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3D printing

international magazine of dental printing technology

interview
"3D printing in dentistry is much more than just a new technology"

case report
A fully digital workflow in implant and restorative dentistry

trends & applications
Printing clear aligners in-house—how accessible is it?

dti] Dental Tribune International

Dr George Freedman

Editor-in-chief

3D printing: Revolution in dentistry

3D printing has arrived in dentistry. Like with the other great paradigm shifts of the past 50 years in the profession (cosmetic dentistry, implants and diagnostics), major advances are very apparent on the near horizon. The needs are many, the technologies numerous, the applications almost unlimited and the potential open-ended. Just like cosmetic materials and techniques brought aesthetic restorative dentistry into the hands of every practitioner, 3D printing promises to bring functional and artistic control of the restorative process into the chairside setting.

The digital transformation of dentistry, including CBCT, intra-oral and extra-oral scanning, milling of ceramic and composite materials, and robotic implant placement, is firmly established.

Stereolithography, first developed in the 1980s, was soon followed by additive manufacturing, the deposition of material in increments. Dental applications are more recent. 3D printing has been utilised for rapid prototyping and modelling for more than a decade. The size and cost of the earlier printers meant that they were limited to larger laboratories. The most recent desktop printers have a much smaller footprint, are easily affordable for the single practitioner, communicate with existing software platforms and offer high levels of precision with a wide range of materials.

Current 3D printers are fully capable of managing the great demand for temporary, transitional, and permanent restorations and appliances and of achieving the clinical excellence required by the dental profession. Consequently, there has been a growing acceptance of this transformative technology. Increasingly, 3D printing is viewed as an industry game-changer and a forecast of the future direction of the dental practice.

3D-printing techniques include stereolithography, fused deposition modelling, selective laser sintering, powder binder printing, photopolymer jetting, electron beam melting and direct light processing.

The documented, wide-ranging 3D-printing applications can be grouped by treatment category:

- *Fixed prosthodontics:* Permanent and provisional indirect restorations (crowns, onlays, inlays, bridges) and permanent monobloc direct restorations can all be custom-fabricated chairside within minutes of scanning the preparation.
- *Removable prosthodontics:* Both complete and partial dentures, including digital occlusal design, are deliverable within hours.
- *Implant dentistry:* 3D printing of surgical guides has facilitated ideal implant positioning. Biomimetic custom 3D-printed bone implants replace missing segments, minimising stress transfer to the remaining bone.
- *Orthodontics:* Aligners, designed using CBCT data and artificial intelligence extrapolation of tooth movement over time, are 3D-printed.
- *Endodontics:* The pioneering 3D-printed endodontic access guide, utilising CBCT data, translates pre-surgical planning into clinical success.
- *Maxillofacial surgery:* Custom-designed bone grafts and fixation plates expedite both the surgical procedure and the healing process.
- *Periodontics:* 3D-printed guides that relieve and retract gingival margins offer aesthetic gingival correction. Soft-tissue printing is currently in the research phase.

3D-printing techniques and procedures are high-quality, high precision, accurate and significantly lower in cost than conventional treatment options. Dentists save money: many desktop printers cost between US$3,000 and US$10,000, and dental 3D-printing materials cost pennies per tooth. Patients save money, by the elimination of intermediate procedures and transportation costs. Treatment is faster, typically same-day services.

Welcome to 3D printing! Welcome to the future of dentistry!

Dr George Freedman
Editor-in-chief

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Cover image courtesy of SprintRay (www.sprintray.com).

Dental 3D printing adoption across Asia Pacific

Top three trends and forecast

By Kiavash Bakrani & Dr Kamran Zamanian, Canada

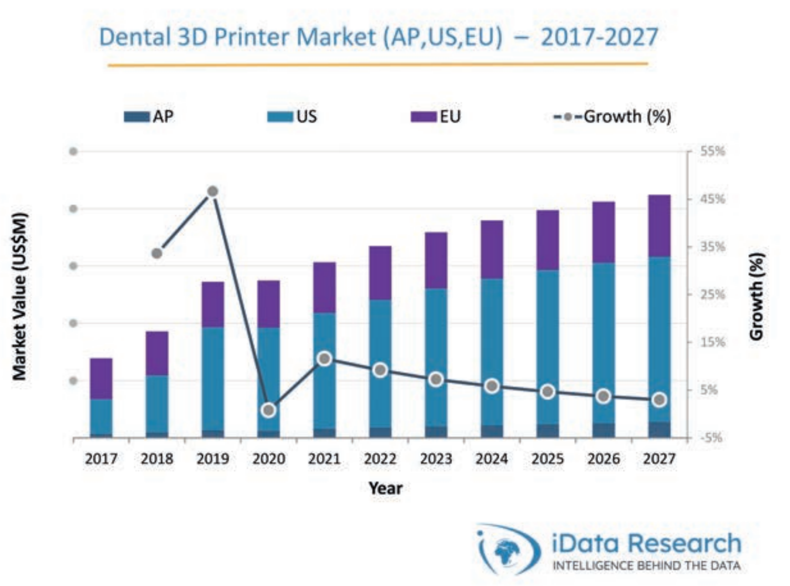

Fig. 1: Asia Pacific, US and European 3D printer markets.

The digital dentistry market in Asia Pacific has started to gain traction because of technological advances and the demand for improved precision, although the markets lag severely behind North America and Europe.

Dental 3D printing has rapidly become an important part of many digital dentistry workflows in countries such as Australia, Japan and South Korea. Dental 3D printers are now an increasingly popular tool in dental laboratories, dental practices and orthodontic practices and have many uses, including the production of crown and bridge models and final prostheses. Whereas the dental 3D printer segment is the smallest segment of the digital dentistry market, it has grown the most rapidly in recent years. Countries such as China and India, who lag behind in terms of novel technology, have not seen nearly as much advancement.

Trend #1: Technological advancements lead to growth opportunities

Dental 3D printing allows for significant time savings for a variety of applications, which is a common feature of most digital dentistry technology. Production of models, surgical guides, night guards and other products is extremely rapid and requires minimal labour. Models, in particular, are often quite laborious to produce traditionally, making this a significant opportunity for time savings. The enhanced productivity offered by digital workflows will continue to drive growth in the dental 3D printing market. Ongoing regulatory approvals of materials for new indications will result in significant growth in the dental 3D printer market. Whereas 3D-printed dental prosthetics are not yet available in many Asia Pacific countries, such approval is likely to induce significant market value growth when it occurs. A single dental 3D printer from a major manufacturer is generally capable of producing surgical guides, models, night guards, dentures and temporary crowns; the technology is, therefore, very versatile, and growth hinges largely on the materials approved for use.

Trend #2: Technological learning curves and regulatory approvals delay market growth

Dental 3D printers are still relatively new technology and tend not to be overly user friendly. A steep learning curve is often involved in the incorporation of dental 3D printing into a digital workflow, limiting access for less technologically adept dentists and dental laboratory technicians. Similar issues limited the growth of the chairside CAD/CAM system market in Asia Pacific; significant time must be invested in learning the technology, and strong customer support from manufacturers is key to success. As dental 3D printers become more user-friendly, this issue will be mitigated, but for the time being, it limits the potential for growth in the Asia Pacific market.

Regulatory approvals for new indications are required for products in the Asia Pacific market. Currently, many of the newest innovations in the CAD/CAM material market are unavailable in Asia Pacific, and it is unknown when they will be approved. This uncertainty limits the potential for market growth.


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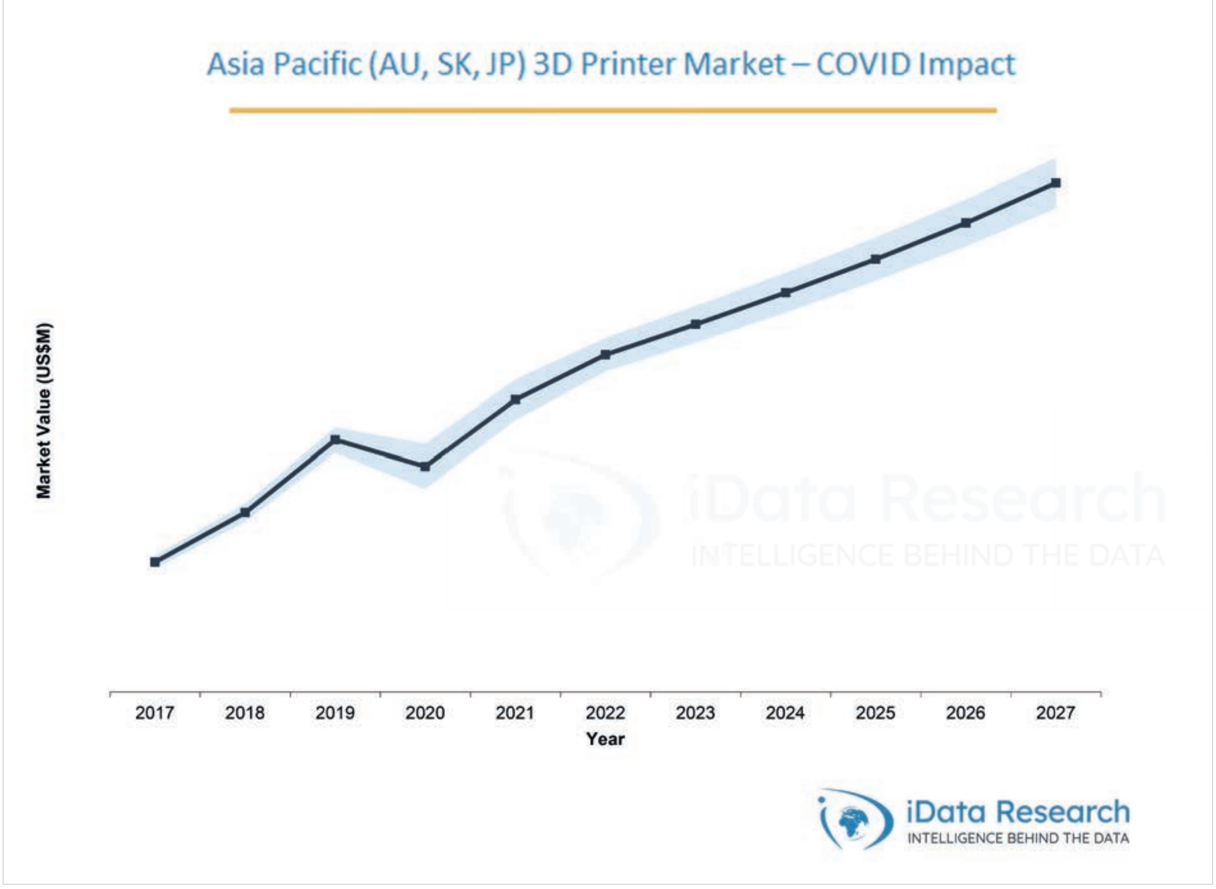

Fig. 2: Impact of COVID-19 on the 3D printer market in Asia Pacific.

Trend #3: COVID-19's impact on the Asia Pacific market

The global dental market was significantly affected by the COVID-19 pandemic, and Asia Pacific was no exception. The markets for dental prosthetics as well as CAD/CAM devices and materials are interdependent and have, therefore, also been similarly affected. The overall market value for dental prosthetics decreased dramatically compared with the previous year because of the elective nature of the procedures and the tight regulations that led to the closure of many dental clinics. Owing to its high price point, the premium market was impacted the most notably. The total market is expected to recover in 2021 and continue to grow at a moderate pace.

3D dental printers market forecast

Overall, the dental 3D printer market in Asia Pacific experienced a decline in 2020 because of reduced dental spending across the nation. This decline is temporary, and the market will return to normal unit sales forecasts by 2022. For the remainder of the forecast period, the dental 3D printer market in Asia Pacific is expected to experience strong unit sales growth; as more laboratories go digital and more CAD/CAM materials receive regulatory approval, the demand for 3D printers will increase.

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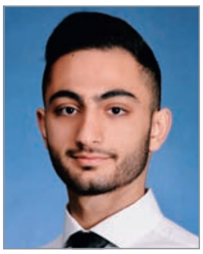

Kiavash Bakrani is a senior research analyst at iData Research. He has been involved in the global research of dental prosthetics and digital dentistry markets, publishing the reports on the Asia Pacific market.

Dr Kamran Zamanian is the CEO and founding partner of iData Research. He has spent over 20 years working in the market research industry with a dedication to the study of dental and medical devices used in the health of patients all over the globe.

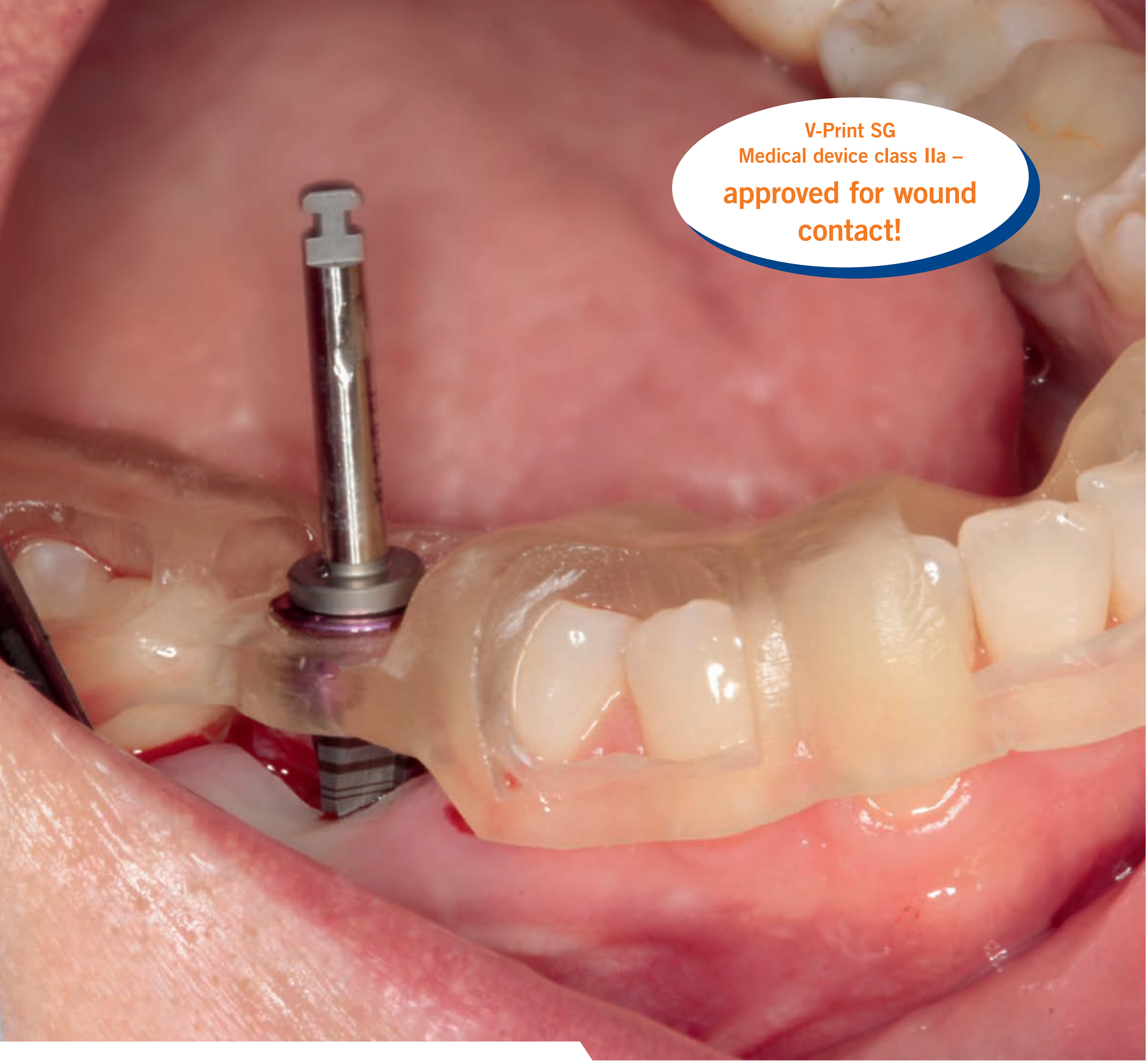

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Fig. 1: Scientists in Germany and Poland are collaborating on the project Additive Technologies for Medicine and Health and the first results are expected later this year. *(Image: © ronaldbonss.com/Fraunhofer IWS)*

3D printing in dentistry: Fraunhofer bringing future technologies into the present

By Jeremy Booth, Dental Tribune International

A project by the Fraunhofer-Gesellschaft aims to harness the transformative potential of additive manufacturing in the medical field. The project brings together a network of partners and encompasses a wide range of additive technologies. It seeks to pair new advancements in 3D printing with tangible and patient-oriented applications. There is a substantial focus on dentistry, and scientists in Germany and Poland are collaborating on a series of pilot projects and working in close cooperation with dental laboratories and dentists from a range of specialties.

The application-oriented research organisation announced in June that a German–Polish Fraunhofer-Gesellschaft High-Performance Center was engaged in the project Additive Technologies for Medicine and Health (ATeM). It aims to incorporate additive manufacturing as an established tool in the field of medical technology, and the first demonstrations of the individual projects are expected around the third quarter of this year.

Prof. Frank Brückner, technology field manager for additive manufacturing and surface technologies at the

Fraunhofer IWS in Dresden, told Dental Tribune International (DTI): “One of the main objectives of ATeM is to increase the technology readiness levels of current research activities in dentistry, for example by introducing novel materials or by integrating additional functionalities; another important goal is the transferral of these to companies—especially to small and medium-sized enterprises—in order to make the new products readily available for clinical practice.”

New functionalities in dental prostheses

In the dental field, Fraunhofer scientists are investigating new areas of application for 3D printing in dental prosthetics. “There is great potential in the use of innovative materials and the integration of additional functionalities in dental prostheses to increase the wearing comfort for the patient,” Brückner commented in a press release.

When asked about the properties and functionalities that were being investigated, Brückner said: “The main purpose is to provide dental components with new functionalities, to improve their aesthetic appearance and to optimise present fabrication routes.” For example, new functionalities can be achieved through intelligent implants. He explained: “For this purpose, sensors for certain biomarkers are integrated into dental components during the manufacturing process. These can then provide information to the dentist regarding the healing progress or the occurrence of complications.”

Fraunhofer IWS mentioned some of the applications that are being investigated in the dental field, stating that advancements in additive manufacturing could allow for faster treatment and the printing of significantly more complex dental implants immediately after the oral cavity is scanned using an intra-oral scanner. Additive processes could also be harnessed in order to combine metal and plastic materials for improved aesthetics, and the production of dental prostheses could also be made faster and more efficient, both in terms of treatment costs and resources.

Tailoring orthodontic appliances to patients and streamlining manufacturing

Developments in additive manufacturing could also enable orthodontic treatment time to be reduced and brackets to be individualised for patients. Brückner explained: “For visible orthodontic components, such as brackets, a targeted multi-material composite design might enable the combination of functionally optimised internal structures, which could bear the mechanical load, with a patient-specific aesthetic external design. In this way, a significantly improved aesthetic appearance of the orthodontic appliances could be achieved, which is especially desirable in the anterior region.”

Dentists well know that many dental products are still manufactured using a number of manual steps. Additive manufacturing already allows for the partial substitution of what can be expensive and time-consuming tasks, and advancement in 3D-printing processes could lead to greater savings of resources in the dental practice and laboratory. The institute explained, for example, that it is examining established process chains for the production of dental components in order to identify possibilities for the seamless integration of 3D-printing technologies. Brückner commented: “A major focus is on the end-to-end digitalisation of the process chain from data collection—for example, using an intra-oral scan—through manufacturing to application. As a result, waiting times and costs for complex dentures could be significantly reduced for the patient.”

Investigating innovative materials and data acquisition

The project is a collaboration between the Fraunhofer IWS in Dresden, the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz in Germany, and the Faculty of Mechanical Engineering and the Center for Advanced Manufacturing Technologies at Wroclaw University of Science and Technology in Poland. This network of partners implicates a wide range of additive technologies, including stereolithography or fused filament fabrication, for example, which can be used to process a wide range of polymers that offer a significantly better aesthetic appearance in the oral cavity than metals do—particularly in visible areas.

Brückner explained that metals, however, play an important role in many load-bearing applications, such as implants or prostheses, and that various processes are available for metal-based additive manufacturing. “For example, even challenging materials can be processed into highly complex, near-net-shape components. Binder jetting also enables the production of complex components, and unlike other powder bed-based processes, no support structures are required, and good surface qualities can thus be achieved in the process,” he said.

In addition to materials that are well established in the dental field, such as titanium-based and cobalt-chromium-based alloys, the scientists at ATeM are also investigating innovative materials that offer, for example, better wearing comfort for the patient, a reduced risk of plaque adhesion or the integration of sensor technologies which could be used to facilitate increased data acquisition.

