Digital Dentistry: Promise, reality and the role of software standards

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Up until now, dentistry was mostly carried out in the “analogue” world: X-rays were examined on film, patient information was recorded on paper, impressions were poured in plaster to create models, models were waxed and physical dental articulators were used. Today, certain steps of the process can be done digitally, but they are still digital islands in an otherwise analogue sea. For example, parts of the implant treatment planning are carried out digitally in the virtual environment. However, the surgical guide is still needed as a physical tool. Even in the so-called digital workflow of fabricating a restoration, a physical model is usually still required to test the fit of the crown.

This results in numerous switches between the traditional and the new (digital) world. In our view, digital dentistry is developing to a world where patient and in-mouth product (bridge, crown, etc.) are analogue, but everything in between becomes digital[1].

Today’s reality

Most people will agree that digital technology offers tremendous advantages for dentistry: it adds flexibility, convenience and precision in addition to saving time and costs. CAD/CAM has the potential to revolutionize the dental prosthetics market. Many scanning modalities are available and dental elements can be designed on CAD stations after which they can be produced in a wide variety of milling or 3D printing machines. The promise is faster production, more accurate and cheaper dental elements.

Although these options already exist, the vast majority of dental elements are still produced in the traditional way and the market for digital dentistry is only growing slowly. Customers seem to be confused by the many different and incompatible offers in the market. If, for example, a dental technician would like to design a multi-unit bridge, a custom implant abutment and a coping he is planning to produce in his own laboratory in one working day, he probably has to use three different kinds of dental design software. Although the design software is similar, one solution may not allow for in-house production and another may not be suited for the design of implant abutments.

Dental professionals feel that they have only two choices: to be locked in by one supplier with an end-to-end solution or to find their way in many incompatible systems, without guarantees. This may be one of the reasons that digital dentistry is not being incorporated into the dental field as fast as might be expected.

End-to-end solution

The first option is selecting a proprietary CAD/CAM system with closed interfaces of a single supplier. As indicated in Figure 1, the user may choose between different scanning devices such as an intra-oral and an extra-oral scanner as well as diverse manufacturing procedures, like in lab or centralized production, milling or rapid prototyping.

Some suppliers offer end-to-end systems, starting with a proprietary scanner and finishing with a proprietary milling machine or centralized manufacturing solution. Some others lock the customer into a scanner and software solution while leaving the choice of manufacturer to the dental professional. Others are open to multiple scanners but
lock the dental design to the manufacturing solution.

The reason that manufacturers are selling proprietary solutions can be explained by the fact the technology is relatively new. Ten years ago, a company had to do everything from scanning to milling to be able to ensure a precise fit of the resulting crown. Times are changing however, more and more scanning technologies become relevant for dentistry (IO, CBCT, lab scanning) and more manufacturing technologies become available (e.g. 3D printing).

As is the case in many other industries that went through digitalization, no single supplier will provide an end-to-end solution in the future. Already, many companies are creating an open architecture of their previously closed systems so that it is now possible to connect scanners from multiple suppliers to various brands of design software and export to multiple manufacturing solutions. There are less and less technical arguments for proprietary end-to-end systems.

The reasons some dental companies stick to proprietary solutions anyway are primarily to protect their past investments and because it is the only approach they are familiar with. The result for the dental professional is that he either has to invest in multiple incompatible systems or decide not to provide certain indications in his business portfolio.

**Future steps**

Proprietary systems are less and less appreciated by dental professionals and dental companies will not be able to develop the required innovations within their solutions. Therefore, it is evident that changes are needed. One of the most important developments is a standardization of software formats that will allow partial solutions of multiple suppliers to work together in an improved way. The initiatives that strive towards a standardized format include the DICOM project to create standards in the prosthetics value chain and the initiative from Straumann (CH-Basel), 3M ESPE (D-Seefeld) and Dental Wings (CA-Montreal) to create a standard for prosthetic design software.

**Standardization according to DICOM**

There is one basic set of standards for image file format, and those are defined in the international DICOM (Digital Imaging and Communications in Medicine) Standard[2]. This is the International Organization for Standardization (ISO) referenced standard for image format and communications that was formed to facilitate the open exchange of medical images and associated information between different devices. It covers all images including visible light and radiographic procedures including simple transmission images, CT, CBCT, MRI, ultrasound, etc. (for further information,
also see DIGITAL_DENTAL.NEWS, May 2007, p. 65-66). The DICOM Standards Committee has 27 active working groups including WG 22 (Dentistry) and WG 24 (Surgery)[3]. These working groups often work together to advance the DICOM Standard and have recently collaborated to develop new supplements for intraosseous implants, including those used for dental implantology.

