Dental technician of the future

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ABSTRACT
The new technologies in the field of dental science have not only changed the way in which dentists run their practice but have also dramatically changed the procedures carried out in dental laboratories. Mechanical engineering, incorporated CMM, laser milling, 3D printing and 3D design in a mechanical tool shop are a few of the fields in which novel dental technologies are emerging.

There has been a tremendous shift towards digital approaches in the dental environment, which has subsequently changed the way of thinking and the daily procedures of all those involved in dental treatment.

The aim of this article is to compare the traditional laboratory workflows with currently applied techniques and explain the latest digital developments determining the future role of the dental technician.

INTRODUCTION
The new technologies in the field of dental science have not only changed the way in which dentists run their practice but have also dramatically changed the procedures carried out in dental laboratories. Mechanical engineering, incorporated CMM, laser milling and 3D design in a mechanical tool shop are a few of the fields in which novel dental technologies are emerging.

Manual waxing up and casting in gold or (precious) metal alloys have given way to computer-aided design (CAD) and computer aided manufacturing (CAM). Milling and printing of implant-supported fixed dentures and superstructure frameworks are today considered to be the golden standard.

The so-called digital workflow has been the focus of the dental world in recent years. Almost all dental/implant companies have become increasingly involved in extending, improving and inventing novel digital procedures and equipment.

Additive manufacturing (3D printing) can be considered the most promising technical development of the last decade and its application in dentistry will likely change the future of our profession.

The aim of this article is to compare the traditional laboratory workflows to the techniques currently applied and explain the digital developments that are determining the role of the dental technician of the future.

IMPRESSIONS
All dental lab work starts with an impression or registration in the patient’s mouth. A dental impression is a negative imprint of oral hard and soft tissues from which a positive reproduction (or model) can be formed. Obviously it is then of great importance that the clinical situation is transferred to the lab as accurately as possible. During the last decade a revolutionary development has found its way into this field, namely intra-oral scanners.
Classic impression techniques (1995)
For indirect restorations, three main groups of impression materials were available: reversible hydrocolloids, polyethers, and addition silicones (or vinyl polysiloxanes – VPS). The biggest difference between these three materials is their respective hydrophilicity.

Reversible hydrocolloid is hydrophilic and a very accurate impression material (Federick & Caputo 1997). To reach its gelation and solid phase, it has to be cooled by continuously circulating cold water through the impression tray and the impression has to be poured within four hours. These two requirements make the process of working with it rather demanding for daily practice. Even in its solid state, the material is flexible and tears quite easily; it is therefore not suitable for implant impressions.

Already introduced in 1965, polyether materials such as Impregum™-3M Espe were a completely new way of thinking. Polyethers solidify via a chemical reaction and become tough and rubber-like. They are therefore a suitable material for implant impression and will not tear when the tray is removed. They are less hydrophilic than hydrocolloid but perform better than VPS on wet surfaces. While they capture details with extreme accuracy, they distort more during curing.

VPS materials were first introduced in 1982 (Reprosil™ – Dentsply Caulk). They have a similar strength to polyethers when solidified and generally show less distortion. They should therefore be suitable for large reconstructions. The first generation of VPS impression materials were however very hydrophobic, which made details in the impressions more likely to distort due to sulcular fluids or wet surfaces. In recent decades, additives were applied to VPS, making it more hydrophilic and therefore easier to use.

Many materials and techniques were described for bite registration, all with their own advantages and disadvantages. The biggest challenge is to have a dimensionally stable material, which can be put back on the casts in the exact same manner as it was in the mouth. Free-end situations in particular are challenging.

Current impression techniques (2015)
With the wide use of CAD/CAM in dental offices and laboratories, the need to apply digital intra-oral registration of the patient’s situation is rapidly increasing. Initially, dental labs digitized cast models using a laboratory scanner to be able to use CAD/CAM technologies. These types of scanners were introduced in 2003. The accumulation of inaccuracies during the production of cast models and their subsequent transformation from the analog to the digital world makes this workflow prone to errors.