Additive manufacturing processes are already highly digitalised; however, scientists at ATeM are aiming to further optimise them in order to incorporate a seamless integration of these processes into digital data acquisition in dentistry. Brückner explained: “For example, dental restorations can be built up directly based on the data of an

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Fig. 2: Fraunhofer IWS says that additive manufacturing could shorten lead times in the production of orthodontic distractors and enable an individualised fit for the patient. **Fig. 3:** The Additive Technologies for Medicine and Health project wants to digitize the production of dental prostheses in order to make it faster, cheaper and more efficient. *(Images: © Christoph Wilsnack/Fraunhofer IWS)*

intra-oral scan. Not only does this facilitate communication between dentists and manufacturers, but also it ensures quality in decentralised production." He said that by integrating sensor technology into dental components, such as prostheses or implants, new features could be integrated to provide information to both the dentist and the patient. "One goal in the project is therefore to derive a digital functional strand for sensor integration, data acquisition and processing across the entire process chain in order to improve user-friendliness for both the patient and the treating dentist," Brückner said.

There is currently great interest in intra-oral scanners and 3D printing for dental applications, and both of these fields are expected to show double-digit growth in the next five years. Dr Kamran Zamanian, a market researcher in specialist dental applications and founding partner of iData Research, commented in June that the technologies are increasingly attractive to dentists owing not only to the seamless workflows that they offer in the practice but also to their ability to better control the risk of infection. In an editorial published by DTI, Zamanian said that the COVID-19 pandemic had already influenced the market for dental 3D-printing technologies. "(Sales) of 3D printers are increasing rapidly now that the pandemic is getting closer to being stabilised. In addition, digital technologies, such as 3D printers and intra-oral scanners, offer better control of contamination risk, and this has already started to drive sales and will continue to do so in the near future," he wrote.

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3D printing in dentistry: Future-proof technology?

By Iveta Ramonaite, Dental Tribune International


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Fig. 1: 3D printing allows dental professionals to stay up to date with the newest technology and dental materials and is a valuable asset to both dental clinics and laboratories. **Fig. 2:** SprintRay's 3D-printed clear aligners. *(Images: © SprintRay)*

Technological advancements in dentistry are like a motor force that drives innovation and growth. This is true for digital dentistry. Digital technology continues to advance dentistry, and although not everyone has embraced this technological evolution, most dental professionals would agree that going digital is the way forward. For one thing, the benefits of 3D printing in dentistry are plentiful. It allows dental professionals to stay up to date and is more cost-efficient compared with analog methods. There are constant software updates, frequent launches of new dental materials and rapidly evolving applications in dentistry.

Most dental professionals are already using the technology of the future today. 3D printing can significantly improve the workflow in any dental practice or laboratory and can drastically reduce patient chair time. It offers flexibility in product customisation and superior quality and accuracy in 3D-printed dental models. Although it was once unimaginable, dental professionals can now print occlusal splints and other dental models in-house in only a day. This not only helps to generate profit but also facilitates dental treatment.

"More and more dental practices and laboratories invest in a 3D printer because it is affordable and accessible. It is the type of tool that empowers dental professionals and makes them more confident in tackling their daily challenges," Rudy Labor, sales and application specialist for orthodontics at SprintRay, a technology company that builds end-to-end 3D-printing ecosystems for dental professionals, told Dental Tribune International (DTI).

With 3D printing, there is always a place for continued development. Every software release or update enhances the hardware and offers new and exciting features. There are constant innovations in 3D-printing materials to provide users with a growing list of indications, and 3D printing can be easily integrated into the workflow of any dental practice or laboratory.

In discussing how 3D printing is the future of dentistry, Labor highlighted the significant role of those working behind the scene to make 3D printing a leading-edge


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Fig. 3: 3D-printed temporary bridge made of VarseoSmile Temp. *(Image: © BEGO)*

technology. He stated: "What makes 3D printing the technology of the future is the commitment of the professionals who work tirelessly to improve and elaborate the existing printing techniques and to explore and exploit new possibilities. As far as SprintRay is concerned, 3D printing will be future-proof."

3D-printing applications in dentistry

Some of the 3D-printing technologies that are currently available and used in the dental industry include digital light processing, selective laser melting, stereolithography and fused deposition modeling. All areas of dentistry are covered by 3D printing, including printed study models, surgical guides, metal frameworks, dental prostheses, temporary crowns and bridges, permanent restorations, occlusal splints, aligners, and removable dentures.

Prof. Markus Blatz, who is chair of the Department of Preventive and Restorative Sciences and assistant dean for digital innovation and professional development at the University of Pennsylvania School of Dental Medicine in Philadelphia, US, previously told DTI that he believes 3D printing to be the future of restoration fabrication in dental laboratory technology and that it is likely to be used for all types of materials and restorations.

In a previous interview with DTI (CAD/CAM *1/2021*), prosthodontist Dr. Ryan C. Lewis noted: "3D printing has changed the way that we produce surgical guides. 3D printers have become so accurate and inexpensive that any dentist can now afford to have them in his or her office and print surgical guides as well as casts for diagnostic purposes or aligners at a relatively low cost."

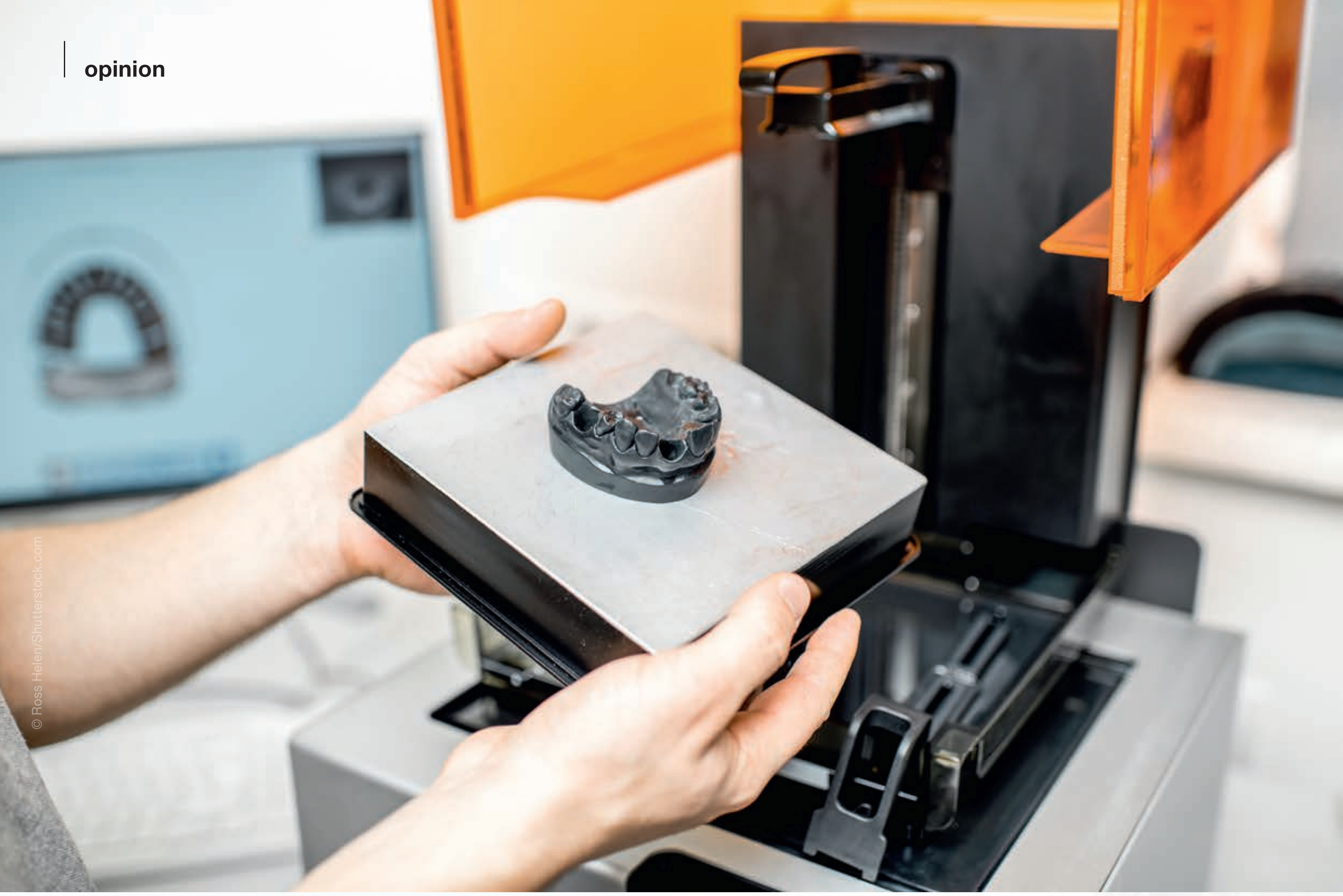
He added that going back to traditional dentistry would have a significant impact on costs, efficiency, quality of work, and ability to communicate with surgeons and dental technicians.

The advantages of 3D printing over CAD/CAM technology

3D printing, or additive manufacturing, consists of adding material. In contrast, milling is a method that involves subtracting material. Labor told DTI that additive manufacturing is more cost-effective than subtractive computer-aided manufacturing and explained that it produces less waste. Additionally, 3D printing is highly accurate, faster for many indications and offers increased production efficiency since the user can produce printable solutions in volume.

Finally, Labor stated that additive manufacturing boasts consistency, which is crucial for successful product fabrication. He explained: "3D-printing technology has proved to be more accurate and more consistent in replicating consistency when mass-producing. When using the analog way of fabricating dental apparatus, you can never replicate a process with exactitude, and we all know how important consistency is in production."

Investing in new technology is a way of reaching and establishing high standards of patient care. As Patrick Thurm, the managing director and general manager for Europe at SprintRay noted, dentists and laboratories are currently seeking efficient solutions for their practices and their patients post-pandemic, and a 3D printer, such as the one from SprintRay, could be a great asset to dental practices, laboratories and patients.



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3D printing: Changing the game

By Dr Florin Lăzărescu, Romania

When I discovered CAD/CAM technology more than ten years ago, I was amazed at the technological world that I was entering. It was novel and it was creative; but it was also rather daunting. My student years had provided some abstract images of various scanners and milling machines that were available at that time, but no actual cases employing these technologies. Once I graduated, the systems were far too expensive for the small office where I was practicing initially.

After I made the decision to purchase a complete in-office system, I discovered an exciting new world, one that I could not have imagined previously. As suggested, I allowed myself a comfortable learning curve at the beginning, starting with easy cases, gradually gaining experience and familiarity with the process, until I was confident enough to push for more. CAD/CAM systems have evolved rapidly, and during the past ten years I have been witness to an accelerated evolution of three generations of scanners and milling machines. Today, I would not even consider opening a new office without, at the very least, a scanner, and preferably, a complete in-office CAD/CAM system.

I remember that when I explained the benefits of CAD/CAM technology to my patients a decade ago, I could not help wondering what lay ahead for dentists, and where the future of the profession would lead us.

As I look at the rapidly developing field of 3D printing, I get the same game-changing feeling that I had when I first discovered CAD/CAM technology. The mainstream dental 3D printing boom began in 2015, following important technological milestones such as the first dental 3D printing in 2000, digital impressions for an analog world in 2005, and the introduction of all-ceramic restorations and desktop scanners in 2010.

There are three distinguishable types of 3D printing that can be categorised from a technological perspective[1]:

1. Photopolymerisation with thermoset plastics. A thermosetting polymer, resin, or plastic is a polymer that is irreversibly hardened by curing from a soft solid or viscous liquid prepolymer or resin. Curing is induced by heat or suitable radiation and may be promoted

by high pressure or mixing with a catalyst. It is also known as stereolithography, and commonly referred to as SLA.
2. Laser sintering with both for metals and thermoplastics is an additive manufacturing process that belongs to the Powder Bed Fusion family. A laser selectively sinters the particles of a polymer powder, fusing them together and building a part, layer by layer. It is known as selective laser sintering and commonly referred to as SLS. Laser sintering is very expensive, with high maintenance costs, but delivers amazing results.
3. Extrusion is a 3D printing process that uses a continuous filament of a thermoplastic material. It is known as fused filament fabrication or fused deposition modeling and commonly referred to as FDM. This technology is based on feeding a modelling filament through a heated nozzle, and printing layer by layer. While very affordable, FDM's accuracy and service quality are quite limited with respect to dental applications.

Various companies utilise differing photopolymerisation technology categories:

1. SLA—Stereolithography printing exposes the liquid resin to a laser light source.
2. LFS—Low force stereolithography can be described as SLA's successor. It uses a flexible tank and linear illumination to polymerise liquid resin.
3. DLP—Digital light processing exposes the liquid resin to a DLP projector light source.
4. LED—New technology that uses LED instead of laser light sources for the additive manufacturing of metal parts and optimises 3D metal printing.

However, the underlying principle is the same: a polymerising light hardens the resin to a solid-state layer by layer. DLP or LED techniques offer faster results, while SLA and LFS modes provide smoother and finer details, but the process is significantly slower.

There are numerous dental applications for 3D printing.[2] In fact, there are many applications that are not possible without 3D printing (aligner thermoforming models, indirect bonding trays). 3D printing can enhance traditional techniques such as surgical guides, custom impression trays, diagnostic models, splints, restorative models, and provisionals. And there are novel 3D printing opportunities such as full dentures and permanent indirect and direct restorations.

In my daily practice, I find many situations where 3D printing allows me to offer existing services more predictably and rapidly. Currently available options include provisional crown and bridge restorations, inlays, onlays and veneers.

The ability to print splints represents a tremendous advantage; a reliable inhouse splint can be completed in a single appointment whereas sending the case to a dental laboratory is far less efficient and much more expensive. The routine use of rapidly printed surgical guides improves the patient's perception of surgical procedures, speeds treatment, and assists in predictable results for every case. In-house 3D printing reduces the waiting time before surgeries.[3]

In the past, it was extremely difficult to treat fully edentulous patients with significant bone loss. Ultimately, the limitations of dentist–technician communications made the process long and tedious, and results were often less than satisfactory. It was also frustrating that during this time-consuming ordeal the patient had no access to provisional dentures. 3D-printed full dentures, available the same day, offer a practical solution to both patient and dentist. Scanner, 3D printer and an in-house technician are the ideal.

As with any new technology, 3D printing has a learning curve. It is highly recommended that the practitioner begins with simpler procedures, and then tackles more complex ones as experience and confidence are accumulating. 3D-printing technology is a game changer in the dental industry that will greatly influence and modify patient treatment in the years to come.

3D printing, taken together with CAD/CAM and CBCT, creates a comprehensive shift to digital dentistry, a trend that is rapidly redefining the dental profession.

Editorial note: A list of references is available from the publisher. This article originally appeared in Oral Health Magazine*, and an edited version is provided here with permission from Newcom Media.*

about

Dr Florin Lăzărescu owns a private dental practice in Bucharest in Romania and in his work focuses on aesthetic dentistry with an emphasis on all-ceramic and implant restorative procedures. He is the author of numerous publications on dentistry, and he is the editor of and a contributing author to the *Romanian book Incursiune în Estetică Dentara* (Immersion in Esthetic Dentistry, Society of Esthetic Dentistry in Romania, 2013)—republished in English as *Comprehensive Esthetic Dentistry* (Quintessence, 2015) and in Chinese (Quintessence China, 2017). He is editor-in-chief of *Dental Tribune Romanian Edition*. Dr Lăzărescu is the president of the European Society of Cosmetic Dentistry and a founding member and director of the Society of Esthetic Dentistry in Romania.


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3D printing promotes individuality and creativity

By Christian Ehrensberger, Germany

Additive manufacturing (3D printing) offers all the prerequisites for customised design. Its adoption in the dental industry means that dentists and dental technicians are therefore destined to take a pioneering role in popularising it. The current status of 3D printing, as well as ideas about its future direction, were highlighted at IDS 2021.

Procedures for processing dental materials are developing rapidly. Precious metals have traditionally been cast, as have non-precious alloys and titanium (under shielding gas). Ceramic materials are milled, but for several years, non-precious alloys (with subsequent sintering) and even precious metals have also been milled. Additive manufacturing has become increasingly established in this time, in part because it involves practically no loss of material.

Crowns, bridges and denture bases, for example, can be fabricated in this manner using non-precious dental alloys (e.g. through selective laser melting, selective laser sintering, direct metal laser sintering or LaserCUSING).

Dentures can now also be fabricated from resin with 3D printing. They are able to be made even stronger and in a more attractive colour through the combination of several resin components—either in ready-to-use formulas or mixed directly during the printing process.

Today, the strengths of resin printing are primarily visible in models or occlusal splints. Veneers and gingival masks too are fabricated on the basis of an intra-oral scan using additive manufacturing. In addition, denture bases and teeth are printed and then bonded to form a full-arch

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Figs. 1 & 2: Dental technology impresses with its wide range of materials and the prosthetic restorations fabricated from them. IDS 2021 demonstrated new options and attractive business models. *(Images: © Koelnmesse/IDS Cologne/Harald Fleissner)* **Figs. 3–5:** The variety of materials and processing techniques in the dental laboratory is enormous: gold, non-precious alloys, ceramics, CAD/CAM and manual working techniques. *(Images: © Koelnmesse/IDS Cologne [Figs. 3 & 4]/Christian Ehrensberger [Fig. 5])* **Fig. 6:** A procedure with high potential: 3D printing of special dental resins. *(Image: © BEGO)*

or complete denture or are even fabricated in one piece through this technique. Furthermore, mock-ups can be printed from try-in resins.

In implantology, a drilling template ensures that the surgeon locates the optimum position and angle determined during planning. Printed orientation templates with separate cranial and caudal sections help during external sinus lift: blood vessels that run through the access are protected.

In endodontics, printed orientation templates make it easier to locate a root apex for resectioning. In orthodontics, high precision is achieved with positioning trays (indirect bonding trays). The positions of the brackets are initially planned virtually, and the brackets then have to be cemented precisely in the correct position in the patient's mouth. The template printed from resin provides additional security in this regard.

The basic strength of 3D-printed objects lies in their possible implementation as one-offs or as a small series—the latter, for example, can prove useful in situations where the dentist requires assistance or when an instrument fails, if a 3D printer is available and the necessary digital infrastructure is in place and so on. Why not simply print several copies of the required instrument according to a blueprint? This works for simpler aids anyway. A holding device for a bag of isotonic saline solution, for example, can be printed quickly and precisely for a dental unit as described by Dawood et al.[1] This demonstrates above all that 3D printing stimulates the creativity of all involved!

Reference

1. Dawood A, Marti Marti B, Sauret-Jackson V, Darwood A. 3D printing in dentistry. Br Dent J. 2015 Dec;219(11):521–9. doi: 10.1038/sj.bdj.2015.914. Erratum in: Br Dent J. 2016 Jan 22;220(2):86.

about

Christian Ehrensberger is a dental journalist from Frankfurt am Main, Germany.

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"Digital technologies are fundamentally changing the dynamics of our industry"

An interview with master dental technician Stephan Kreimer

By Iveta Ramonaite, Dental Tribune International

Stephan Kreimer is a master dental technician who runs a dental laboratory in Warendorf in Germany. Since he developed an interest in technology early on, Kreimer was always eager to integrate dental technologies into his workflow. Now, more than a decade later, innovative technologies such as CAD/CAM, CNC milling and 3D printing are shaping his work and offer increased efficiency. In this interview with Dental Tribune International, Kreimer shares his journey from a conventional to a digital laboratory and weighs up the advantages of investing in an in-house 3D printer.

Mr Kreimer, when did you first start working in the dental field, and what led you to a career in dentistry?
Technology has always been an interest of mine. Since 2009, I have been able to combine this interest in technology with dentistry through my education in dental technology. At the time, my parents were operating a conventional dental laboratory in Germany that made little use of digital technologies such as CAD/CAM.

After completing my master's in dental technology, I took over as managing director of our family laboratory.

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Fig. 1: Master dental technician Stephan Kreimer believes that digital technologies such as 3D printing will help establish new standards of care in dentistry and create new business models. **Fig. 2:** Stephan Kreimer bought his first 3D printer back in 2016 and has significantly scaled up digital production in his dental laboratory ever since.

I was betting strongly on innovative technologies such as CNC milling and 3D printing and closed collaborations with leading manufacturers, including 3Shape and Formlabs. Smartly combining the passion for aesthetics and craftsmanship, which is inherent to our industry, with the enormous potential of digital technologies is definitely the way forward.

Your dental laboratory has eagerly adopted digital technologies into its workflow. Could you tell us more about it and discuss some of the digital solutions you are using?

It has been a journey. We started as a conventional dental laboratory and have been operating with traditional workflows for over 30 years. In 2009, we adopted our first CAD software but outsourced all of our digital production to service providers. Things changed quickly when we invested in our first 3D printer, a Formlabs Form 2, in 2016. At the time, the system was not optimised for dentistry, but it was clear that it had great potential. Within the less than five years since then, most of our customer base has adopted intra-oral scanners and we scaled our digital production capabilities significantly. Today, we use an imes-icore milling machine and multiple 3D printers that run almost 24/7 and work with both 3Shape and exocad. Around 70% of our customers send us digital impressions.

