of Diagnocat allow a dentist to save effort and time when analysing CT images and concentrate on treatment, offering the patient the best plans and retaining control of the outcome. Diagnocat allows a dentist to evaluate CBCT images obtained with any CT units without using the conventional software (viewer). The software has a convenient, intuitive interface.

**How does Diagnocat work?**

A neural network, while processing DICOM files of CT images, finds and segments the main anatomical regions (jaws, teeth, periapical space). Diagnocat identifies various conditions and disorders by assessing 50 signs (normal appearance, filling, crown, treated root canal, implant, sign of periapical lesion, etc.). Diagnocat helps the dentist to quickly make a diagnosis in the region of interest, evaluate the overall state of the teeth and jaws, and select images to aid preparation for dental implant placement or root canal therapy.

**Diagnocat cloud service**

To use the service, a dentist needs a computer connected to the web. A desktop, laptop or tablet are all suitable. CT images and reports are stored in the dentist’s personal account (Fig. 1). The dentist thus receives a data storage system platform in which data may be arranged by patient name, medical condition, and creation and modification dates. CT images may be transferred from dentist to dentist in a protected protocol involving no file transfer procedure. Immediately after uploading files, the dentist obtains access to Diagnocat Viewer, which automatically produces:
1. panoramic view of various thicknesses (Fig. 2);
2. a set of slices in three planes for each tooth (Fig. 3); and
3. a patient report to inform the patient and to motivate him or her to continue and complete treatment (Fig. 4).

![Fig. 1: View of dentist’s personal account. Fig. 2: Separate panoramic image of 7.5 mm in thickness. Fig. 3: Tooth visualisation.](image)
Apart from a panoramic image, a patient report contains the dental chart with annotation in colour: teeth with findings requiring the dentist’s attention are marked in red. Other interactive report formats may be generated and obtained from Diagnocat at the dentist’s request.

**Diagnocat Report**

In addition to tooth slices, the system generates a textual description of each tooth after analyzing over 50 parameters: anatomical structure, status post-treatment, and signs of crown, root, canal and peri-apical space abnormalities. The dentist has an opportunity to define an area of dental interest so that only selected teeth are included in the printout. The dentist can also make changes to the descriptions.

**Diagnocat Implant**

The most frequent indication for CT is implant planning. Diagnocat automatically generates images that an implant surgeon would need. The only thing the dentist needs to do is select a region of interest. Diagnocat will illuminate the mandibular canal and the bottom of the maxillary sinus, and will make measurements between key points.

**Diagnocat Endo**

Complicated anatomical structures of roots and canals require careful studying of the image by the treating dentist; however, it is not so easy to understand 3D views. A dentist often has to work under time pressure while the patient is waiting. Diagnocat comes to the rescue. The dentist just needs to select a tooth and all images (roots, canals, apical damage areas) will be ready within one minute.

**Diagnocat and medical records**

Diagnocat enables recording of diagnostic protocols in just a few clicks. Medical record entries will always be correct, as the

Diagnocat terminology has been carefully examined by an experienced dentomaxillofacial radiologist. Images can be added in only a few seconds. Accurate and fast processing of CT images by the artificial intelligence of a neural network offers exciting diagnostic opportunities.

The company is exhibiting at this year’s International Dental Show in Cologne in Germany (Hall 2.1, Booth C089).

www.diagnocat.com
New intraoral scanner

Primescan perfects digital impressions

Easier than ever, faster than before, more accurate than previously possible—all describe Primescan, the new intraoral scanner from Dentsply Sirona. With its completely new, patent pending digital impressioning technology, Primescan enables high-precision digital impressions to be taken of the entire jaw. These scans present numerous possibilities for users. Primescan was designed for various digital workflows—with the laboratory directly in the practice, with CEREC, or in cooperation with external partners. Validated interfaces noticeably simplify the process, offering dentists the flexibility they desire.

What was considered an absolute sensation more than 30 years ago is almost taken for granted today. In terms of quality, digital intraoral impressions are in no way inferior to conventional methods1, and therefore, are becoming a reliable alternative for taking impressions of both individual teeth and the entire jaw for more and more dentists. Dentsply Sirona introduced the digital impression to dentistry with CEREC. Now, with Primescan, the company is introducing an intraoral scanner with outstanding technology, which enables scans that are more precise than anything we have known before. This has been substantiated by a new study at the University of Zurich.2 “Dentists rightly expect products and solutions from Dentsply Sirona, that make their work at the dental practice easier, safer and better,” says Dr Alexander Völcker, Group Vice President, CAD/CAM and Orthodontics at Dentsply Sirona. “Primescan is the solution to an important issue in practices—the option of faster, precise impressioning—which is easy to manage in the usual practice environment, which is reliable, which delivers clinically flawless results, and which is simply fun to use.”