A project initiated by WG 22 of the DICOM Standards Committee has started in 2011 to extend the DICOM Standard to the prosthetics value chain. At first, a standard between dental scanners and dental design software will be defined. After that, a standard between dental design software and manufacturing devices will be created. Many dental companies are involved, both small and large. The project was approved at the end of 2010 and has started in early 2011. The project is expected to be finalized in 2012 or 2013.

The fact that a DICOM Standard can work in dentistry is shown in the dental surgery value chain which has benefited from this standard for many years. For example, third party pre-operative planning software works with data from any CBCT scanner, as long as that scanner generates DICOM compatible results. There is no technical reason for a pre-operative planning company to develop their own CBCT scanner. In addition, there is no technical reason for an oral surgeon or an implantologist to own more than one CBCT scanner.

**Standardization of dental design software**

Another initiative that strives for standardization – in this case of design software – was formed in early 2011. The three companies Dental Wings, 3M ESPE and Straumann have announced at the IDS 2011[4] that they are joining forces to create an open global standard software platform for use across a range of dental applications (Fig. 2).

The software will be completely independent of scanning and manufacturing solutions. Both 3M ESPE and Straumann have adopted the software platform of Dental Wings, DWOS, as the core operating solution in their CAD/CAM systems Lava Precision Solutions and Straumann CARES. This means that the dental technician can now design his multi-unit bridge fabricated in a milling center, a premium CAD Abutment and a coping produced labside using a single software solution. DWOS already has well-established interfaces to the leading intra-oral and laboratory scanners (e.g. Cadent iTero, Straumann, and Lava Chairside Oral Scanner C.O.S., 3M ESPE) and milling devices as well as 3D printers of different suppliers (Figs. 3 and 4). As a result, the dental professional can choose between diverse options and, at the same time, benefit from defined and secure interfaces.
In order to ensure independence between the DWOS software and the scanners of the company Dental Wings and focus more intensely on software development, Dental Wings has split off its software business in a new entity called Open Digital Dentistry (ODD) (CH-Zug).

Since the three companies that started the initiative plan to establish a global software standard, other companies are invited to join the project at any time.

**DWOS**

The DWOS software was created by Dental Wings over the last four years. Interesting historic fact is that the software development started before the scanner was developed. This made it a lot easier to separate it from the scanners in 2011. The DWOS has open interfaces at both ends. This means that it allows importing scan files from different scanners and scanning technologies as well as exporting generic STL files that can be used for production employing any machine with open interfaces. Alternatively, the user can choose to get a specific file that can be exported to one milling device or proprietary workflow. The reason is that DWOS wants to provide an open interface to connect with open architecture devices as well as a secure connection with leading scanning and manufacturing processes. The latter allows guaranteeing the quality of the end result since it is possible to incorporate the specifics of material requirements (e.g. wall thickness) on specific manufacturing devices (e.g. milling versus laser sintering).

Secure integrations are provided on the scanners side e.g. with Cadent iTero and Lava C.O.S., as well as multiple lab scanners like Lava Scan ST (3M ESPE), Straumann CARES Scan CS2 (Straumann) and 3Series, iSeries and 7Series (Dental Wings) (Figs. 5 to 7). The company Open Digital Dentistry is planning to connect more scanner types and brands in the future. The same applies on the manufacturing side where tight integrations are provided with the leading milling and laser sintering machines. Also here, further connections will follow, soon.

**Software modules of DWOS**

The main screen of the software offers an overview of the workflow. There are five icons in the top menu bar that show the basic workflow of DWOS: it begins with creating the order in an order form where the user indicates which prosthetic element will be designed for whom (it will contain...
information about dentist and patient). The second icon represents the scan import application. The scanner can either be present near the design station or the scan data is imported as a file from a scanner elsewhere in the world. The third icon is the CAD engine that provides the automatic proposals based on the specification provided in the order and the scan information. The fourth icon is the CAD application that allows changing or optimizing the automatic proposal and the fifth icon addresses the production management.

The DWOS software consists of the five modules that can be used independently or as an integrated suite.

**Crown & Bridge**

The DWOS Crown & Bridge module is the foundation of prosthesis design. This software allows designs from coping to full contour, from a simple unit to a full arch design. The framework designs are dynamically adjusted to the full restoration morphology to allow optimum porcelain support.