How did you integrate digital technologies, including 3D printing and CAD/CAM, into your laboratory?

It was definitely through trial and error. Especially in the early days, which was just a few years back, 3D printing was not well optimised for a dental workflow. Interfaces to materials, software and other workflow requirements have not been coordinated well between different manufacturers. This has led to the formation of a highly active international community of dental technicians who exchange through social media what they have learned. Personally, I've learned a lot from my peers around the world, and I'm equally giving back to the community

> "Combining the passion for aesthetics and craftsmanship, with the enormous potential of digital technologies is definitely the way forward."

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Fig. 3: 3D-printed dental appliances. *(All images: © Stephan Kreimer)*

and the manufacturers. Dentistry is at the intersection of multiple disciplines, and we need to have good communication to make progress.

The rate of innovation in digital dentistry is extremely high. We now see manufacturers coordinating much better and creating more accessible ecosystems that are much easier to use. At the same time, most of the potential is still untapped and will become apparent as we undergo significant transformations within our industry.

"We are undergoing a paradigm shift in dentistry because digital technologies are fundamentally changing the dynamics of our industry."

Having worked with digital technology for over a decade now, what benefits do you see of using dental technology, especially 3D printing, in a dental laboratory?

To me, dental technology is about combining the best of two worlds: analogue and digital. We still need and will continue to need traditional craftsmanship to meet the high requirements for individualised aesthetics in complex cases. At the same time, the holistic digital workflow works well in an increasing number of areas, enabling significant increases in efficiency while maintaining or improving overall quality. Digital fabrication in particular enhances production speed and reproducibility.

Dentistry is constantly evolving. What lies ahead for dentistry, and what dental technology is most likely to shape its future?

In my view, we are now at a point where most of the industry understands and embraces the vast potential of digital technologies. At the same time, we are just about to move from an early adopter stage to the early majority stage when it comes to the adoption of digital technologies. In Germany, for example, only 15% of dental practices are using intra-oral scanners, much less than in the US. However, the trend towards digital impressions is accelerating fast!

We are undergoing a paradigm shift in dentistry because digital technologies are fundamentally changing the dynamics of our industry. We will see entirely new business models, and together we will establish new standards of care. It is an exciting time, and for those who embrace this change, there will be many opportunities.

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“3D printing in dentistry is much more than just a new technology”

An interview with Patrick Thurm, managing director and general manager for Europe at SprintRay

By Claudia Duschek and Iveta Ramonaite, Dental Tribune International


Patrick Thurm

3D printing is here to stay, and it continues to be one of the major topics in dentistry. Just recently, Dental Tribune International had the pleasure of speaking with Patrick Thurm, the managing director and general manager for Europe at SprintRay. In this interview, Mr Thurm talks about expansion and about the current state of the 3D-printing market and discusses what distinct features set the SprintRay Pro apart from other 3D printers currently used in dentistry.

Mr Thurm, in March, you became the general manager for SprintRay’s operations in Europe and subsequently opened the company’s European branch office in Germany. How have SprintRay’s solutions been accepted by European dentists so far?
We have received great feedback from dentists and laboratories. We opened the European branch office in May 2021 in Weiterstadt in Germany, close to Frankfurt Airport.

Recently, we have welcomed several dentists, orthodontists and dental laboratories to our showroom and have spread our message in webinars and online. We are proud to be working with dental key opinion leaders who quickly adapted our solutions into their practices and laboratories.

We work with leading dental distributors across Europe and have attracted a great amount of dental and non-dental talent to join us in our journey to provide frictionless dental workflow solutions. The best feedback we have received was from a dentist, who commented that our product was providing the "experience as if Tesla and Apple had built a 3D printer together". Our customer support has also received very positive feedback.

3D-printing systems were introduced to dentistry about two decades ago. However, the technology has been rather costly. Do you think that more dental laboratories and practices will consider 3D printers in the near future now that new companies are entering the market and offering more affordable solutions?

All dental practices, laboratories and even patients can benefit from 3D printing. It offers frictionless integration with intra-oral scanners and digital workflows, fast in-house production for many indications, and efficient treatment workflows. It boasts rapid development, with many innovations in material for an even broader range of indications. Needless to say, 3D printing also allows for faster delivery of solutions to the patient, and investing in our solution is affordable for practices and smaller laboratories.

Based on your experience, which have been the quickest countries in Europe to adopt 3D-printing technology, and in which countries has the development been rather slow?

In general, countries with a higher rate of digitisation of laboratory scanners, intra-oral scanners and chairside dentistry are adopting the technology faster, and at the moment, these countries are Germany, Italy and Spain. However, other countries are catching up quickly, as the benefit of reduced production costs, time to market and patient satisfaction are valid in every market.

What impact did the COVID-19 pandemic have on the dental 3D-printing market and on your company in particular?

The beginning of the pandemic was an unprecedented time for all of us. However, many dental professionals

SprintRay's motto is "The next 100 years in dentistry". How is your company living up to this?
3D printing in dentistry is much more than just a new technology. It has the potential to control costs, improve flexibility and expand the scope of patient care. To deliver on this potential, we made the SprintRay Pro the most user-friendly, powerful and reliable desktop 3D printer in dentistry.

Our 3D-printing solution is born from the dental community. It arises from the collaboration of master designers, world-class dental professionals and superlative engineers, who operate in total alignment with a single goal, which is to revolutionise dentistry by bringing affordable and easy in-office manufacturing to every dental practice in the world.

What are the distinctive features of the SprintRay Pro?
SprintRay provides a frictionless digital dental workflow, from the seamless integration of a dental scanner and the possibility of choosing a digital design service to the 3D printing, washing and curing. It is also easy to operate since it boasts plug-and-play, intuitive handling and easy-to-use 3D-printing software. It is fast, effective and precise.

Also, SprintRay has an open certified system and works with SprintRay resins as well as with other verified resins. Finally, it offers high-class customer support.

What advantages does the printer have compared with competitor's products?
Our 3D-printing system was exclusively developed with dentists and dental laboratories for the dental market, and our team consists solely of 3D-printing experts. We do our best to understand and meet the needs of the dental community and offer solutions that drive high patient satisfaction.

started looking for new solutions to increase relevance for their patients, and that's when 3D printing and intraoral scanners became the most popular investment. SprintRay, which provides technology solutions to the dental market only, has benefited greatly from this. Our teams did an outstanding job under pandemic circumstances to further develop and enhance our solutions, and we have invested a great deal in sales, services and support structure in order to become a relevant partner for dental practices during these uncertain times. Having achieved this very positive development in the US market, we made the decision to start a business in Europe and subsequently opened our European headquarters.

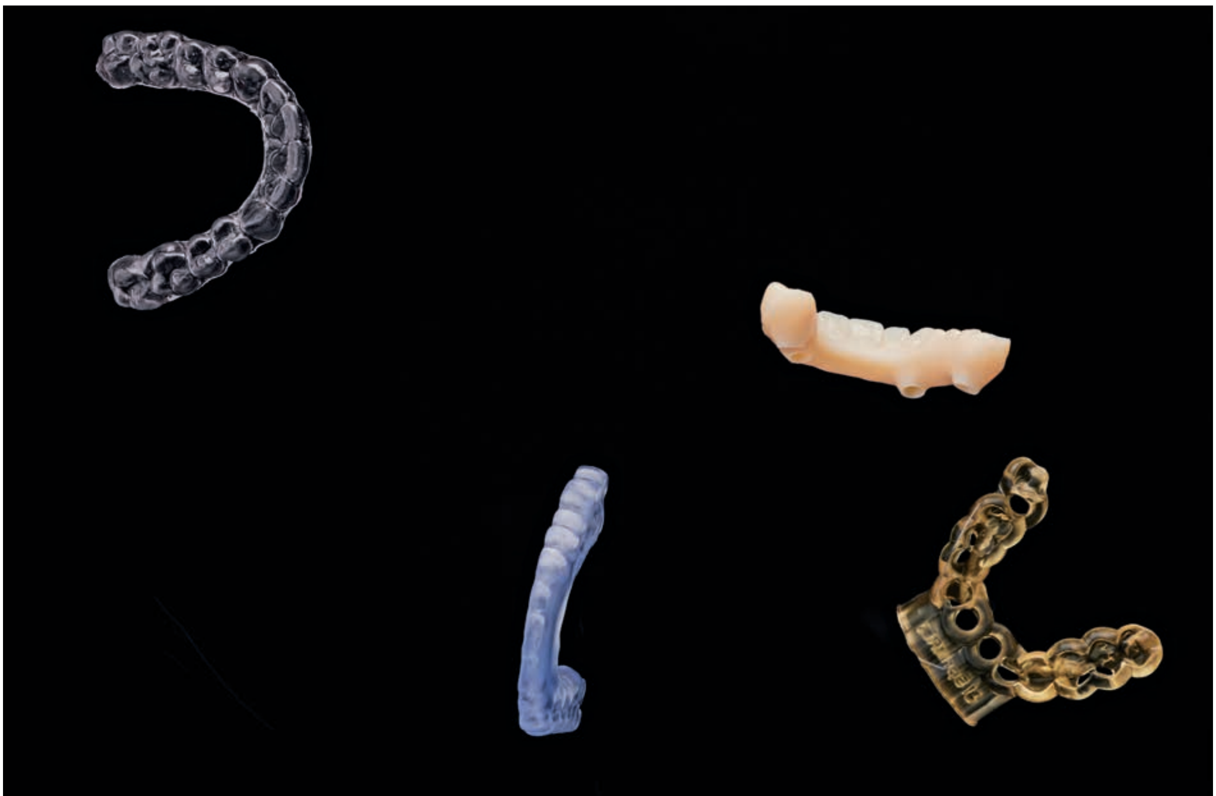
Having lived in a pandemic for over a year now, dentists and laboratories are seeking efficient solutions for their practices and their patients, and a 3D printer from SprintRay is a perfect investment.

What exactly can be printed and with which materials?
We are able to print a broad range of applications and materials. All kinds of models can be printed, including aligner models and die models and study models, and our portfolio includes biocompatible dental applications such as occlusal guards/splints, permanent and temporary crowns and bridges, surgical guides, indirect bonding trays, denture bases/teeth, and wax-ups. We have a wide range of high-quality SprintRay resins, but also a broad range of validated and certified materials available from other 3D-printing resin manufacturers. Users are free to choose from either range of materials.

The majority of dental impressions are still fabricated using conventional methods. What developments do you foresee in the coming years in this field?
We are expecting a fast growth and adoption rate in intra-oral scanners and dental technology, despite the pandemic. By purchasing a SprintRay 3D printer, the users of intra-oral scanners and CAD/CAM technology are able to offer solutions that further accelerate the fast adoption of intra-oral scanning for their patients.

Cost efficiency, speed and usability are key advantages of 3D printing. The material used is the most important factor for innovation in the upcoming fields. More and more indications can be printed already, and more are coming in the near future. If one has an intra-oral scanner, there is no reason why one should not invest in a 3D printer.

Do you think that 3D-printing technology could replace milling systems in the long run?
Yes and no. Yes, because printing is cheaper and faster for many indications, and no, because materials such as ceramics and metals will always have their place in dentistry. I believe that milling and printing will go hand in hand.



Fast, affordable and aesthetic 3D-printed dental restorations

An interview with Thomas Kwiedor, head of business development for 3D printing at BEGO

By Iveta Ramonaite, Dental Tribune International

BEGO is a modern company with 130 years of dental expertise that has made a name for itself in 3D printing—most recently with the introduction of the world's first tooth-coloured, ceramic-filled hybrid material, VarseoSmile Crown plus, for the 3D printing of definitive restorations. In this interview, Thomas Kwiedor, head of business development for 3D printing at BEGO, speaks about the advantages of 3D printing compared with current digital dental solutions and about the benefits it brings for dentists, dental technicians and patients.

Mr Kwiedor, 3D printing is often described as the most innovative manufacturing technology of the future. Is that your assessment?
Yes, in my opinion, 3D printing is the most important manufacturing method of the future. Based on this conviction, we at BEGO have utilised 3D-printing technology from a very early stage, although we ourselves did not call it 3D printing 20 years ago. I am talking about selective laser melting (SLM), in which frameworks are additively built up from a metal powder using a laser beam.

Fig. 1: BEGO's VarseoSmile Crown plus is the world's first ceramic-filled hybrid material for the 3D printing of permanent restorations. *(All images: © BEGO)*

Fig. 2: Thomas Kwiedor has more than four decades of experience in the dental industry.

We pioneered this 3D-printing process with metal powder for the dental sector, making the CAD-supported, fully automated production of crown and bridge frameworks possible early on.

For us, milling is only a kind of bridging technology, which is why we have at all times resisted the temptation to offer milling machines for decentralised production. Over the last two decades, we have invested heavily in the development of customised solutions for dental 3D printing, not only with metal powder but also with resins and ceramic-filled hybrid materials, in order to enable users to produce a wide variety of dental restorations.

What do you regard as the advantages of 3D printing over milling, which you described as a kind of bridging technology?
Today, 3D printing already offers the possibility of quickly and inexpensively producing, for example, aesthetic crowns for temporary and permanent retention in the patient's mouth. 3D printing is superior to subtractive or milling techniques not only because of freedom of design but also because of efficiency, as it is much more resource-effective. Compared with milling, the investment costs for 3D-printing technology are also significantly lower. Already today, there are powerful 3D printers on the market that require only a fraction of the usually high five- or even six-figure acquisition costs for milling units. 3D printing is therefore suitable for all users who want to produce high-quality dental restorations with contemporary and future-oriented technologies while keeping investment costs low and thus avoiding the risk of a bad investment. This is particularly relevant as technologies are developing ever more rapidly and becoming obsolete after only a few years.

Last year, BEGO caused a sensation in the 3D printing area by introducing VarseoSmile Crown plus. What are the performance features of 3D-printed restorations made out of this material?
VarseoSmile Crown plus is the world's first ceramic-filled hybrid material for the 3D printing of permanent restorations. It has been given 510(k) clearance by the U.S. Food and Drug Administration and fulfils all the requirements for a Class II medical device. Restorations made of VarseoSmile Crown plus are characterised by high aesthetics, a low ageing and discoloration tendency, and high patient comfort. VarseoSmile Crown plus is offered in seven shades according to the proven VITA classical shade system. The high bond strength of the material with luting composites prevents decementation and thus reduces the risk of secondary caries formation.

Renowned universities and institutes have tested the long-term performance of 3D-printed restorations made of VarseoSmile Crown plus and confirmed the excellent properties of the material. The results of these studies are available for download from our website (https://www.bego.com/3d-printing/materials/varseosmile-crown-plus/scientific-studies/).

In what aspects are 3D-printed crowns made of VarseoSmile Crown plus superior to milled crowns made of hybrid ceramics?
Here again, the main issue is efficiency. Thanks to full integration into the digital workflow and low material costs, a permanent crown can be printed with a material input of about US$2 and, depending on the printer, in significantly less than an hour! Patients thus receive direct, permanent restorations in just one session. These resto-


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Fig. 3: VarseoSmile Crown plus restorations possess natural aesthetics, as well as a low ageing and discoloration tendency.

rations are not only affordable but also highly aesthetic and long-lasting.

Can only permanent crowns be printed with VarseoSmile Crown plus, or does it work for other types of restoration?
VarseoSmile Crown plus can be used for 3D printing not only crowns but also inlays, onlays, tabletops, veneers and veneers on metal frameworks—in each case for permanent retention in the patient's mouth.

"We want to make our innovative material available to as many users as possible—regardless of which qualified 3D printer they use."

The multi-talented character of our material is also expressed in the fact there is a wide range of compatible 3D printers for which the use of VarseoSmile Crown plus is approved. We want to make our innovative material available to as many users as possible—including those who do not own a 3D printer from the BEGO Varseo printer family. Therefore, we have also recently entered into partnerships with well-known 3D printer manufacturers, such as Formlabs, Asiga and SprintRay, which specialise in 3D-printing technologies. We are continuously working to qualify VarseoSmile Crown plus and other materials from our 3D-printing portfolio for other printer partners as well.

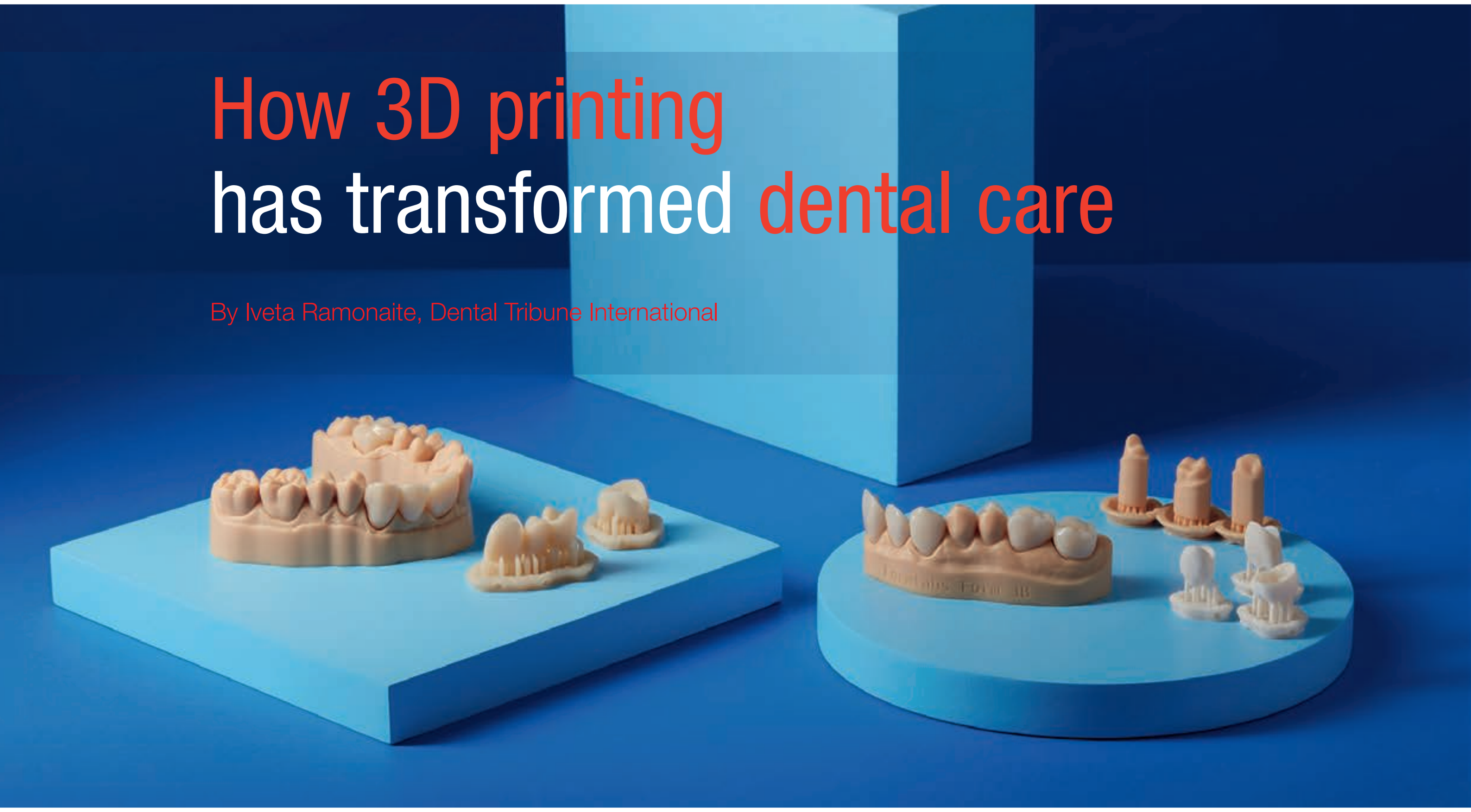
For some time now, 3D printing has been used more and more for the production of provisional restorations. What solutions do you offer for this?
Since the beginning of 2019, we have offered a special resin, VarseoSmile Temp, for the 3D printing of short- and long-term temporary restorations, and we can definitely confirm that this trend for the use of 3D-printing technology for temporary restorations is growing. The range of indications for our resin, which is also a tooth-coloured biocompatible Class IIa material, includes 3D-printed crowns, inlays, onlays and veneers as well as bridges with a design length of up to seven units. With VarseoSmile Temp, very aesthetic restorations can be realised that also feature high strength and thus provide a precise and dimensionally stable fit in the patient's mouth. These have significant advantages over conventional direct temporary restorations. We have received feedback from a large number of customers informing us that they also love to use the material for try-ins or mock-ups in order to give patients an impression of the shape, functionality and aesthetics of their future final prosthetic restoration.

What can be expected for the future of 3D printing?
The potential that 3D printing offers now and will offer in the future is enormous. We ourselves are currently working intensively on a material that enables the 3D printing of artificial teeth.