Scans up to 20 millimetres in depth

Primescan’s optical impression system has been decisively developed. The scan of the surfaces of the teeth is performed with high-resolution sensors and shortwave light, capturing up to one million 3D data points per second. With optical high-frequency contrast analysis, they can now be calculated more accurately than ever before. Dentsply Sirona has submitted a patent application for this process. With Primescan, it also is possible to scan deeper areas (up to 20 mm). This enables digital impressions even for subgingival or particularly deep preparations. Virtually all the tooth surfaces are captured, even when scanning from very shallow angles. Primescan captures the dental surfaces immediately, in the required resolution and with a high sharpness even at great depths, thereby ensuring a much more detailed 3D model.

To monitor the scanning process simply and easily and to be able to assess the model immediately, the accompanying Primescan AC acquisition center has a modern touchscreen that pivots and swivels as needed to ensure it is always set to the most favourable ergonomic position. Dentists acknowledge the intuitive operation

Fig. 1: Primescan—the new intraoral scanner from Dentsply Sirona that takes digital impressions to the next quality level. Fig. 2: Thanks to the smooth surfaces of Primescan and the acquisition center, the hygienically critical areas, which are often difficult to clean, can be reprocessed safely, quickly and easily.
and high level of comfort during first-time use, which is also greatly appreciated by patients.
Primescan also scores in terms of hygienic safety. Thanks to the smooth surfaces of Primescan and the acquisition center, the hygienically critical areas, which are often difficult to clean, can be reprocessed safely, quickly and easily.

Comprehensive range of applications
The precise scanning technology enables Primescan to be implemented universally. Not only does it produce high-precision images of natural teeth and preparations, it also provides extremely accurate images of other materials commonly used in dentistry. For example, implant specialists appreciate the simple impressions of edentulous arches or sites with implants, and orthodontists highly rate the detailed scan results for soft tissues (gums, frenulum). With this new scanning technology, impressions can be completed very quickly. A full jaw impression, including model calculation, is complete in just two to three minutes.

Maximum flexibility for further processing of the scanned images
With Primescan, users can leverage the full potential of digital processes for better treatment. The modular concept offers a suitable solution for every need within the practice. The digital 3D model can be transmitted to a laboratory via the new Connect software (formerly Sirona Connect), and can also be further processed with different software, e.g. for orthodontic or implant treatment planning. The newly developed Connect Case Center Inbox enables laboratories around the world to connect to the Connect Case Center. In the process, validated scan data from both Primescan and Omnicam can be received easily for further processing in the desired programmes and workflows. Alternatively, the restoration can be planned and manufactured in the practice using the new CEREC software 5, with its pleasing fresh, new design, intuitive touch functionality and noticeably improved screen resolution.

Dr Alexander Völcker expresses his confidence: “Digital impressions with Primescan are the starting point for other exciting digital processes without limiting the future decisions of dental practices. With our seamless solutions and validated workflows with external partners, we are setting new standards, which, thanks to digital technologies, enable even better dentistry.”

Due to various certification and registration periods, not all products are immediately available in all countries.

Dentsply Sirona at IDS 2019
“Inspired by your needs” is the motto under which Dentsply Sirona will demonstrate at the IDS 2019 how it is redefining dentistry. From 12 to 16 March 2019 in Halls 10.2 and 11.2, dentists and dental technicians can look forward to revolutionary technologies and equipment for practices and labs, and simpler, more clinically safe solutions along with an attractive trade show bonus.
Visit our website www.dentsplysirona.com/ids.

Editorial note: A list of references is available from the publisher.
Cooperation between Dentsply Sirona and exocad

Digital workflow in the practice and laboratory

Dentsply Sirona, the world’s largest manufacturer of dental products and technologies, and exocad, one of the leading dental CAD/CAM software manufacturers for the dental lab, have announced their extensive cooperation in the field of digital dental workflows. International customers of both companies will now benefit from the direct transmission of digital impressions from Dentsply Sirona’s intraoral scanners to exocad labs. Furthermore, both companies will align elementary interfaces between the inLab hardware and exocad software and, among other aspects, implement Dentsply Sirona tooth lines and material-specific parameters in the DentalCAD software from exocad.

Flexible open systems play an important role in digital dentistry. At the same time, ensuring the maximum compatibility of the systems used in practices and labs is becoming increasingly important to design reliable and efficient digital workflows. Considering these objectives, the cooperation between Dentsply Sirona and exocad offers completely new options in the digital production chain.

Validated workflow for digital impressions

Thanks to this cooperation, dental practices with Dentsply Sirona intraoral scanners will now, for the first time, be able to work with exocad laboratories in a validated workflow and transmit digital impressions conveniently and directly for a broad range of indications. Using the new software application, Connect Case Center Inbox from Dentsply Sirona, exocad labs have direct access to the complete intraoral scan and order data in the Connect Case Center Portal.

“With the connection of exocad labs to Dentsply Sirona’s intraoral scanners, the digital production options based on intraoral impression data for practices and dental labs around the world are expanded,” explained Dr Alexander Völcker, Group Vice President CAD/CAM & Orthodontics, Dentsply Sirona. “Furthermore, the high level of scanning accuracy offered by our new intraoral scanner Primescan is set to inspire digital dentistry among numerous dental practices and labs.”