The introduction of intra-oral scanners made it possible to exclude these steps and digitize directly at source. Intra-oral scans were already described by Francois Duret back in 1973 in: “The Optical Impression” (Duret 1973). In 1985 another system named CEREC was launched by Mörmann and Brandestini (Mörmann et al. 1987). Although the technique was thus available early on, its rapid worldwide growth came after the introduction of three other scanning systems (iTero 2007, Lava C.O.S. 2008 & E4D 2008). These devices (and a next generation of CEREC as well) were developed to replace cast models and make it possible to work with an external lab instead of “in-office” chair-side milling.

Today, these scanners can be used for almost any indication for tooth-borne restorations. It becomes more challenging when implants are involved, especially if full-arch reconstructions are desired. This is due to several factors. First of all, implants do not have a periodontal ligament and therefore show less flexibility when a multiple abutment reconstruction is placed; a natural tooth can be slightly displaced by force if a multi-unit restoration does not show a 100% passive fit (van der Meer et al. 2012). Secondly full-arch intra-oral scans can show some distortion (bending or twisting) due to the huge number of images that have to be “stitched” together. Clinical and preclinical research is currently being performed to improve scanners and validate the workflows of these challenging reconstructions (Figs 1 and 2).

Other difficulties associated with intra-oral scanning of dental implants are the implant location and the requirement to copy an emergence profile created earlier that can be of importance during the soft tissue management phase in esthetic situations. There are some techniques for dealing with this difficulty, for example, by making multiple scans (Figs 3–8), but experience and lab flexibility are a prerequisite as not every lab is able to combine multiple scans. A difficulty pyramid for using intra-oral scanners on implants, based on the indication and location, was recently developed at the university for training purposes (Fig. 9).
Since acquiring intra-oral scanning skills has a certain learning curve and not all indications are scannable, the previously described conventional impression methods are still applied in modern dental offices. The only change in comparison to 20 years ago is that the impression materials have improved to distort less, behave in a more hydrophilic manner and are suitable for immediate laboratory scanners (digitizing the impression itself instead of pouring a cast first).

Bite registration with intra-oral scanners has taken a step forward in terms of ease of use and accuracy. Since partially edentulous patients can often find a stable occlusal position with even only a few remaining teeth, a buccal scan (upper and lower teeth in occlusion) can be made and the virtual model is positioned correctly even when there is no posterior support. Another reason why digital bite registration may be more accurate is the fact that no registration material is needed between the antagonist teeth while the registration is being made. However, these thoughts are hypothetical and clinical studies are needed to support these arguments.

That brings the discussion to the fact that it is extremely difficult or even impossible to include fully edentulous cases in these digital impression protocols. As illustrated by the black color in the difficulty pyramid (Fig. 9), completely edentulous cases cannot yet be performed in a full digital workflow since the bite and functional borders (for labial flanges) cannot be scanned.

**Future impression techniques (2025)**

New scan technologies are nonetheless being developed as we speak and future technologies such as echo or 3D-video capture might be a solution for the previously explained challenging situations. The use of echo technology or magnetic/force field technology for intra-oral scanning might also eliminate the necessity to expose the margins of tooth preparations by retraction or gingivectomy since these scanners are able to “see” through the gums. It may also provide the possibility to make a dynamic impression for full denture wearers.
Other developments, which are already taking place today, are the combination of intra-oral scans with 3D facial scans. These techniques will likely be enhanced in such a way that complete smile design, including movements and adjustable lip support can be carried out without a physical try-in.

A technology, which in theory can already be applied today but might become the standard of care in preventive control, is the digital registration of chipping, wear and movement of teeth. If an intra-oral scan is made at regular intervals, more can be understood about (para-)functional activity and progression of wear. Combining other technologies in the wand that is used for intra-oral scanning, such as color determination, breath analysis, bacteria detection or saliva analysis are also applications we can expect in the near future. Using the current technology known as the Internet of Things, this information can be transferred directly to the dentist’s, GP’s and/or medical specialists’ computers who are responsible for the patient’s general health.