One area that will certainly be exciting is that of multi-material and multi-colour printing, which among other things, will make it possible to reproduce the light-optical properties of natural teeth in the best possible way. In the future, we will also encounter material combinations that enable different properties within one material. It can also be assumed that the automation of individual work steps, such as post-processing, will be further professionalised.

How 3D printing has transformed dental care

By Iveta Ramonaite, Dental Tribune International



3D printing offers a high level of customisation of dental products, is highly efficient and cost-effective, and has many applications across a wide range of industries, including dentistry. *(Image: © Formlabs Dental)*

Dentistry has come a long way since the first introduction of digital technology. Georgio Haddad is an intrapreneur who is in charge of the development of dental strategic partnerships and initiatives at Formlabs. Haddad spoke to Dental Tribune International about the various applications of 3D printing in dentistry, reflected on how 3D printing has reshaped the dental industry and weighed the risks associated with embracing the technology.

How has the introduction of digital dentistry facilitated the carrying out of dental procedures, and why should dental professionals consider investing in new technology?

Digital technology has changed the way we deliver dental care. With advanced imaging, case diagnoses have improved significantly, and treatments are now more predictable. With milling and 3D printing, professionals can produce extremely high-accuracy dental products in order to offer their patients the best results. As technology continues to evolve, these products are produced faster and become more cost-effective, improving the end result for the patient.

Dental professionals are lucky to be in such a dynamic field. Staying curious and investing in new technology is a must in order to keep up with the increasingly high standards of patient care.

3D printers offer an infinite number of applications. How is 3D printing used in dentistry, and what are some of the advantages of 3D printing for dentistry?

3D printing is used in many areas of dentistry. There are three basic categories:

– *Applications that would not be possible or would not make sense without 3D printing.* These products cannot efficiently be made differently and include surgical guides, models for aligner thermoforming and indirect bonding trays.
– *Applications for which 3D printing improves on traditional manufacturing methods.* These products can be made without 3D printing, but printing offers increased accuracy and control, and shorter delivery times. This category includes castable and pressable frameworks, temporary restorations, splints and custom trays.
– *Novel applications for which 3D printing offers a disruptive alternative.* These are the real cutting-edge use cases, such as fully 3D-printed dentures and permanent restorations. They are not the most common uses, yet, but indeed some of the most exciting.

3D printing offers advantages beyond opening up new applications. Products are more accurate, turnaround time is shorter, and it allows for a more flexible and open communication between the practice and the laboratory.

3D printing is a powerful technology on its own, but the real impact comes from the people who use it. We see new 3D printing applications all the time, whether they are born of necessity or innovation. That is why Formlabs is committed to increasing access to powerful digital technology.

What are some of the criticisms of dental 3D printing, and do the benefits offered by using 3D printing outweigh the associated risks?
Ten years ago, the biggest problem with 3D printing was the prohibitively high cost of a printer. Luckily, with the success of manufacturers such as Formlabs in the market, printers are more affordable, more reliable and easier to use than ever before.

Now, the only risk lies in having false expectations. A 3D printer is a piece of equipment, and learning to use a desktop unit like the Form 3B is easy, but it does take some time. Those who choose to adopt digital technology should embrace the learning curve, ask for advice from their peers and seek out professional development opportunities.

Moving forward, 3D printing needs to overcome the dental industry's skepticism about novel printing materials and applications such as printed dentures and permanent restorations. Manufacturers like Formlabs need to be proactive about teaching experts and validating new technology in the industry in order to achieve a mindset shift. But it will eventually happen. We have already seen it many times in the dental industry. Implants, zirconia, intraoral scanners, chairside milling and many other materials and technologies overcame the initial skepticism. I am glad to be part of the movement that is leading and revolutionising digital dentistry.

Georgio Haddad, dental strategic partnerships and initiatives lead at Formlabs, a 3D-printing technology developer and manufacturer. *(Image: © Georgio Haddad)*

"3D printing is a powerful technology on its own, but the real impact comes from the people who use it."

Editorial note: The Formlabs Dental webinar, titled "Revolutionizing digital dentistry with 3D printing—accessible solutions and new applications," is available on demand at www.dtstudyclub.com. Registration is free of charge.

Formlabs' Form 3B printer. *(Image: © Formlabs Dental)*

"Our service meets all of the needs that arise in the dental clinic and laboratory"

An interview with Riccardo Molinelli

By Jeremy Booth, Dental Tribune International

Intra-oral scanners and 3D printers were two of the biggest topics in the halls of this year's International Dental Show (IDS) in Cologne in Germany in September. At the show, Dental Tribune International visited the booth of SHINING 3D and spoke with Riccardo Molinelli, regional sales manager for the Europe, Middle East and Africa region, about the company and its new Aoralscan intra-oral scanner and AccuFab-L4D large-format dental 3D printer.

Could you please tell us about SHINING 3D?
The company was founded in 2004, and for the last 17 years, it has been focused entirely on the development of 3D-digitising and 3D-printing solutions. We are fully focused on the development of scanners and 3D printers for multiple applications. Indeed, dentistry is only one of the business areas served by the company. We also cover industrial and metrological applications and the 3D-digitising of most common objects. These

Fig. 1: Digital dentistry specialist SHINING 3D demonstrated its new Aoralscan 3 intra-oral scanner at the recent International Dental Show in Cologne. *(Image: © SHINING 3D)*

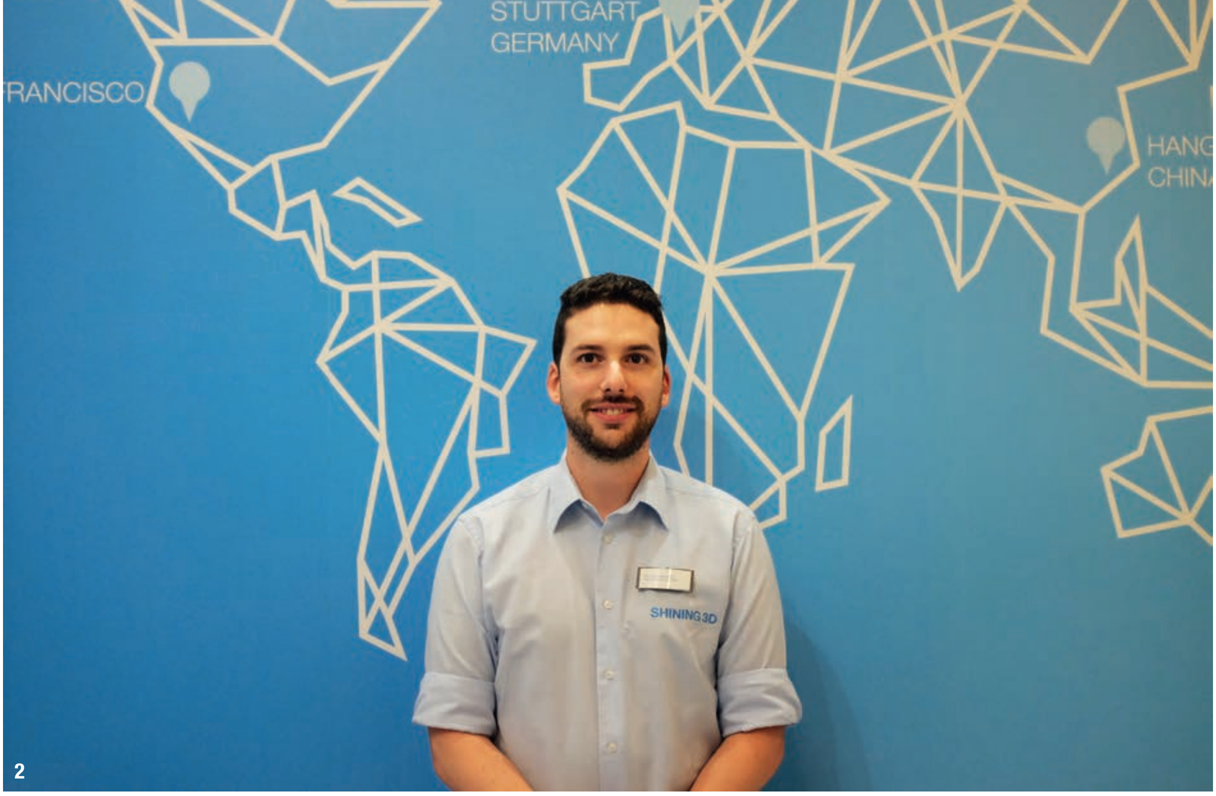


Fig. 2: Riccardo Molinelli, SHINING 3D's regional sales manager for the Europe, Middle East and Africa region. *(Image: © DTI)*

different business units have application for both scanning and 3D printing.

What is the company offering to dental professionals?
We began developing dental scanners around 2012. We are proud to look back to our very first product, which was a desktop scanner for a dental laboratory, and to compare it with what we see around us here at our IDS booth—a full suite of digital solutions for both dental clinics and dental laboratories. Over the years, we have developed more powerful and better-performing desktop scanners, and we have also developed and launched 3D printers and our intra-oral scanning solution.

The company is exhibiting two new products at IDS: Aoralscan 3 and AccuFab-L4D. What should dental professionals know about these new products?
The first thing that I would say is that we can think about these two products either as stand-alone solutions or as a bundled solution that has been developed specifically for a dental clinic. That does not mean that the L4D printer cannot be used in the laboratory. However, from our point of view, this is an ideal 3D printer for use with the intra-oral scanner in order to cover the needs of dentists. There is a series of different reasons behind this. Firstly, the footprint and design of the unit are ideal for clinics, where space is often limited. Furthermore, all of the possible applications that the printer is equipped for—such as printing crowns, orthodontic models and surgical guides—make it an ideal choice for dental clinics. One additional point I would like to stress is that the printer is an open system. This means that, if the dentist is already familiar with third-party materials, we can integrate those third-party materials into our 3D printer without any limitations.

We just saw a demonstration of the Aoralscan intra-oral scanner. How have dental professionals at IDS reacted to it?
Aoralscan is something that we are very proud of. We have worked on this technology for several years, and what we see being demonstrated here at the booth is the result of our constant investment in research and development and in product improvements.

This intra-oral scanner comes with a lot of nuances, both from the hardware and software point of view. The previous generation remains an excellent product, but what I can say about the new scanner at the end of this four-day exhibition is that we have received extremely positive feedback from users from all around the world. We have had excellent feedback with regard to the scanning speed, the precision of the data collected, and the multiple applications and options that can be covered by this brand-new device.

The company has a global network. What are the advantages of this for dental clinics and laboratories?
We have a sales network that covers five continents and three offices. Our headquarters is located in Hangzhou in China, and we have offices in San Francisco in the US, and in Stuttgart in Germany. The greatest benefit of this structure is that, for technical support and sales support, our customers know that there will always be somebody to assist them.

What we do on a daily basis is to support dentists and laboratories all over the world. Fortunately, we can also rely on the wonderful support of our dealers around the world. It is a matter of cooperation, and we are very satisfied with the partnerships that we have and the advantages that they bring for our customers.

Fig. 3: SHINING 3D said that IDS visitors were impressed with the Aoralscan 3—in particular with its scanning speed and the precision of the data collected. *(Image: © SHINING 3D)*

Does SHINING 3D cater to smaller dental clinics and laboratories as well as to larger businesses?
Yes. Our service meets all of the needs that arise in the dental clinic and laboratory. For example, there may be a very simple restoration that is required—like a single crown restoration—and, thanks to the process of scanning, CAD and 3D printing, this can be done directly in even the smallest of clinical settings. In contrast, thanks to the interconnection between our devices and the software that we have, SHINING 3D's solutions can cover even the most complicated type of restoration for every type of patient, including restorations that require multiple steps to be completed between clinics and laboratories.

> "Digital dentistry represents an advantage for dentists and dental technicians only if it is integrated into a complete system."

What more can you tell us about the software?
We work in partnership with exocad—the world leader in CAD—and through this partnership, we have direct integration of exocad software. Both our scanners and printers directly communicate with exocad in the most efficient way, and we also have integration with other software providers on the market.

What I can say is that we offer a fully open system. Our devices, scanners and printers are an open system that can communicate and interact with any other open system.

Our philosophy is to provide products that have the longest possible lifetime—not only from the hardware point of view but also in terms of software. That is why we provide software licences that do not have annual fees and do not have fees involved for updates.

What should dental professionals watch out for in order to ensure that these digital tools remain an asset in their daily practice?
Digital dentistry represents an improvement and an advantage for dentists and dental technicians only if it is integrated into a complete system—only if the digital tools assist them from the beginning to the end of the treatment or task. Otherwise, it is possible that the technology can represent an obstacle.

If one company provides all the steps of the digital solution, and if that company has expertise in the different segments of this digital workflow—scanning, CAD and 3D printing—then this represents the greatest advantage for clinicians. There is a simple reason behind this: the learning necessary for the individual steps will be drastically reduced, owing to the fact that the customer will always be able to rely on the most direct support.

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The AccuFab-L4D is a large-format dental 3D printer developed completely in house by SHINING 3D to make 3D printing solution more accessible to everyone.

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Printing clear aligners in-house—how accessible is it?

By Jeremy Booth, Dental Tribune International

A growing number of dental practices are choosing to manufacture their own clear aligners in-house using 3D-printing technology.

Bellevue Orthodontics says that its patients can walk out of their first appointment with a set of fully customised clear aligners. Utilising an all-digital workflow, Bellevue has joined the 3D-printing revolution that has seen private dental practices begin producing clear aligners in-house. The founders of the practice have also launched an educational community to help dentists and team members incorporate 3D-printing technology into their workflow. But what exactly is required and what advantages does in-house production offer?

The clear aligner market leader Invisalign is facing increased competition from smaller, localised manufacturers. Dentists wishing to offer clear aligner treatment have a number of options. Manufacturing and selling an in-house brand directly to patients is one option that a growing number of practices are choosing.

A dental practice requires an intra-oral scanner, a suitable 3D printer and photopolymer dental resins for 3D-printing applications, a thermoforming machine for adapting the aligner material to printed models, and a digital workflow in order to bring it all together. Practice owners need to invest in material resources, but they also need to invest in education to help their team implement a 3D-printing workflow.

3D printing offers workflow control

Dr Christopher Riolo founded Bellevue Orthodontics in 2019 after a decade of providing orthodontic treatment to patients in the Seattle area from his downtown Riolo Orthodontics clinic. In the clear aligner category, Bellevue offers its patients Invisalign but also its own in-house product.

According to the practice, the benefits offered by making its own aligners in-house include a lower treatment cost for patients owing to factors such as the ease of making 3D-printed retainers. A lifetime retainer policy is offered to patients, for example, which lowers the overall cost of treatment. The practice also points out that many patients nowadays are conscious of the impact of their treatment on the environment and that its in-house aligners result in a lower environmental impact because shipping and handling are not required. It says that having a better understanding of the materials used to make its own aligners means that staff can offer patients greater peace of mind.

Clinic Manager Cali Kaltschmidt told Dental Tribune International that the benefits of offering an in-house brand also include an expedited start to treatment, the possibility of same-day replacements and improved compatibility with fixed appliances for hybrid treatments. “The ability to provide aligners on the same day or even in the same week is huge. Our busy adult clientele love it,” Kaltschmidt explained. She said that integrating 3D printing is inevitable once a practice has begun using intraoral scanners and that doing so has allowed Bellevue to take control of its workflow.

“3D printing has allowed us to be in control of our own workflow, and with that, the possibilities are endless. We are able to provide aesthetic treatment options for our patients and keep the cost down by not accruing large laboratory fees from third-party companies. This includes in-house clear aligners, lingual braces and hybrid treatment using a combination of both. 3D printing has truly changed the way we practice,” Kaltschmidt said.

“We’re so used to next-day delivery with Amazon and other services, why should straightening teeth be any different?” Riolo asked in a press note. “Orthodontists have the technology and clinical expertise to expedite care in ways that major corporations cannot deliver. This is why we decided to adopt these technologies early on.”

“The investment for orthodontists and dental professionals to get started (with a 3D printer) can be anywhere from $500 to $20,000 or more,” Kaltschmidt said. “Technology is advancing so quickly, and the cost of 3D printers will continue to come down. Our advice for those interested in getting started with 3D printing is to spend less on the printer and invest more time into refining your digital workflow. You will begin to notice the differences when you go from analog to digital.”

“Orthodontists can definitely brand their own aligners and they absolutely should,” Kaltschmidt continued. “The product you design and manufacture in your office as an orthodontist is a superior product in the end, and you should package and brand your aligners to reflect that. In-house aligners give the practitioner full control over workflow, time to delivery, trim line and choice of aligner materials.”

Last year, Riolo and Kaltschmidt founded the Tooth Movement 3D-printing educational community in order to share their expertise on using 3D-printing technology for orthodontic applications like clear aligner therapy. Kaltschmidt said that demand from within the dental community for the limited courses on offer has been significant and that she and Riolo have worked mostly with orthodontists, members of the treatment team and recent graduates. “Many residents do not have any exposure to 3D printing while in their schooling,” she pointed out.

Manufacturers are bullish on adoption of 3D printing in dentistry

Advancements in 3D-printing technology have seen the quality of desktop models for dentistry climb while costs have fallen.

According to Dr Baron Grutter, who owns a dental practice in Kansas City, being able to offer clear aligner treatment at a lower cost has improved case acceptance at his practice for a product that is known for its high earning potential. Grutter was an early adopter of 3D-printing technology in the dental practice and has manufactured his own clear aligners in-house for some time. He told the manufacturer SprintRay in its Practice Insights series last year that a return on the investment of a 3D-printing workflow can be made by selling as few as three or four cases.

> “Orthodontists have the technology and clinical expertise to expedite care in ways that major corporations cannot deliver”— Dr Christopher Riolo, Bellevue Orthodontics

Growing demand for this technology from dentists is being met by companies manufacturing solutions that are tailored to a number of dental applications, including making clear aligners. Manufacturers predict that sales will climb this year and that integrated digital workflows will make the technology even more accessible.

Lee Kwang Min, vice president of the Korean 3D-printer manufacturer Carima, told the online trade journal *3D Printing Industry* in 2019 “[2020] will be a full-scale digital dentistry year. The emergence of a variety of 3D scanning solutions with an affordable price range, which has been an obstacle to the spread of digital dentistry, will replace the milling machines in the market and, furthermore, (will accelerate) the rapid adoption of 3D printers.” Min said that he expects that a collaborative approach between individual manufacturers of 3D printers, software and scanners will act to increase the accessibility and adoption of the technology by dentists.

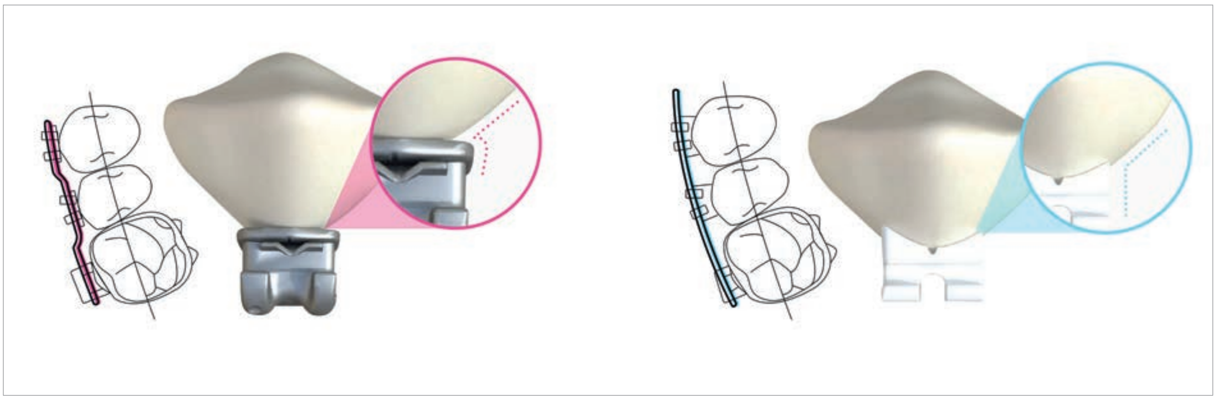
Digital orthodontics company raises funds for 3D-printed brackets

By Jeremy Booth, Dental Tribune International

Dr Alfred Griffin III said that LightForce brackets reduce practice visits—a crucial factor for patients and orthodontists and their teams during the pandemic.

LightForce Orthodontics is a digital dentistry platform that provides orthodontists with fully customised 3D-printed tooth-moving tools. Its customisable 3D brackets are the first of their kind on the market, and they are designed to reduce patient visits and treatment duration. The company launched LightForce in 2020, after five years of research and development, and has now raised $14 million (€12 million) in funding for the further development and commercialisation of the system.

The LightForce treatment process begins with the orthodontist sending a scan of a patient's teeth and a treat-



3D-printed brackets that can adapt to achieve a desired final tooth position for that unique patient. *(All images: © LightForce Orthodontics)* ment plan to the company's technicians, who then create customised brackets and trays. The system uses ceramic material that is specially formulated for 3D printing, but which is otherwise virtually identical to that used in injection-molded brackets.