In this module, a wide range of editing tools is available. These include a tool for insertion axis modification, a virtual wax knife (allowing adding, removing and smoothing material) and clinical handles (enabling to correct morphology, to control contacts points with adjacent teeth, and antagonist teeth). In addition, global transforms are available allowing rotations from buccal to lingual and from distal to mesial as well as free scaling and positioning of the design object (Fig. 8). Simultaneous designs of upper and lower arches, mirroring, and wax ups are possible as well. The latest 3.0 version of the DWOS software has integrated a virtual articulator and has significantly increased the capabilities to come with automatic proposals to save the dental professional time. Figure 9 shows the change indication screen which allows altering the indication during the design process at any time without restarting the full procedure from the beginning. Examples include change from a simple coping to full crown, splitting of a bridge into three parts because of diverging preparations or removal of a pontic as a result of limited space.

**Implant Custom Abutment**

The design strategy of this module enables one-step design of custom abutments by taking into account the clinical situation. The anatomy of the patient is automatically computed to fit the designed implant abutment. An implant library is available so that the correct interface geometry is always deposited (Fig. 10). The framework design is dynamically adjusted to the prostheses morphology. In one design session, the custom abutment, the framework and the full contour design are obtained (Figs. 11 and 12).
Partial Frameworks
The Partial Frameworks module provides automated functions such as undercut measurement and block-out as well as free-form design tools that transfer a dental technician’s technical know-how into a digital environment: for example, clasps are designed and retention grids drawn and, if required, pins for artificial teeth and attachments can be added by the dental technician. Partial frameworks are designed in less than ten minutes (Figs. 13 to 15).

Virtual Model Builder
The Virtual Model Builder module meets specific requirements associated with the development of intra-oral and impression scan technologies. The DWOS Virtual Model Builder allows laboratories to replace their current manual model by generating a virtual one and producing it with their preferred manufacturing solution.

Manufacturing
The manufacturing modules, DWOS-CAM and DWOS-RPM, constitute the interface between the design and production environments. DWOS-CAM handles digital processes such as blank management and nesting, automatically takes into account the shrinkage factor and calculates the tool path.
trajectories for milling (Fig. 16). DWOS-RPM provides automatic generation e.g. of supports for rapid prototyping.

The network: Dental Hub System (DHS)

It may be expected that digital dentistry will allow dental professionals to specialise and focus on specific steps in the process or on specific indications. Prior to the integration of advanced technologies in the dental laboratory, one lab typically provided many indications and both design and manufacturing of prosthetics. Thus, the dentist was able to obtain all he required from one single laboratory. In the digital era, some dental professionals may decide to focus on design only or manufacturing only. Others may decide to focus on high margin elements such as bars which will be distributed to other laboratories or dentists in a much bigger geographical area. Distance becomes less important when physical products such as models are replaced by files that can be sent via the internet.

These trends lead to the need for dental networks that allow dental professionals to connect. The DHS (Dental Hub System) is such a network that has been developed over the last four years and is connected to the DWOS software. Currently, many milling centers use it to collect dental design files from their customers. In this case, all scanners which are used in laboratories in combination with DWOS are connected to the DHS and the order specification, file transport and order tracking are provided by this system. Being connected allows laboratories to optimize their investments, since they no longer have to own all the manufacturing equipment and processes.

The DHS provides a worldwide collaboration platform for dental professionals and service centres with real-time traceability. All DWOS users are DHS enabled and can connect to the fastest-growing open dental network.

**DWOS in the market today**

The installed base of DWOS has grown to thousands in the four years since the product was introduced. After the announcement of 3M ESPE and Straumann that they are using DWOS as the core of their prosthetics offering, it is expected that further dental companies are going to join the project and contribute to improved compatibility in the dental CAD/CAM market. An interesting example of a company that has joined the platform is biodenitis (D-Leipzig) which is integrating Dental Wings’ DWOS software platform in its CAD/CAM system. The company will offer custom abutments for all leading implant systems, in addition its own Infix technology that will be an additional indication in the DWOS software. A shared standard software platform enables companies like biodenitis to provide integrated workflows to their customers. At the same time, it does not prevent them from competing for prosthetic business with other companies that also use DWOS.

**Conclusion**

Digital dentistry has already become part of the everyday work processes in the dental practice and laboratory. It is clear that changes among dental professionals and suppliers of dental technology are required to deliver on the promise of digital dentistry and make the market grow. Some suppliers have started to change their previously closed systems and provide solutions with open or selectively open interfaces. Others are still selling their closed proprietary end-to-end systems. This paper has hopefully shown that it is not a black and white discussion. It is possible to provide the dental professional with multiple options regarding the whole production process and materials while still ensuring a secure connection to leading scanning and manufacturing solutions. A software platform like DWOS may be the basis for successful standardization.
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References


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