DENTURES

Perhaps one of the most traditional workflows, which hasn’t changed much since the 1950s, is the production of (complete) dentures. Although the introduction of implant-supported overdentures has changed the outcome of the treatment tremendously, the process has remained quite similar.

Dentures in 1995

In this workflow, patients normally visit the dental office 4–7 times, depending on the clinician’s preferences. Two sets of impressions, a bite registration and one or two try-ins would lead to fitting a denture with acrylic or porcelain teeth. When implants were present either a classic gold Dolder-bar or ball attachments would have been used.

Dentures in 2015

Although in many cases the workflow still remains the same, some new technologies have been introduced in recent years. In 1997 the use of composite occlusal surfaces was introduced (Vergani et al. 1997). Extreme wear on acrylic teeth and the problems of retaining porcelain teeth in the acrylic itself were the main reason for developing this novel material. Nowadays nano-hybrid composite teeth are available that exhibit excellent esthetics, showing adequate wear resistance and are, if necessary, easy to repair in the dental office.

With implant-supported overdentures, a major shift has taken place. The introduction of CAD/CAM has led to a huge shift in bar-retention systems. Next to milled classic Dolder-bar devices, several other designs have been introduced to improve the retention of implant-supported overdentures. Telescopic milled retention bars with matching telescopic mesostructures (some of which are even provided with sliding locks) are now available that provide the same performance and give patients with this type of overdenture the feeling of a fixed restoration (Figs 10 and 11).

Probably the most recent development in dentures is the use of additive manufacturing (3D printing). The complete denture is designed and produced using CAD/CAM. The benefits of this procedure could be:

- The fit of a printed prosthesis should be more accurate since it shows virtually no deformation during production.
- It can be duplicated as a spare denture and manufacturers claim that only one session of data collection is required to finish a denture.
- The material itself is monomer-free and therefore associated with less risk of an allergic reaction in patients.

These techniques are promising and currently there are different developments in this field, such as applying the use of facial scanners to predict esthetic outcomes and printing multi-colored teeth.
Dentures in 2025
Dentistry of the future shows a decrease in patients requiring dentures; nevertheless, this group of patients will probably remain an important part of the dental service.

The further development of the described additive techniques will probably continue in coming years. The promising facts about these CAD/CAM technologies, intra-oral and facial scanners are that a clinician might be able to store the original characteristics of a patient’s dentition so that, if required, a denture can be fabricated that mimics the original situation.

FIXED DENTAL PROSTHESES

For decades indirect tooth shade restorations were made using gold cast copings with veneered feldspathic porcelain. These PFM restorations are still appreciated by some clinicians as the golden standard but increasing esthetic demands require full ceramic restorations. The introduction of CAD/CAM changed a lot in this field.

Crowns and Bridges in 1995
As stated, PFM crowns were the most commonly used indirect fixed restorations early on. The metal provides strong compression and tensile strength, and the porcelain gives the crown a “white” tooth-like appearance for esthetic purposes. After a conventional impression and subsequent pouring, trimming, sawing, ditching and articulating, a cast model was prepared by the dental laboratory. A “lost-wax method” was first applied to design and produce the metal copings in such a way that the veneering porcelain was anatomically supported. When the gold (or alloy) cast was finished, several layers of porcelain were veneered on the restoration using a heat oven. Since every alloy or form shrinks and expands in its own way, the strength of these veneered layers was very dependent on the experience of the dental technician.

For implant-borne fixed dentures the workflow did not differ much from conventional restorations. Instead of a prepped tooth as an abutment, a titanium abutment in a similar shape was used. Many of these fixed PFM implant restorations were cement-retained. Exceptions were the transversal screws and the gold UCLA abutments on which alloy could be cast directly to give screw-retained, one-piece PFM restorations.