The founder of the company, Dr Alfred Griffin III, told Dental Tribune International that the digital workflow resembles that used in clear aligner therapy. "LightPlan is the proprietary treatment software developed by LightForce that enables mass-customised braces," he said. "Doctors have complete control over every aspect of the treatment plan and can utilise a simple cloud-based interface for adjustments and approvals."

"Our treatment plans are unique to each individual patient and largely follow the clear aligner workflow," Griffin continued. "Where our technology diverges is when the orthodontist uploads the patient's scan to our LightPlan software, which enables the doctor to adjust the teeth virtually in order to create a perfect smile and bite for that unique patient, enabled by automatically designed braces."

Griffin explained that the LightPlan software generates bracket files, which are then printed at LightForce's centralised manufacturing plant in Cambridge. The brackets are then delivered to the orthodontist's office about a month later.

LightForce says that orthodontists should "move teeth, not brackets."

Increased personalisation using digital tools

LightForce aims to provide treatment for malocclusion, which is as individual as each patient is. "A person's lips, jaws, teeth and smile are individual, and it's important to customise the tools that impact his or her face," Griffin explained. "3D printing provides the ideal solution for patients, as it allows for customisation and uses modern technology to address an age-old problem. We've found 3D printing to be the best solution for orthodontic applications because it enables complete personalisation for each patient—it can print complex geometries, in this case unique tooth morphology that would otherwise be unavailable to patients."

He added: "On the one hand, we believe that the days of bracket prescriptions are numbered; on the other hand, we welcome the days of 'tooth prescriptions' for mass-customised appliances like aligners and 3D-printed brackets that can adapt to achieve a desired final tooth position for that unique patient." Griffin said that, in the future, he expects that there will be a rapid expansion of 3D-printing technology within the dental industry.

LightForce Orthodontics was founded in 2015. Over the last five years, Griffin and his team have undertaken extensive research and development for what is now the company's eponymous treatment platform. No one could have predicted that the 2020 launch of the bracket system would take place in the midst of a global pandemic, but it seems that the outbreak of SARS-CoV-2 has not hampered the company's plans.

> "Our treatment plans are unique to each individual patient and largely follow the clear aligner workflow."

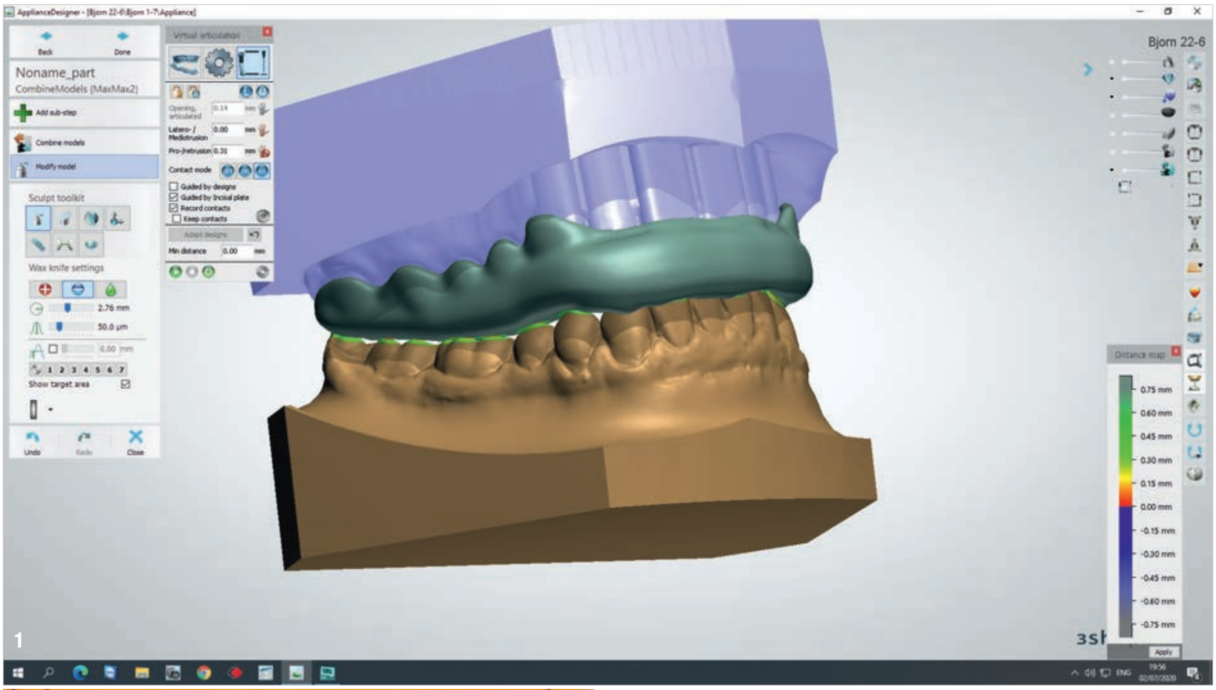
"In light of the ongoing pandemic, technology that reduces in-person dental visits is crucial not only for patients but also for the orthodontists and their teams that are caring for them," Griffin said.

Hundreds of orthodontists throughout the US are already providing treatment using LightForce brackets. Griffin said that the company will use its newly acquired funds to further develop its technology and product offerings and to scale its operations in order to meet what he called a recent surge in demand for more efficient dental technologies.

The funds were raised in a Series B funding round that was led by investors Tyche Partners, Matrix Partners and AM Ventures.

Fully digital workflow for producing an individual occlusal splint

By Sokratis Gonidis, Greece



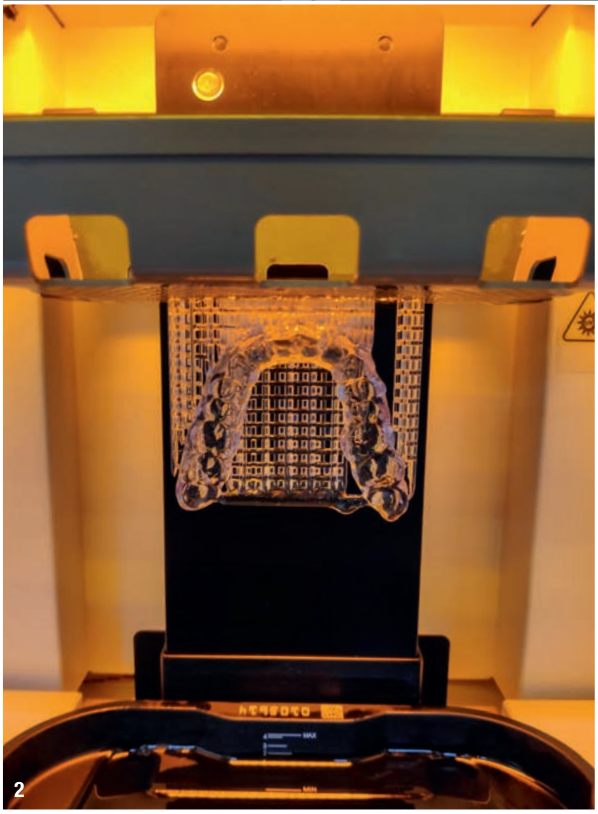


Fig. 1: 3Shape dental CAD software.

Introduction

In order to produce an individual occlusal splint, several steps have to be taken. First the dentition and articulation of the patient need to be digitised using an intra-oral scanner. These digital impression files are then transferred to dental 3D design software to prepare the design of a dental occlusal splint. Once the design is finished, the splint can be produced using 3D-printing technology with a certified specialist 3D resin.

Workflow

When using an intra-oral scanner, it is important to capture all areas of the dentition, including the relevant portion of the gingiva. It is important that the camera is capable of registering the bite accurately.

Fig. 2: NextDent Ortho Flex print on the platform on the NextDent 5100.

Fig. 3: High-gloss and transparent splint made of NextDent Ortho Flex.

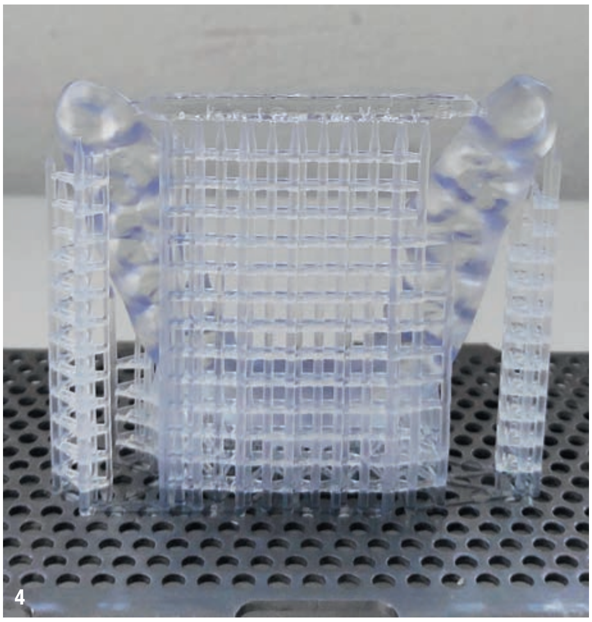


Fig. 4: Special support placement.

After importing the digital impression scans into the dental CAD software (3Shape), the wizard will guide the operator through the design of the dental splint (Fig. 1). Different parameters can be controlled, and block-out of undercuts is automated. Different design options are achievable, giving the technician and/or clinician options for selecting occlusal guidance etc. Once the dental splint design has been finished, it can be shared directly to a 3D printer. In our dental laboratory, we use the NextDent 5100 (3D Systems). The software (3D Sprint, 3D Systems) that controls the printer is very user-friendly and helps with positioning and support of the file.

Fig. 5: NextDent Ortho Flex resin.

For printing the occlusal splint, a specialist resin has been developed by 3D Systems called NextDent Ortho Flex (Fig. 2). This resin is optimised for occlusal splints and exhibits excellent mechanical properties, has a transparent appearance and is easy to polish after production. A high-gloss and transparent splint can be achieved by conventional polishing techniques, fine pumice and a lathe, and a high-gloss polishing compound at the final stage (Fig. 3). The unique printing style created for NextDent Ortho Flex provides support placement in such a way that the supports do not touch the occlusal surface (Fig. 4). As a result of this optimised printing style and supports, the dental splint fits the patient's dentition comfortably and the bite and occlusion are correct without manual altering. This is a huge step forward in the construction of digitally manufactured splints, saving a great deal of time for dental laboratories. The NextDent Ortho Flex resin (Fig. 5) has shown excellent results clinically, as it is more durable because of the specially developed flexibility. This has been confirmed by zero splint failures reported in six months of use.

contact

Sokratis Gonidis is the owner of Gonidis LAB located in Athens in Greece and is specialised in orthodontics and orthodontic CAD/CAM. He may be contacted at sgonidis@gmail.com.

3D-printed indirect bonding tray resin aims to halve orthodontic chair time

By Jeremy Booth, Dental Tribune International

Launched this year Formlab's new indirect bonding tray (IBT) resin is Class I compliant and biocompatible. *(Image: © Formlabs)*

Formlabs has launched a new indirect bonding tray (IBT) resin that it says will bring the benefits of 3D printing to orthodontic practices by streamlining workflows and drastically reducing patient chair time. The company's dental product manager, Sam Wainwright, says that the IBT resin provides an attractive alternative to traditional methods of placing brackets.

An appliance found in most orthodontic practices, the IBT allows dentists to place in one procedure multiple brackets that precisely fit a patient's dentition and prescription. The process of individually placing the brackets can be time-consuming, and Formlabs says that orthodontists can drastically reduce patient chair time by using 3D printing and its new resin when working with IBTs.

Speaking to Dental Tribune International (DTI), Wainwright said: "With 3D printing and the new IBT resin, the time-consuming process of individually placing the brackets can now be done with a custom appliance that saves the orthodontist's time by cutting patient chair time in half."

He explained that the company had worked with leading orthodontists during the development of the IBT resin. Trays made using the resin are flexible and provide for easy insertion and removal, but are firm enough to hold the brackets in place, Wainwright said. "The superb fitment and ease of 3D printing these appliances on the Form 3B, Wash and Cure make efficient orthodontic bracket placement accessible to any orthodontic practice," he added.

The IBT resin offers a completely digital workflow, and treatment planning is done using advanced orthodontic CAD software. Wainwright says that the workflow can result in a more efficient process, that it improves communication and that it can result in an easier exchange between dental practices and laboratories.

"Once the appliance has been designed, the file is ready to print, and the Form 3B's industry-leading ease of use makes this process as simple as possible. And once the appliance is ready to use, the process of placing brackets becomes so much easier than traditional methods. The brackets can be inserted into the appliance before the patient arrives, the appliance is easily inserted over the teeth, and every bracket is then held precisely in position," Wainwright said.

Launched on 16 February, the IBT resin is Class I compliant and biocompatible. DTI recently reported on a study that called into question the safety of 3D-printable resins used to manufacture oral retainers, including certain resins marketed by Formlabs as biocompatible. According to company information, Formlabs' biocompatible resins are developed in accordance with a number of ISO standards, and pass the requirements of those standards.

At IDS 2021, exocad announced the release of ChairsideCAD 3.0 Galway, the next generation of its easy-to-use CAD software for single-visit dentistry.

Imagine the CADabilities

By exocad, Germany

At IDS 2021, exocad, an Align Technology company, presented highlights of its three core products—DentalCAD 3.0 Galway, exoplan 3.0 Galway for implant planning and ChairsideCAD 3.0 Galway for single-visit dentistry.

The 360 m² booth was a central meeting point for exocad's global community at IDS. The trade show offered a rare opportunity for exocad users to meet specialists and developers from the Darmstadt-based software company in person. Visitors could linger at the booth's dozen software stations, learn about the 3.0 Galway release's highlights and ask exocad's software experts questions.

DentalCAD 3.0 Galway

Visitors experienced the 90 new and 80 additionally optimised features of DentalCAD 3.0 Galway. For example, they had the opportunity to try out the new Instant Anatomic Morphing. This feature automatically adjusts teeth in real time, greatly improving the speed and precision of anatomical tooth placement. Another exciting feature is parametric shape adjustment, which can transform all tooth libraries from a younger to an older anatomy. At another station, on-site experts demonstrated how the Smile Creator module can automatically recognise facial features using new artificial intelligence-assisted technology. Other demonstrations included: the improved processing of bridge connectors and how multiple connectors can now be adjusted simultaneously, the creation of mock-up tooth set-ups and how the software supports virtually prepared models, and virtual tooth extractions.

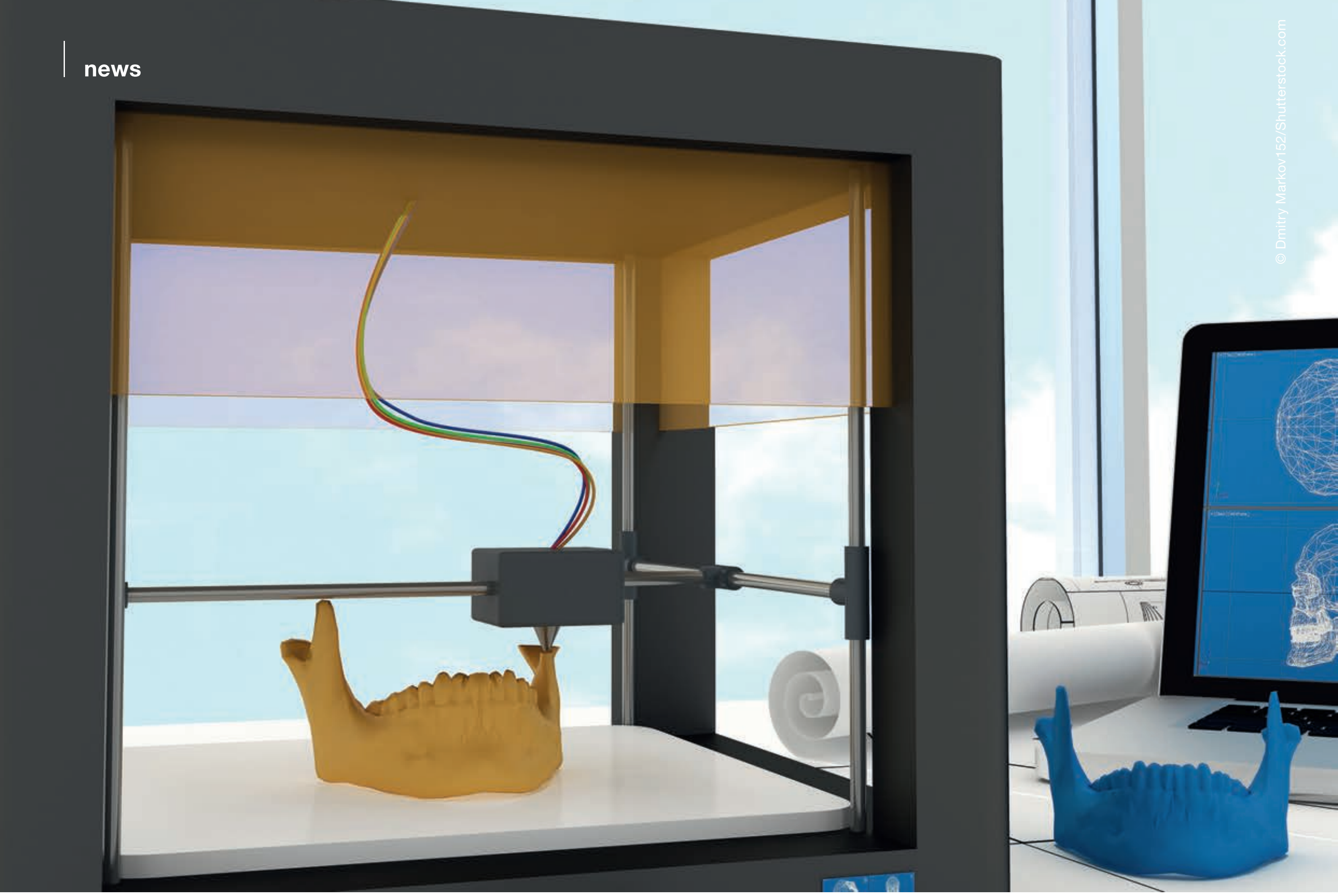
Exoplan 3.0 Galway for implant planning

Exoplan 3.0 Galway is a powerful, open and efficient software package for virtual implant planning. Having over 40 new and over 60 improved features, the new Galway version represents a significant expansion of guided implantology possibilities and offers improved integration with exocad's DentalCAD software.

ChairsideCAD 3.0 Galway for single-visit dentistry

During IDS, exocad announced the release of ChairsideCAD 3.0 Galway, the next generation of its easy-to-use CAD software for single-visit dentistry. With this new release, exocad offers dentists design tools for a vast range of indications with a wide choice of integrated devices. The new chairside workflow is highly automated, intuitive and optimised for practice use. In 2021, for the third year in a row, ChairsideCAD was selected for the Cellerant Best of Class Technology Award. ChairsideCAD 3.0 Galway is now available in the EU and other select markets.

ChairsideCAD: Simple interdisciplinary collaboration between practitioner and dental laboratory is achieved through integration with DentalCAD, exocad's leading lab software, and exoplan, the software for guided surgery. ChairsideCAD 3.0 Galway now features a dark mode.



3D printing continues to revolutionise dentistry, and recent evidence suggests that dental professionals can greatly benefit from printing 3D dental prostheses in-house.

Study highlights benefits of in-house 3D printing for immediate dental implant placement

By Iveta Ramonaite, Dental Tribune International

Owing to the growing popularity of point-of-care 3D printing and the subsequent creation of 3D-printing laboratories, a recent study aimed to compare the benefits of printing dental prostheses for fibula and implant reconstructions in-house with those of using traditional techniques that involve outsourcing to dental laboratories. The researchers found that in-house printing offers considerable benefits, such as reducing the waiting period before surgery, but that it requires an initial investment in 3D-printing equipment.

3D printing has recently helped to save the lives of many health care professionals fighting on the front line against COVID-19. It was seemingly impossible to comply with the updated recommended infection control practices in light of the shortage of proper personal protective equipment, and 3D-printed masks and face shields were produced to assist in this situation. Dental Tribune International (DTI) has also previously reported on the advantages of using a fully digital workflow and printing clear aligners in-house. The benefits of 3D printing are manifold, and so are its applications for medical use.