An application-oriented approach to developing digital dental technology

This cooperation also comprises the alignment of data interfaces between the exocad DentalCAD software and the inLab CAD/CAM components from Dentsply Sirona, such as the highly accurate scanner inEos X5, and the laboratory production units, inLab MC X5 and inLab MC XL. Above and beyond this, the material-related design parameters of selected Dentsply Sirona CAD/CAM materials and dental databases will be integrated in the exocad software.

“The integration of material parameters and tooth lines in the DentalCAD software offers exocad users additional advantages, as well as enhanced process safety in terms of indication-tailored designs and reliable workflows in the lab”, explained Tillmann Steinbrecher, the CEO of exocad.

The cooperation between these two dental companies not only promotes digital dental technology and dentistry as a whole, but also the position of the individual user groups—for even safer and more efficient dentistry.
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Nobel Biocare Global Symposium in Madrid to open new chapter in implant dentistry

A new and revolutionary chapter for implant dentistry will open this summer in Madrid. At the upcoming Global Symposium, the first of three international events hosted by Nobel Biocare, outstanding developments in the field of implant design and site preparation will be unveiled. Supporting these groundbreaking innovations will be new advancements in implant surface technology, as well as long-term implant care.

Leading international clinicians—all experts in their field—will be onsite in Madrid to share their experiences with the new technology and products. They will also demonstrate how these can help clinicians to further shorten time-to-teeth and to improve long-term clinical results. Participants will be able to further explore the innovations and more through a number of dedicated hands-on sessions and product demonstrations.

Held at the Marriott Auditorium Hotel and Conference Center from 27 to 29 June, the Nobel Biocare Global Symposium in Madrid is kicking off the new global event series which was announced last year to extend the originally planned Nobel Biocare Global Symposium 2019 in Las Vegas. Following the meeting in the Spanish capital are two additional Global Symposia in Las Vegas in 2020, as well as in Tokyo in 2021. Through this unique event concept, more dental professionals than ever will be able to experience firsthand this new wave of innovations by Nobel Biocare.

Commenting on the upcoming events and launches, Hans Geiselhöringer, President of Nobel Biocare said: “We are excited to welcome dental professionals from all over the world to Madrid in June where we will present the next revolutionary steps in dental implant care with a host of new and forward-thinking innovations. With two more events to come, it will be a once-in-a-generation opportunity to experience true game changers in implant dentistry.”

More information about the Nobel Biocare Global Symposium events series, as well as how to register for the kick-off meeting in Madrid, can be found online at www.nobellbiocare.com/global-symposia. Dental professionals who have already registered for the original Nobel Biocare Global Symposium in Las Vegas will be given the opportunity to transfer their registration to any of the three upcoming events.
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Please note that all the textual components of your submission must be combined into one MS Word document. Please do not submit multiple files for each of these items:

- the complete article;
- all the image (tables, charts, photographs, etc.) captions;
- the complete list of sources consulted and
- the author or contact information (biographical sketch, mailing address, e-mail address, etc.).

In addition, images must not be embedded into the MS Word document. All images must be submitted separately, and details about such submission follow below under image requirements.

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Article lengths can vary greatly—from 1,500 to 5,500 words—depending on the subject matter. Our approach is that if you need more or less words to do the topic justice, then please make the article as long or as short as necessary.

We can run an unusually long article in multiple parts, but this usually entails a topic for which each part can stand alone because it contains so much information.

In short, we do not want to limit you in terms of article length, so please use the word count above as a general guideline and if you have specific questions, please do not hesitate to contact us.

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We also ask that you forego any special formatting beyond the use of italics and boldface. If you would like to emphasize certain words within the text, please only use italics (do not use underlining or a larger font size). Boldface is reserved for article headers. Please do not use underlining.

Please use single spacing and make sure that the text is left justified. Please do not centre text on the page. Do not indent paragraphs, rather place a blank line between paragraphs. Please do not add tab stops.

Should you require a special layout, please let the word processing programme you are using help you do this formatting automatically. Similarly, should you need to make a list, or add footnotes or endnotes, please let the word processing programme do it for you automatically. There are menus in every programme that will enable you to do so. The fact is that no matter how carefully done, errors can creep in when you try to number footnotes yourself.

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- We require images in TIF or JPEG format.
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You may submit images via e-mail, via our FTP server or post a CD containing your images directly to us (please contact us for the mailing address, as this will depend upon the country from which you will be mailing).

Please also send us a head shot of yourself that is in accordance with the requirements stated above so that it can be printed with your article.

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**Author or contact information**

The author’s contact information and a head shot of the author are included at the end of every article. Please note the exact information you would like to appear in this section and format it according to the requirements stated above. A short biographical sketch may precede the contact information if you provide us with the necessary information (60 words or less).

**Questions?**

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