A paramount change of concept was the introduction of the Procera® system in 1993. Alumina white copings could be produced in the lab using CAD/CAM. Obviously it was not the first CAD/CAM system, since CEREC had already been commercially launched by Siemens in 1987, but it was revolutionary in the sense that it changed the way the copings were made in dental labs.

Zirconia CAD/CAM copings were introduced in the late 90s. This material was stronger and therefore more suitable for load-bearing reconstructions such as posterior FDPs. The first generations of these ceramic copings were, due to software limitations, often standard-shaped; closely following the abutment shape and with typical connector diameters (Figs 12 and 13). These restorations did not support the veneered porcelain properly and therefore chipping often occurred (Larsson & Vult von Steyern 2010). This might be considered a step backwards when well-designed PFM restorations were already providing an anatomic support to reduce the load on the veneered porcelain.

Fixed Dental Prostheses in 2015
Although conventional methods such as lost-wax techniques and PFM are still applied, many new materials and techniques have become available. CAD/CAM, adhesive dentistry, and monolithic restorations are frequently mentioned in the current literature and used in dental offices. The biggest difference between today’s structures and the CAD/CAM zirconia of the 90s is that it is now possible to stain zirconia in tooth-shade colors instead of using plain white zirconia only. When zirconia is in its pre-sintered phase it has a porous structure and can be infiltrated with staining colors. After sintering it at around 1450°, the density and strength of the structure increases and reaches its final color. This pre-sintered staining has two large benefits. 1. It is possible to design a complete tooth-shaped framework leaving just a little space for
a thin layer of veneering ceramic (Fig. 14). This is possible since no gray (alloy) or white (earlier zirconia) has to be camouflaged by the veneered layer. 2. Monolithic restorations are also fabricated using this “colored” zirconia. Monolithic means that the entire restoration is milled out of the same material. Despite the fact that this material is extremely hard and strong (tensile strength 1000–1400 Mpa), polished zirconia is the least abrasive restorative dental material available (Kim et al. 2012). A commonly reported problem is the “dead” or unesthetic appearance of these restorations. This is caused by the fact that the material lacks the translucency of the incisal edges that natural teeth exhibit. To mimic a more natural color gradient, several techniques have been successfully integrated. Instead of staining the restoration in its pre-sintered phase ‘en bloc’ (Fig. 15), it is also possible to stain some parts more than others. The more of this staining fluid that is infiltrated, the darker/yellower the color will become. Using a brush, the cervical area can, for example, be infiltrated with the staining fluid six times, whereas the incisal part will only be stained twice (Fig. 16). To give more identity and detail, a very thin layer of veneering porcelain is often used to glaze and stain these monolithic restorations (Figs 17–19). This obviously means that the shape will change by a couple of microns, which might interfere with occlusion and contact points. Additionally the wear characteristics change, therefore monolithic zirconia always needs to be polished before a glazing layer is applied.

Lithium disilicate (also known as e.max) is another popular material used for monolithic single crowns. In addition to the material being reasonably strong (400 Mpa), it can be adhesively cemented to teeth very firmly and is therefore not only suitable for crowns but also for inlays, onlays and veneers. Lithium disilicate can either be produced using CAD/CAM technology or using more conventional methods such as press or layered veneering techniques.

A new generation of materials specifically designed for CAD/CAM monolithic restorations are hybrid ceramics such as Lava™ Ultimate or VITA ENAMIC®. These materials are a combination of ceramic and nano-composite. It gives these restorations high flexibility without compromising its strength. Since these materials are less brittle than other ceramics, they are more suitable for milling thin margins. Although the light conductivity of these materials makes the colors of the restorations blend easily, individualization with transparency, stains or cracks is difficult to achieve.

All monolithic materials described are also suitable for implant restorations: zirconia for bridges and posterior crowns, hybrid ceramics and lithium disilicate for single crowns. Transparency might however cause problems with the latter two if the thickness of the restorative material on gray titanium abutments is too thin.