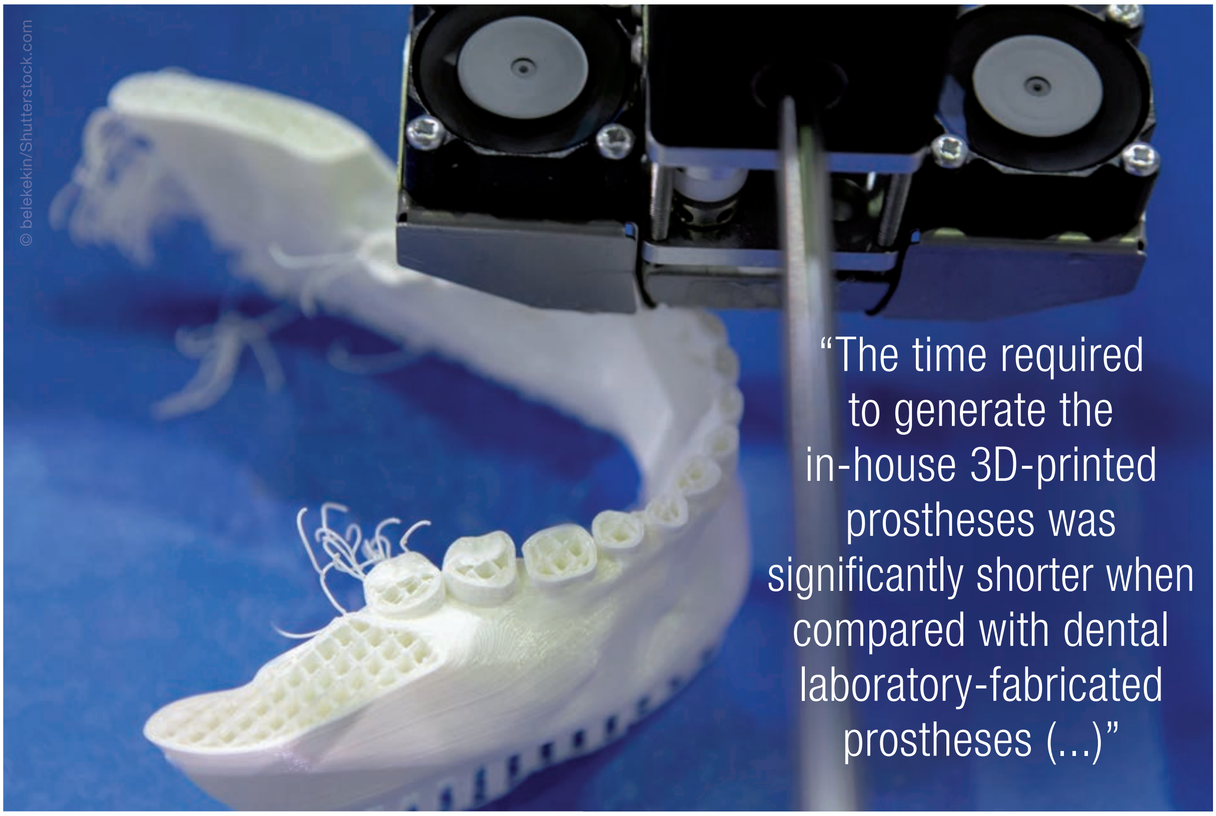
The present study included 12 patients who underwent free fibula reconstruction of the mandible or maxilla with immediate implants and immediate restoration. The restorations were created before surgery, and the first five patients each received a prosthesis that was fabricated by a dental laboratory after virtual surgical planning. The remaining patients each received a prosthesis that was designed by a surgeon and 3D-printed via the in-house laboratory.

The researchers fabricated a dental prosthesis using point-of-care 3D printing within 24 hours of the virtual surgical planning session. The time required to generate the in-house 3D-printed prostheses was significantly shorter when compared with dental laboratory-fabricated prostheses, which typically take weeks. Additionally, the procedure was more cost-effective. Whereas the prostheses created by an off-site dental laboratory averaged $617.00, each in-house 3D-printed prosthesis cost an average of $8.34 for resin, and the researchers noted that a full-arch prosthesis 3D-printed in NextDent Micro Filled Hybrid costs under $50.00. The price includes the costs for the resin and the export fee for Blue Sky Plan, a 3D-printing software.

"The study describes a digital workflow to design and 3D-print an immediate provisional dental prosthesis to be placed during jaw reconstruction when using a fibular free flap. This surgery has been called 'Jaw in a Day.' Previous methods involved third-party dental laboratories which require additional time, laboratory expertise and are more expensive. Our technique allows surgeon-guided virtual planning, just like we do with the jaw and fibula," Dr Fayette C. Williams, fellowship director in the Division of Maxillofacial Oncology and Reconstructive Surgery at John Peter Smith Health Network, told DTI. "Creating a 3D-printed dental prosthesis in-house allows more control for the surgeon to create the occlusal scheme. It is also much quicker. I can generate this prosthesis in one day, whereas dental laboratories can take two or more weeks," he added.

According to the researchers, outsourcing dental prostheses to a dental laboratory has previously created a delay in the treatment, which has limited its usefulness to benign conditions. In the present study, the digital workflow used allowed for immediate dental restoration for patients with malignant disease. "This time is significant for a patient with cancer waiting to get their surgery to remove their jaw and tumor," Williams explained. Despite its clear advantages, the researchers believe that the digital workflow presented in the study is most suitable for patients with teeth in place preoperatively that will be removed with their tumor. For more complex cases, it is necessary to familiarise oneself with image manipulation and prosthesis planning. Additionally, the researchers calculated that the total initial cost of a 3D printer and post-processing supplies can reach around $3,000.00, plus additional costs associated with using the software.

Editorial note: The study, titled "Immediate teeth in fibulas: Planning and digital workflow with point-of-care 3D printing," was published on 1 August 2020, in the Journal of Oral and Maxillofacial Surgery.



A recent study found that printing dental prostheses for fibula and implant reconstructions in-house eliminates the additional waiting period before surgery, making the treatment suitable for patients with malignant disease.

Guided applications for partial extraction therapy

By Drs Scott D. Ganz & Isaac Tawil, USA

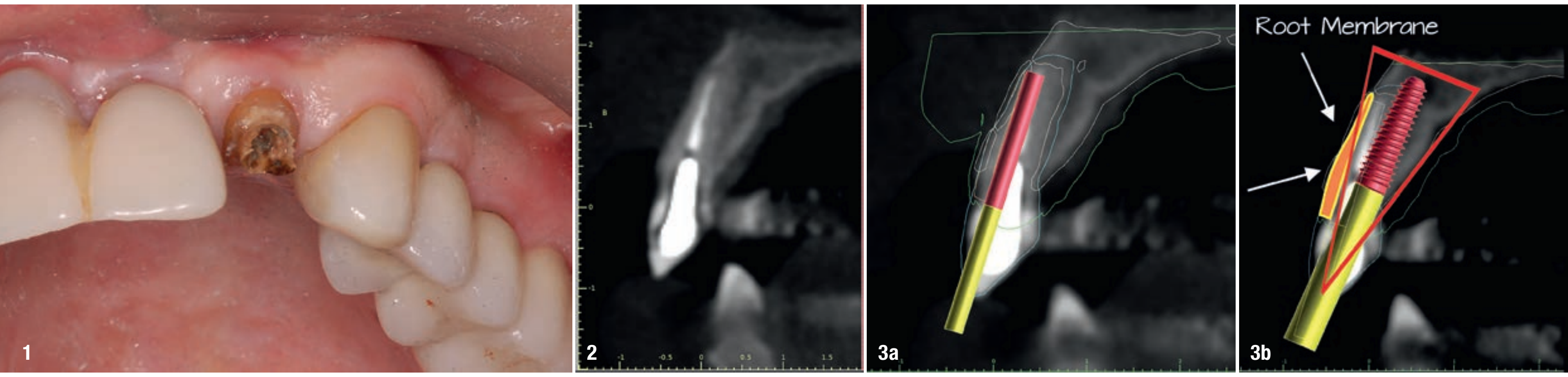


Fig. 1: The patient presented with a horizontally fractured clinical crown, an indication for a partial extraction therapy procedure. **Fig. 2:** The trajectory of the root in relation to the alveolus can be visualised with a cross-sectional image. **Fig. 3a:** Planning the initial drill path using a custom implant design (red) to match the diameter of the initial drill to reach the tooth apex. The abutment projection is shown in yellow. **Fig. 3b:** The simulated implant within the Triangle of Bone (red), placed to avoid the root fragment seen in yellow (white arrows).

Dental implants to replace missing teeth have become an integral part of current conventional dentistry. Accepted protocols now include two-stage delayed loading, one-stage delayed loading, immediate loading in a healed receptor site, tilted implant placement, immediate loading in fresh extraction sites, partial extraction therapy (PET), socket shield technique and root membrane concept.

Technology has provided clinicians with enhanced tools for diagnosis and treatment planning, instrumentation for surgical intervention, improved implant surface treatments and thread design, improved abutment-to-implant connections, sophisticated dental laboratory software and CAD/CAM applications, a greater selection of transitional and definitive restorative materials, static and dynamic navigation, and changes in drill designs and drilling protocols. Dental implant procedures are predictable, effective and essential to address the needs of patients.

Partial extraction procedures in their various formulations have been demonstrated to be proven methodologies for preserving bone and soft-tissue volume.[1–7] Our 2017 article (The Root Membrane Concept: In the Zone With the "Triangle of Bone", Dentistry Today CE, October 2017) reviewed 3D diagnostic tools for planning and executing root membrane and PET procedures based on the

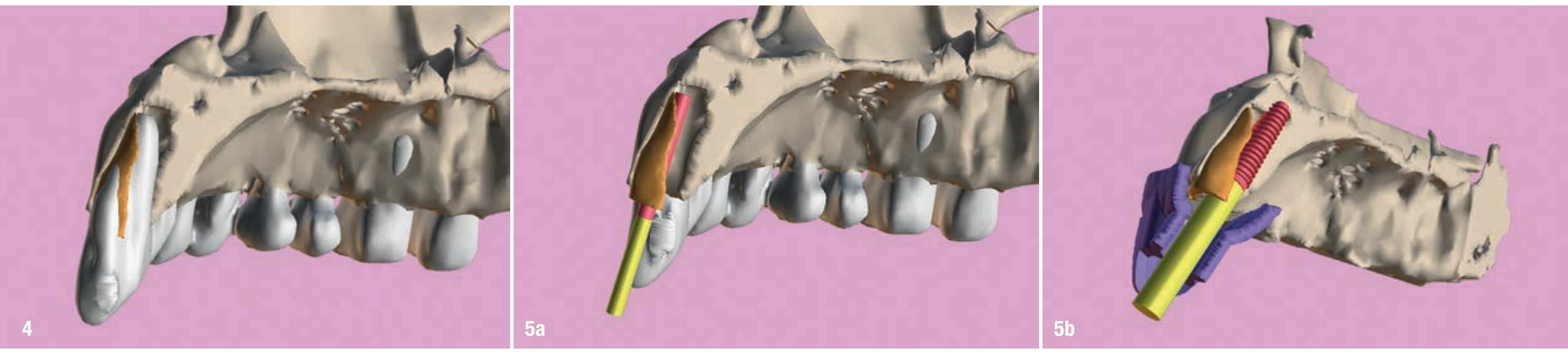
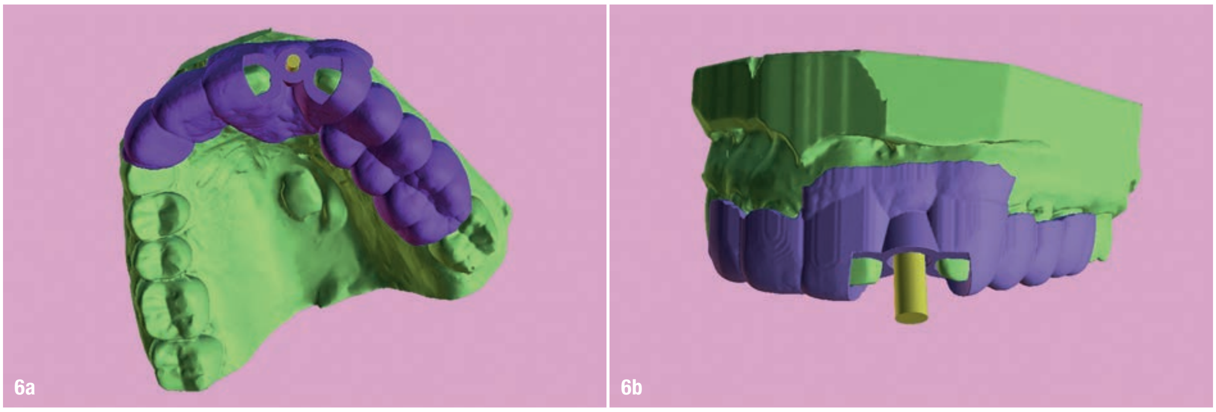


Fig. 4: The segmented root (white) and the root fragment (brown) within the sectioned maxillary surface model. **Fig. 5a:** Virtual sectioning of the segmented root using Meshmixer with a simulated custom implant to reach the root apex. **Fig. 5b:** The apical portion of the simulated AnyRidge implant can then be positioned so as not to touch the root fragment while engaging in host bone for stability.



Figs. 6a & b: Two 3D-printed templates designed on the digitised model (green): one for the initial drill to section the tooth at the root apex **(a)** and the second for using sequential guided drills to drill through the root itself **(b)**.

"Triangle of Bone" concept and specific instrumentation to achieve successful outcomes.[5]

The ability to perform the procedures requires careful diagnosis, treatment planning and excellent control of the drilling process to ensure that the root fragment will be maintained while maximising implant stability. In many cases, it may also be possible to provide immediate transitional restorations when high implant stability is achieved. However, complications can also arise when the root fragment is lost or the implant fails to integrate. It should be noted that PET has mainly been accomplished with a diagnostic freehand method for sectioning roots, osteotomy preparation and implant placement. The current article describes methods of providing PET procedures using full-template guidance based on a thorough appreciation of the existing anatomical structures utilising advanced state-of-the-art treatment planning tools, 3D design software, 3D printing and/or CAD/CAM surgical templates.

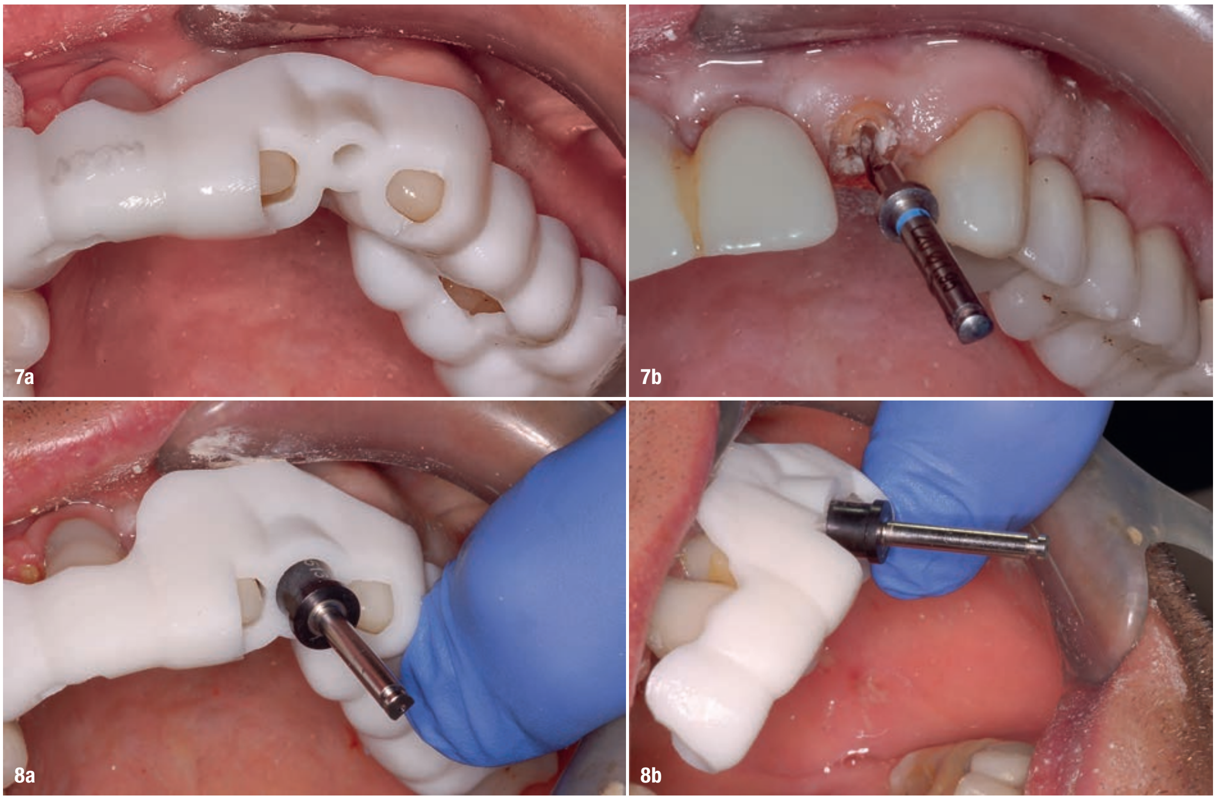


Fig. 7a: A sleeveless guide to accommodate a 2 mm long pilot drill that was used to reach the root apex. **Fig. 7b:** Removing the guide allowed for inspection of the drill embedded within the tooth. **Figs. 8a & b:** Using drill guides with long shanks to engage the sleeveless template allowed for sequential and accurate drilling of the tooth and subsequent bone for implant placement.

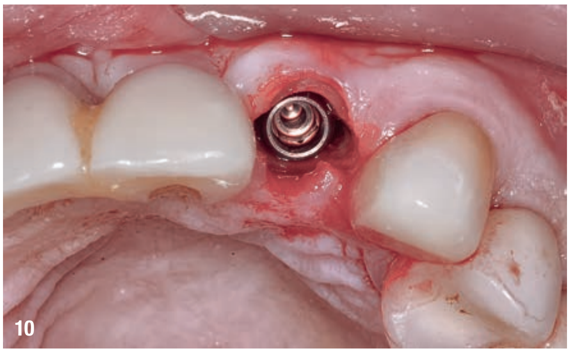




Fig. 9: The cylindrical tooth preparation resulted in the desired crescent shape of the root fragment to provide adequate space for the implant. **Fig. 10:** The implant was placed into the osteotomy through the template using a special manufacturer-specific carrier. **Fig. 11:** The stackable tooth-borne guide and the three other separate components seen in Figures 15a–c.

One indication for PET is when a patient presents with a horizontally fractured clinical crown (Fig. 1). While a 2D radiograph will reveal the extent of the horizontal fracture, length of the remaining root and approximation of the bone apical to the root, there is not enough information to plan for a PET procedure. A CBCT scan is recommended in order to fully appreciate the root position within the alveolus and the potential difference between the trajectory of the bone and the trajectory of the root as can be visualised with a cross-sectional image (Fig. 2).

Utilising interactive treatment planning software makes it possible to plan the initial drill path to accurately section the root to its apex (Fig. 3a). This can be accomplished by creating a custom implant design to match the diameter of the initial drill with an abutment projection in order to



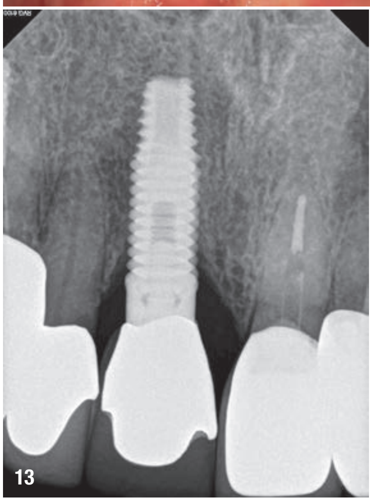
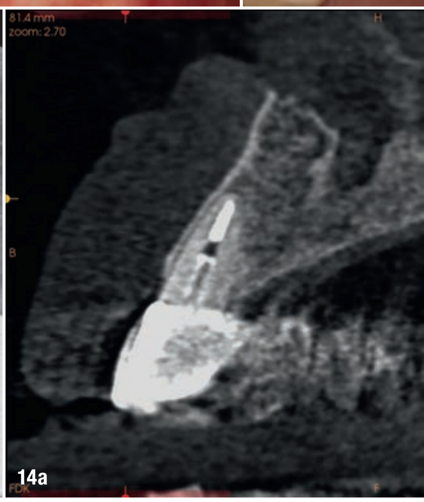
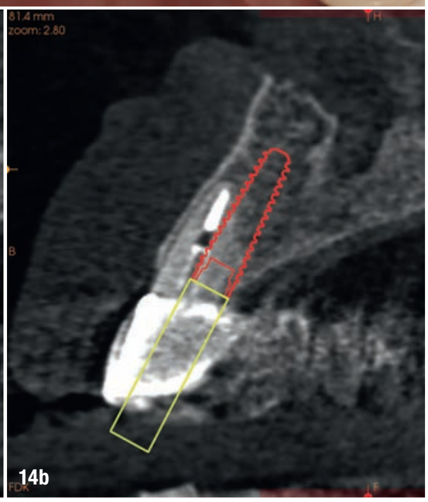




Fig. 12a: A post fracture presenting in the left central incisor, requiring extraction. **Fig. 12b:** The occlusal view illustrated the cervical tissue volume and contours. **Fig. 13:** The pre-op periapical radiograph revealed an existing implant-supported metal–ceramic restoration for the adjacent region #11. **Fig. 14a:** The CBCT cross-sectional image revealed a favourable pre-op condition for a PET procedure. **Fig. 14b:** Using the native Carestream 3D Imaging Software, a simulated implant (red outline) and abutment projection (yellow outline) was positioned within the available bone to avoid the root fragment.