Since these monolithic materials are strong, screw retention can be safely applied without fear of chipping veneering ceramic adjacent to the screw access holes. Special abutments have recently been introduced for this purpose. These, so called, Ti-bases are titanium abutments with a standard shape that often have a deep abutment shoulder position and are available as open-source in CAD/CAM software. This means that any dental technician can, once the implant position has been scanned, download the abutment shape and import it into his design software. The subsequent milled or printed restoration will be luted on the Ti-base in the dental laboratory. To give more retention and prevent rotation of the restorations on these small round abutments, retention grooves or pins are often incorporated in the abutment shape (Fig. 20).

When monolithic restorations are combined with intra-oral scanning, a full digital workflow can be applied without the use of a model of any sort. In a full digital workflow information about the implant’s position is obtained with an intra-oral scan, the technician designs the abutment and restoration in the design software (CAD) and after its production (CAM) the dental lab finishes the restorations with staining and glazing. Since there is no model to verify the fit, glazing on occluding surfaces and contact points should be minimized to prevent adjustments when the restoration is placed.

A recent development in CAD/CAM restorative materials is the introduction of a new “hybrid” zirconia with a higher
Y2O3 content (Prettau® Anterior). It is as translucent as lithium disilicate but strong enough (670 Mpa) to be used for 3-unit (anterior) FDPs. However, no scientific data is available yet to support the use of this material.

Fixed Dental Prostheses in 2025
Probably the most important shift in modern dentistry will be from milling to additive manufacturing (3D printing). The most important benefit is that the additive procedures require far less raw material than subtractive procedures such as milling. Thus the costs should in theory be lower.

Additionally, the cutting heads (or drills) of milling devices have a minimum required diameter; consequently thin outlines can hardly be milled and all restorations exhibit rounded shapes. With printing, these problems will no longer occur.

Another important factor is the color of CAD/CAM restorations. For milled CAD/CAM, multi-layered blocks with a color gradient are already available. With additive techniques, multiple-color printers could be used. It will then be possible for a crown to be built up in the exact same way as a natural tooth and the colors and shape can be mimicked perfectly. In addition, introducing energy to the printed crown, such as laser, will also influence the structure of the tooth and the way it reflects light, thus influencing the color and opacity of the tooth. The structure will be designed in the dental office either by the dentist or an in-house technician.

Conclusion and future perspectives
Next to IO scanners and model scanners, 3D cameras and CT scanners with minimal invasive technology will also be present. Full treatment planning will take place in the digital environment. The technician will also have a role in implant treatment planning, the design of the drill guide and printing of these materials. As far as fixed and removable prosthetics go, the technician will also play a role in designing the restorations in the CAD environment as well as the coloring and finishing of the printed restoration. The restorations will be printed either in composite materials or zirconia (crowns, FDPs, RPDs) or metals. In the full digital workflow the technician together with the dentist will be able to create a treatment model in which the patient only has to visit the clinic for a limited length of time. Try-ins will be designed digitally and the patient’s photographs with the “new teeth in situ” can be viewed via the internet or the practice intranet with limited patient access. Patients will have simple tools to change the try-in proposal to make it more individual. The technician can then play a role in finalizing the design. The printing technology combined with color technology will probably be able to run without intervention by the technician or dentist. Both the technician and the dentist must respond to a major change in their profession. The dentist will probably focus more on oral pathology, oral diagnostics and the way...
the mouth shows us where pathology might be manifested in the rest of the body. The technical aspects of the profession will be CAD/CAM controlled.

The speed at which this evolution will take place depends on the industry and government. Will the industry allow the innovations to take place at the speed they are developed or will they control the introduction of new technology with patents and NDAs (Non-Disclosure Agreements)? It seems that investment in technologies must first be recouped before industry brings new technologies to the market. Governments use tools such as subsidies to speed up the implementation of innovation in the (health care) system. Are these institutions prepared to invest in the further digitization of dental care or will there be lobbies against these developments aimed at stabilizing the established order of things?

Advanced use of IT will provide the dentist with enough tools to manufacture everything he needs to meet the patient’s restorative needs. The question then arises: what is left for the dental technician?

REFERENCES