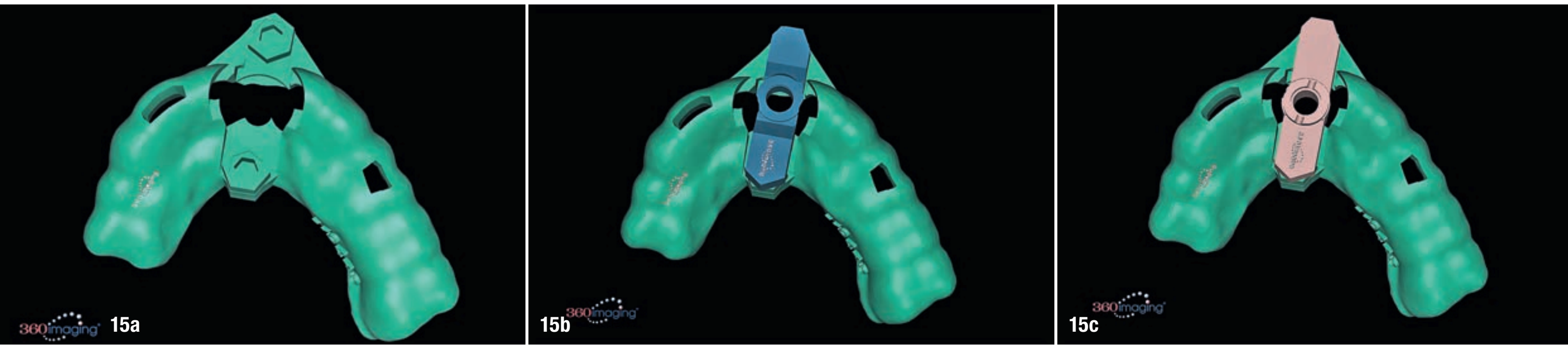


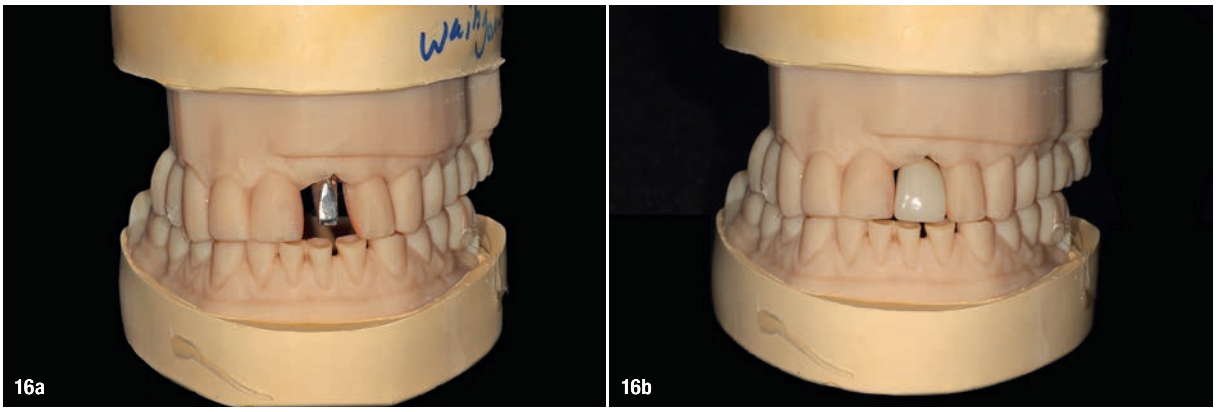
Fig. 15a: The base template was designed to seat firmly on the adjacent teeth, incorporating buccal and lingual hexagonal offsets to engage the different drill guide inserts. **Figs. 15b & c:** Separate inserts were fabricated for the initial drill guide to reach the root apex to accommodate sectioning, followed by a second guide for final osteotomy drilling and implant placement.

fully appreciate the trajectory through the clinical crown (Blue Sky Plan, Blue Sky Bio). It is important to visualise the root fragment that will remain in order to properly simulate the position of the implant in the alveolus (Fig. 3b). The apical portion of the implant can be positioned to gain stability in host bone using the Triangle of Bone. It is important to note that a cross-sectional slice may only be 0.125 mm in thickness based on the CBCT acquisition, and therefore all images in all views must be visualised to confirm the plan. Utilising 3D segmentation (separating objects by density values), it is possible to define each root and further assess the simulated position of the implant with a sagittal cut through the 3D reconstructed volume (Fig. 4).

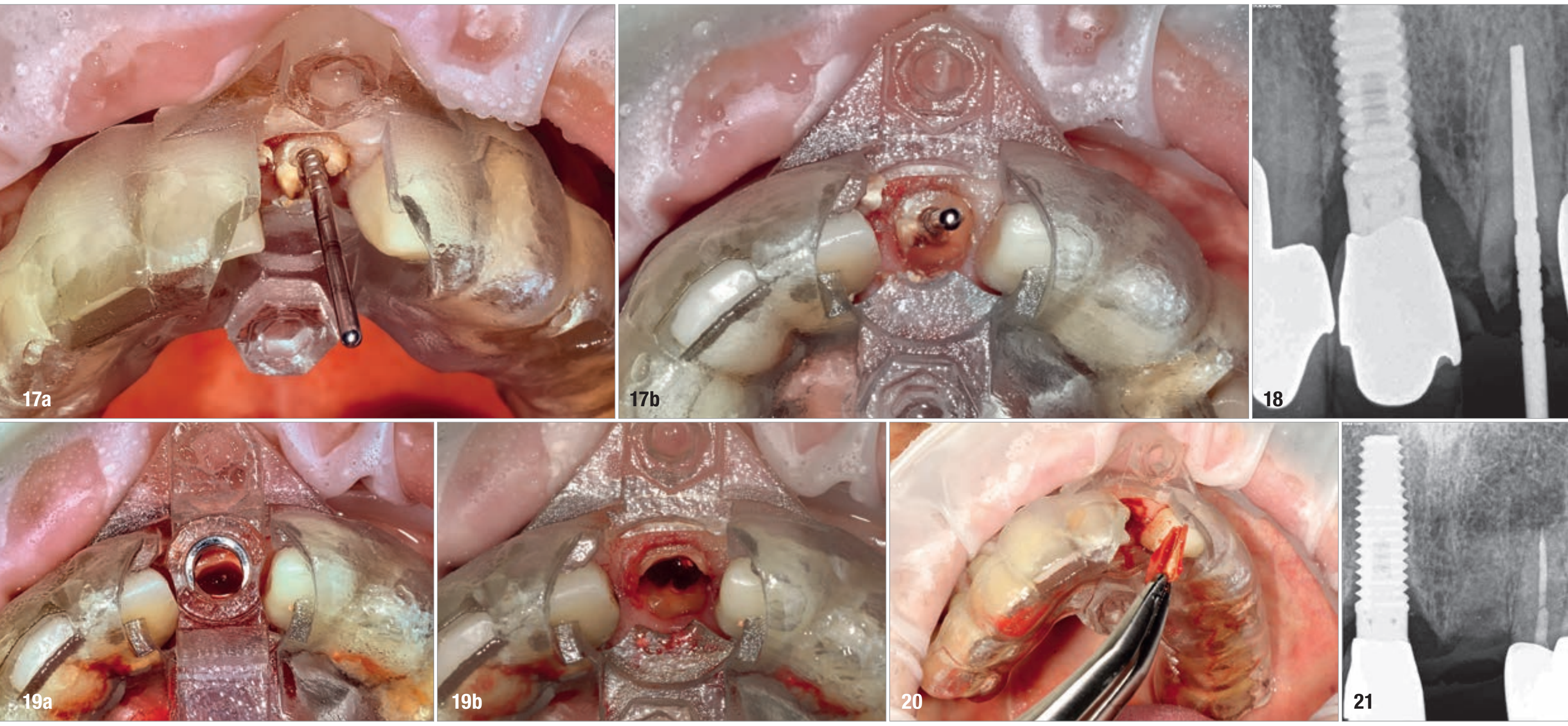
The ability to export volumes in STL format allows these objects to be edited and utilised in other software applications, such as Meshmixer (Autodesk). The STL file of the root image was imported into Meshmixer, and the root was virtually sectioned using Boolean difference to mimic the crescent shape for PET (Fig. 5a). The apical portion of the simulated implant can then be positioned so as not to touch the root fragment while engaging in host bone for stability (Fig. 5b).

Planning with such precision is predicated on the acquisition of a satisfactory CBCT scan with a proper field of view and the incorporation of occlusal surface data STL files of the arch form, digitised through either an intra-oral scan or a desktop scanner imported into the software. Two 3D-printed templates were then designed on the accurate digitised surface model, one for the initial drill to section the tooth at the root apex and the second to use sequential guided drills to drill through the root itself (Fig. 6).

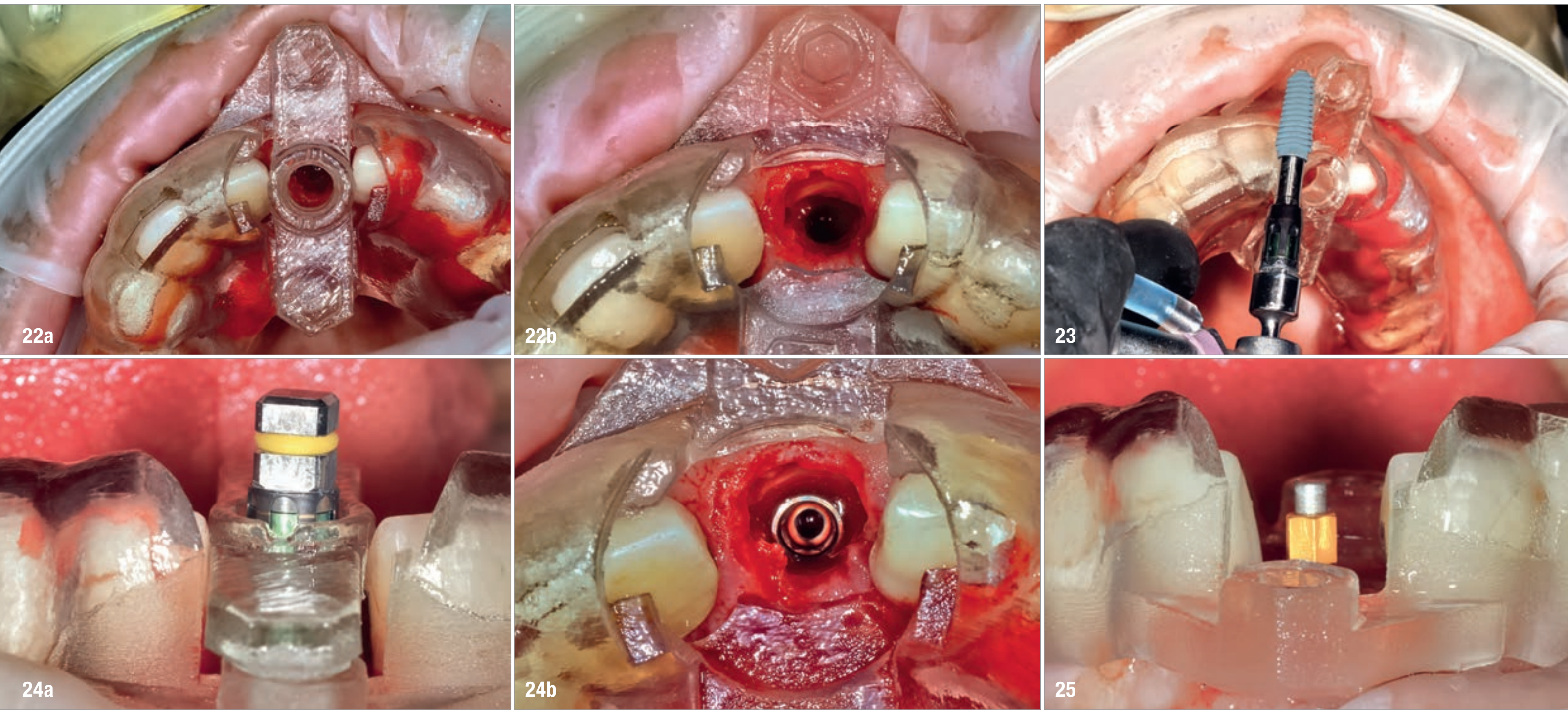
A 2 mm pilot drill, which was long enough to reach the root apex with the tooth-borne surgical guide in place, was utilised with a sleeveless guided approach (Fig. 7a). Removing the guide allowed for inspection of the drill through the tooth (Fig. 7b). Using guided drills with long shanks in a sleeveless guide allowed for sequential and accurate removal of the tooth and subsequent bone beyond the apex of the natural tooth root (R2Gate, MegaGen; Fig. 8). The cylindrical tooth preparation/osteotomy resulted in the desired crescent shape to provide space for the implant (Fig. 9). The root was then sectioned mesiodistally using specialised drills (Root Membrane Kit, MegaGen) and the palatal section removed. Utilising



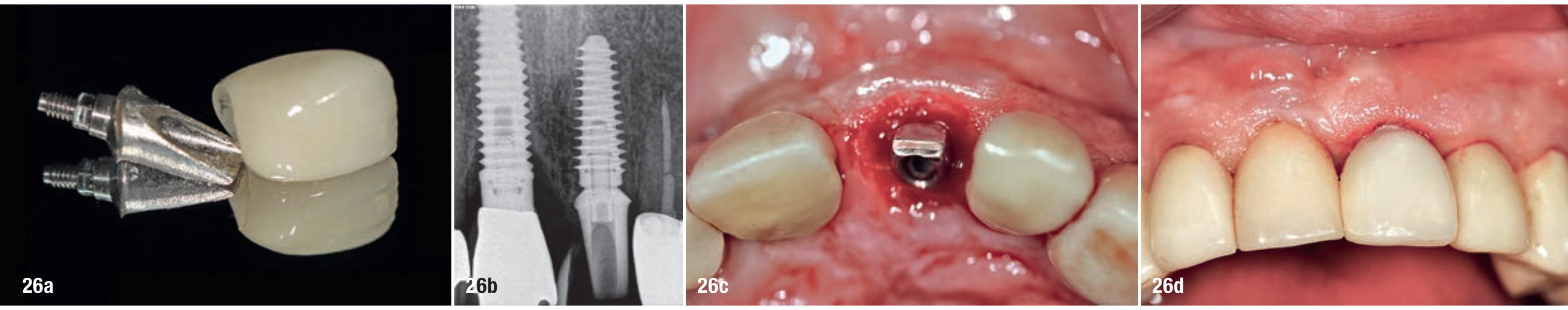
Figs. 16a & b: The accuracy of the implant and template design allows for true restoratively driven planning combined with CAD/CAM applications for the design and fabrication of a patient-specific abutment and transitional restoration.



Figs. 17a & b: Utilising the tooth-borne template and the first insert, initial long shaper drills were used to reach the apex of the root. **Fig. 18:** A periapical radiograph with a drill in place confirmed that the apex length had been reached and that all the gutta-percha had been removed. **Figs. 19a & b:** The second metal cylinder insert allowed for the long, round diamond drills to shape the root into the desired crescent shape **(a)**. The insert was removed to access the palatal root **(b)**. **Fig. 20:** The sectioned palatal root was carefully removed. **Fig. 21:** A periapical radiograph confirmed that the palatal root and all the gutta-percha had been completely removed.



Figs. 22a & b: The final insert was designed to receive the guided sleeveless drills for accurate osteotomy preparation **(a)**. The osteotomy was prepared to avoid proximity to the remaining root fragment while leaving sufficient restorative space as previously planned **(b)**. **Fig. 23:** The implant, seen prior to placement, using the R2Gate surgical carrier for full-template guidance through the sleeveless guide. **Figs. 24a & b:** Depth control and rotational positioning were accurately confirmed with the notch indicator on the template corresponding with the insertion tool **(a)**. The occlusal view illustrated that the anti-rotational internal conical–hexagonal connection was positioned towards the facial aspect **(b)**. **Fig. 25:** Using an implant-specific SmartPeg, a baseline ISQ value of 76 confirmed sufficient initial stability to place an immediate restoration.



Figs. 26a–d: The prefabricated CAD/CAM abutment and transitional crown **(a)**. A post-op periapical radiograph confirmed successful sub-crestal placement of this platform-switched design **(b)**. The abutment in place **(c)**. The soft-tissue contours were excellent; no sutures were required for the transitional restoration **(d)**.

the template, the implant was placed into the osteotomy using the correct implant carrier to achieve full-template guidance and stability measured using resonance frequency analysis (RFA) to obtain the implant stability quotient (ISQ; Fig. 10).

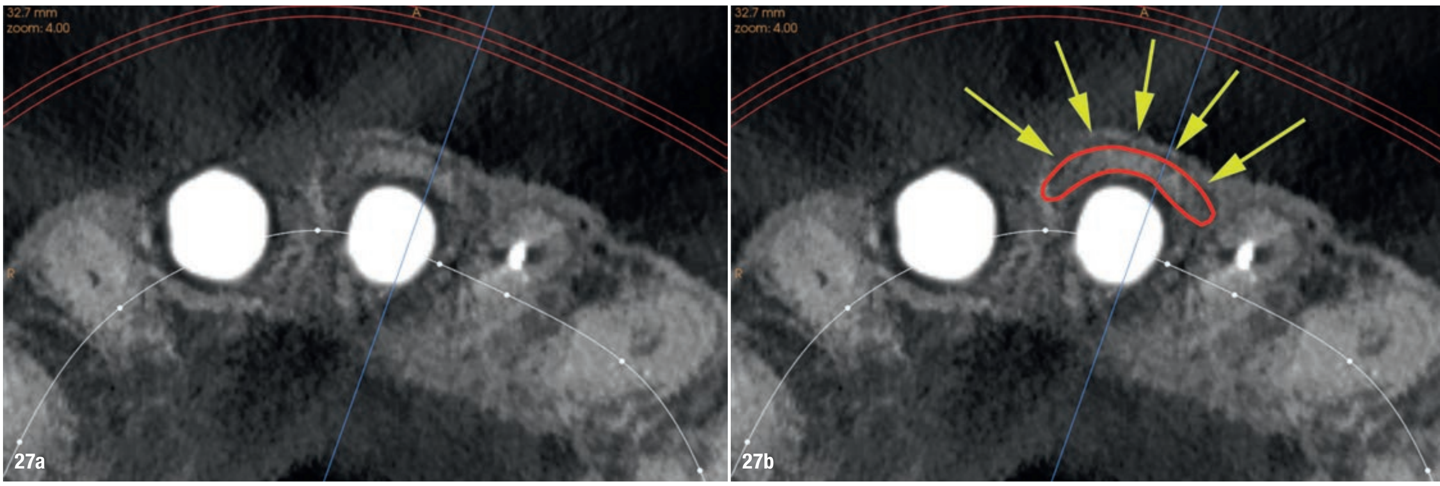
The concept of drilling through the root is not new and has been reported in the literature.[8] Using guided methods for the socket shield technique has also been reported using a CAD/CAM-fabricated template.[9] However, the ability to use technology to plan and execute a fully guided procedure for a PET, socket shield technique and root membrane technique illustrates additional methodology to aid clinicians in successful outcomes.

The first concept described the use of two separate templates, one for separating the root at the apex and the second for drilling through the tooth and placing the implant. Continuing the evolution, we present a second option, which does not require the removal of the base template, but has inserts to allow for the different drills and angulation required for the PET technique: the stackable tooth-borne guide. The new technique has four separate components: (1) a base template (stackable tooth-borne guide); (2) a pilot drill guide for the root apex (APEX STACK); (3) a crescent-shaped guide for shaping root fragments (PET Shaper STACK); and (4) a guide for osteotomy drilling and placing the implant through the guide (Surgical Guide STACK; Fig. 11).

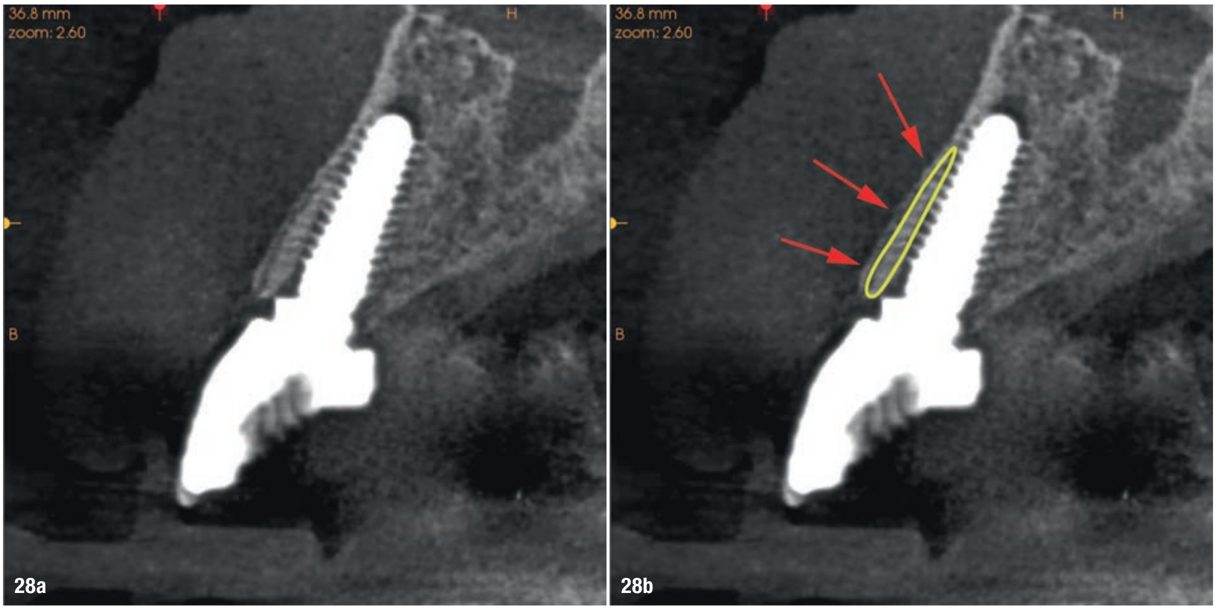
Case report

A 62-year-old male patient presented with a hopeless prognosis for a post fracture in the left central incisor requiring extraction (Figs. 12a & b). The preoperative periapical radiograph revealed an existing implant supporting a metal–ceramic restoration for the adjacent region #11 (Fig. 13). The CBCT (CS 9600, Carestream Dental) cross-sectional image revealed a favourable preoperative condition relating to the trajectory of the endodontically treated root to the alveolus for a PET procedure (Fig. 14a). Using the native Carestream 3D Imaging software, a simulated implant and abutment projection was positioned within the available bone to avoid the root fragment (Fig. 14b).

The final positioning of the implant, as determined by the restorative requirements, and design and fabrication of



Figs. 27a & b: The post-op CBCT scan axial view revealed the intact crescent shape of the root membrane **(a)**, as outlined in red in facial to the opaque implant position **(b)**.



Figs. 28a & b: The post-op cross-sectional view clearly illustrated the position of the implant **(a)**, the definitive restoration located palatal to the root membrane **(b)**, as outlined in yellow (red arrows).

the tooth-borne stackable surgical template, was accomplished using dedicated interactive treatment planning software (360dps, 360Imaging). The base template was designed to seat firmly on the adjacent teeth, incorporating buccal and lingual hexagonal offsets to engage the different drill guide inserts (Fig. 15a). Separate inserts were then fabricated for the initial drill guide to reach the root apex to accommodate sectioning, followed by a second guide for final osteotomy drilling and implant placement (Figs. 15b & c). The accuracy of the implant and template design provides the opportunity for true restoratively driven planning, which can then be combined with CAD/CAM applications to also design and fabricate a patient-specific abutment and transitional restoration in advance of the surgical intervention (Fig. 16).

Prior to the guided drilling, a Gates–Glidden drill was used to remove any gutta-percha within the root. Utilising the tooth-borne template and the first insert, initial long shaper drills (IS1, IS2 from the Root Membrane Kit, MegaGen) were used to reach the apex of the root (Root Membrane Kit; Fig. 17). A periapical radiograph confirmed that the apex length had been reached and that all the gutta-percha had been removed (Fig. 18). The second insert had a metal cylinder that allowed for the long, round diamond drills to shape the root into the desired crescent shape (Fig. 19a). The insert was removed to access the palatal root (Fig. 19b). Using appropriate instrumentation such as periotomes, elvatomes or FRINGS forceps (both TBS Dental), the palatal portion of the root was carefully removed (Fig. 20). A periapical radiograph confirmed that the palatal root had been completely removed (Fig. 21). The next insert contained the final diameter to receive the guided sleeveless drills for osteotomy preparation (Fig. 22a). The osteotomy was prepared to avoid proximity to the remaining root fragment while leaving sufficient restorative space, as previously planned in the software simulation (Fig. 22b). Implant placement

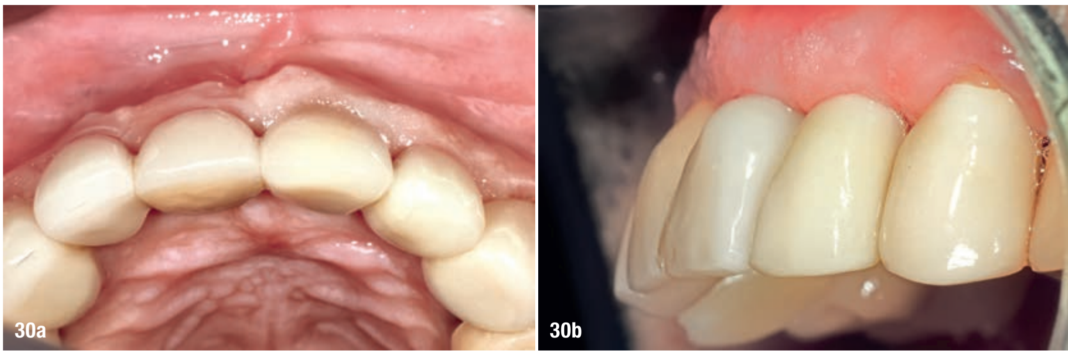


Fig. 29: The definitive restoration exhibited excellent retention of the soft-tissue profile. **Figs. 30a & b:** The occlusal view revealed the volume maintained with the soft-tissue cervical contours **(a)**, and the lateral retracted view revealed an excellent soft-tissue emergence profile **(b)**.

(AnyRidge, MegaGen) was facilitated by the R2Gate surgical carrier for full-template guidance at the appropriate torque values (Fig. 23). Depth control and rotational positioning were accurately confirmed with the notch indicated on the template to correspond with the insertion tool (Fig. 24).

The initial plan was for immediate extraction, immediate placement and immediate restoration. Therefore, it was essential to measure the implant's stability with an objective technology, RFA, which provides an ISQ value utilising an implant-specific SmartPeg (Osstell; MEGA ISQ, MegaGen). The baseline ISQ value (76) confirmed sufficient initial stability to place an immediate restoration (Fig. 25). The prefabricated CAD/CAM abutment was then secured to the implant, and a postoperative periapical radiograph confirmed successful sub-crestal placement for this platform-switched design (Fig. 26a). The transitional acrylic restoration was then placed and examined for any occlusal interferences (Fig. 26b). It was important that the restoration be out of occlusion to avoid premature forces that could complicate integration. The soft-tissue contours were excellent, and no sutures were required, since no flap was raised (Figs. 26c & d). After a period of eight weeks, the implant stability was measured to be at 80 ISQ, confirming that the integration process had continued to progress successfully and that the implant was ready for the definitive restoration. An intra-oral scanner and scanning abutment were then utilised to capture the position of the implant and soft-tissue emergence profile. The postoperative CBCT scan revealed the intact crescent shape of the root membrane (Figs. 27 & 28). The definitive restoration was then delivered and exhibited excellent retention of the soft-tissue profile (Figs. 29 & 30).

Conclusion

PET, root membrane and socket shield concepts have gained popularity as the techniques have been refined and their efficacy proved in published long-term studies. The purpose of retaining the root is to maintain the periodontal ligament attachment to the bony walls of the socket in order to prevent subsequent resorption and loss of tissue volume which often occurs after tooth extraction. PET has been proved to preserve bundle bone and tissue volume with and without immediate implant placement, yet this minimally invasive treatment modality is highly technique-sensitive and may result in complications if proper protocols are not followed. Therefore, a complete understanding of the 3D anatomical presentation is essential for preliminary diagnosis, treatment planning and execution of the procedure. The present article has described two alternatives that maximise the diagnostic phase using state-of-the-art CBCT imaging and planning software to provide full-template guidance with a new stackable tooth-borne guide with specific inserts for the root preparation as well as the osteotomy preparation and delivery of the implant. As with most techniques, further clinical trials are recommended to provide additional long-term data to validate these treatment modalities.

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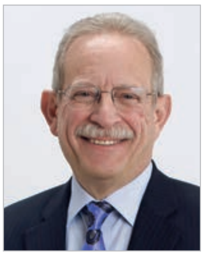
about

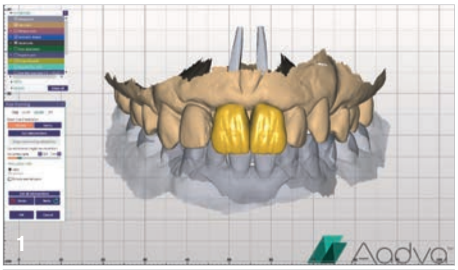


Dr Scott D. Ganz received his specialty certificate in maxillofacial prosthetics and prosthodontics, and this led to his focus on the surgical and restorative phases of implant dentistry and his subsequent contribution to 15 implant-related textbooks. He is a fellow of the Academy of Osseointegration, a diplomate of the International Congress of Oral Implantologists (ICOI), US ambassador of the Digital Dental Society, president of the US branch of the Digital Dentistry Society (DDS) and a co-director of Advanced Implant Education (AIE). Dr Ganz is on the teaching staff of the Rutgers School of Dental Medicine in Newark in New Jersey and maintains a private practice in Fort Lee in New Jersey. He can be reached at drganz@drganz.com.

Dr Isaac Tawil sits on the Digital Dental USA Society Board of Directors, and is a diplomate of the International Academy of Dental Implantology, the IADFE, a fellow of the Advanced Dental Implant Academy, and the ICOI. He is one of Dentistry Today's Top Leaders in CE, a faculty member of the Osseodensification Academy, Brighter Way educational director (Phoenix, Arizona), and digital director of Guided Smile. Dr Tawil is an ambassador of MegaGen International Network of Education and Clinical Research, a member of MINEC USA and an ambassador for the Slow Dentistry initiative. A recipient of the Pierre Fauchard award and the Presidential Service Award for outstanding achievements in dentistry. He is the founder and co-director of Advanced Implant Education, a partner in TBS instruments, and Universal Shapers LLC, and a new product consultant for dental industry. Dr Tawil has held main podium sessions and workshops globally and maintains a private practice in Brooklyn, New York. He can be reached at iketawil@mac.com.

GC Temp PRINT—a versatile material

By Stephen Lusty, UK



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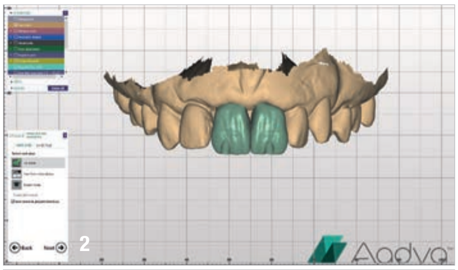

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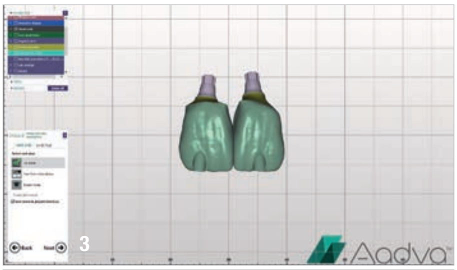

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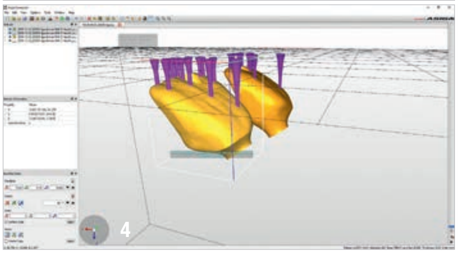
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Having been fortunate enough to have trialled the GC Temp PRINT, I have had enough time to evaluate and develop my own methods of working with this material. In this article, I aim to share some of these experiences.

GC Temp PRINT is a temporary material for any type of temporary restoration up to a maximum of one pontic. This material first appealed to me as a way of reducing the number of acrylic units that I would need to mill, thus freeing up time in my milling machine to mill zirconia. It does not replace every type of temporary restoration, as longer-span bridges are still better off being milled or made using a substructure and traditional techniques.

This material has lived up in every way to my expectations, and I now use it for the vast majority of the temporary crowns that I produce; however, this is not all that I use it for. It occurred to me that as a material that is approved for use in the mouth and with the shade being based on tooth shades it is a great material for trial smiles, checking occlusion on larger cases and mimicking stump shades for all-ceramic work.

Workflow

With a growing number of dental professionals sending their work through various scanner portals, it is becoming increasingly important to work in a digital environment for planning and executing cases. GC Temp PRINT has proved to be the missing link in this digital chain. I can now create a digital diagnostic, which can be manipulated to become the temporary restoration and then finally the definitive restoration in a completely controlled manner, maintaining consistency and therefore living up to patients' expectations. The case is designed in the dental design software (in this case exocad; Figs. 1–3).


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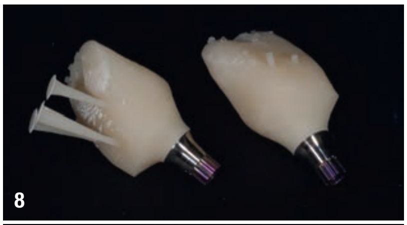
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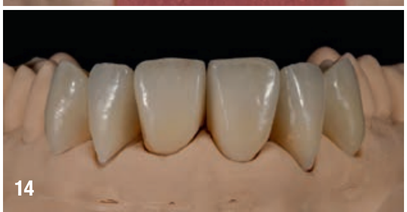
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The crowns are nested and ready for printing; each material requires a different amount of light intensity, support size and separation force. The properties of GC Temp PRINT make it incredibly easy to print and leave a perfectly smooth finish. After printing, the crowns are cleaned in isopropyl alcohol and final polymerisation is performed in the Labolight DUO (GC; Figs. 4–6).

I always post-polymerise with the supports on. The material finishes better after post-polymerisation, and I stand the restorations on the supports to polymerise, giving the light full access to the restoration. The fit directly after polymerisation is absolutely perfect, which is why I prefer working with printable temporary materials over milled materials. The properties of GC Temp PRINT make it incredibly easy to print and leave a perfectly smooth finish (Figs. 7–9).

I control the shape and emergence profile manually, because at the end of the day I am still a dental technician and prefer to give all cases the personal touch. The contouring is finished and the emergence is checked, and if any addition is necessary, I would do this now using GRADIA PLUS (GC). These temporary restorations are now ready for fitting and are a great way of assessing the final shape and shade for the long-term restorations. If all goes well, the same file can be used and manipulated to create the definitive restorations (Figs. 10–12).

Stump shades

Although the majority of my temporary restorations are now made using this material, this is not the most common use of GC Temp PRINT in my laboratory. I use far more of this material to aid with shade assessment by creating natural colour dies.

When I am producing all-ceramic work from intra-oral scans that will have a degree of translucency, I print two dies to work on, one in regular model material and another in GC Temp PRINT. This die is then shaded using OPTIGLAZE color (GC) to the same shade as the remaining stump in the patient's mouth. This die is used for colour assessment, while the model material die is used to check the fit. The GC Temp PRINT die is in fact accurate enough to check fit; however, by adding a layer of OPTIGLAZE, I am adjusting the fit surface slightly. I therefore prefer the security of having a second die to double-check the fit of the restoration. The final shades are balanced and controlled through the knowledge of what lies underneath the restorations (Figs. 13–15).

Function

I also use this material to help assess bite and form on larger cases prior to committing to a finish. In these cases, it is not necessary to use OPTIGLAZE color, as the function is what is being assessed. The single crowns can be temporarily bonded on to the framework and then once assessed and adjusted if necessary can be re-scanned back into the software for further processing prior to finalising (Fig. 16).

In conclusion, GC Temp PRINT (Figs. 17–19) has been one of the most exciting additions to the material portfolio in my laboratory owing to its versatility and ease of use, and I now have more time available in my milling machine to allow it to be more productive with the milling of final pieces of work. GC Temp PRINT is probably the easiest material to print and finish with a very smooth surface by comparison with some other printing materials. It is incredibly rare to get a misprint using this material.

about

Stephen Lusty qualified in Cape Town in South Africa. Since 2008, he has been running his laboratory in Cornwall in the UK, specialising in aesthetic dentistry. His passion for the art of dentistry is what drives him to continue to strive for perfection. He works closely with his clients, seeing patients for custom shade matching and finishing.

A fully digital workflow in implant and restorative dentistry

A novel approach using optimised scan strategies and 3D printing

By Drs Anthony Mak & Andrew Chio, Australia

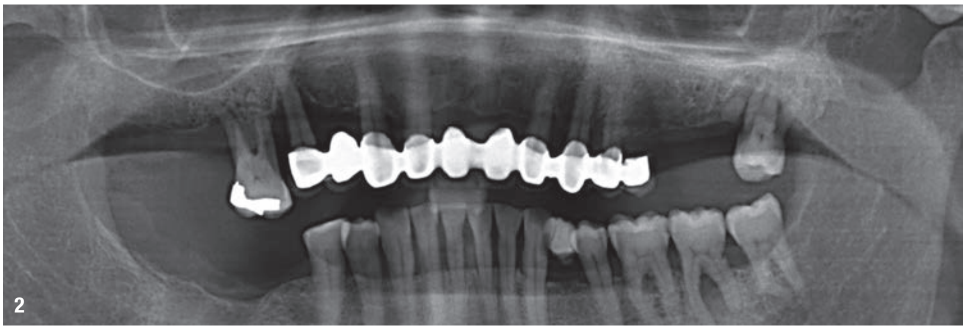


Fig. 1: Pre-op situation. **Fig. 2:** Pre-op panoramic radiograph.

Introduction

The evolution of digital technologies in dentistry has paved the way for the development of simplified and predictable protocols in field of restorative dentistry. This article, supplemented with a case study, illustrates the many aspects in which the use of digital dental technologies, including intra-oral scanning, implant treatment planning and 3D printing, has allowed the seamless delivery of treatment that traditionally has been regarded as difficult and complex. Proper treatment planning protocols are the foundation of any fixed restoration in the arch involving dental implants. They generally include the following protocols:

- articulated study models from diagnostic impressions;
- diagnostic wax-ups, intra-oral wax-ups or diagnostic appliances fabricated to evaluate aesthetics and phonetics;
- radiographs, including periapical radiographs and CBCT scans, to evaluate osseous support for dental implants; and
- fabrication of a radiographic and surgical guide.

Figs. 3a & b: Pre-op occlusal **(a)** and lateral view **(b)**.

There are two types of workflows in implant and indirect restorative dentistry: the traditional analogue treatment modality and the digital implant or restorative workflow. Analogue systems have traditionally relied on conventional impression techniques to create a plaster model from which all subsequent procedures, from the diagnostic wax-up to the prosthesis, are manually fabricated by the ceramist. The utilisation of a fully digital workflow eliminates the disadvantages and difficulties commonly associated with conventional analogue techniques. Some of these common limitations include:

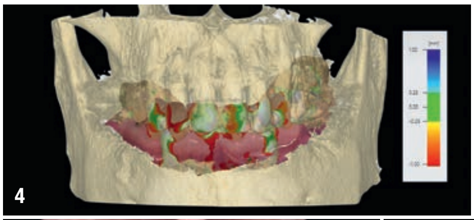
- the discomfort commonly associated with the impression procedure;
- the potential for distortion of the impression material and inaccuracies of subsequent steps in the manufacturing process;
- potential damage to the dental cast; and
- delay due to logistics of sending laboratory work between the dental practice and the laboratory.

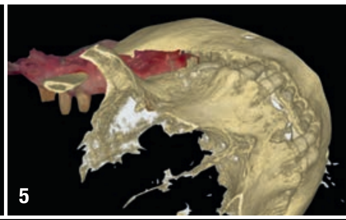
These disadvantages of the analogue system do not occur in the fully digital workflow, where the impression is taken with an intra-oral scanner such as TRIOS (3Shape). The data or information from the digital impression or surface scan, combined with the use of a CAD software program, allows the simplification of workflows, including those for diagnostic facially driven mock-ups, implant treatment planning, and the design and fabrication of surgical guides. In addition, the design of the temporary and permanent prosthesis and the design of the master die model can all be done on CAD software and then manufactured with either 3D printing or traditional CAD/CAM dentistry via milling of the prosthesis. The data from the digital impression is also simply sent over the Internet, significantly reducing the time needed to manufacture the wax-up and prosthesis.

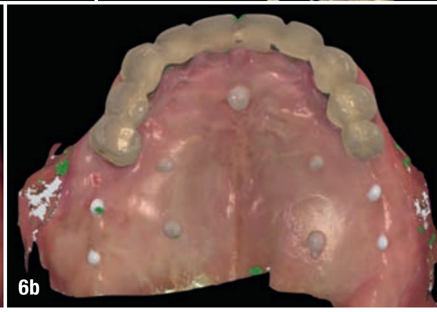
In the field of implant dentistry, one of the main advantages of the fully digital workflow is the ability to accurately diagnose and virtually plan the implant position using the digital surface scan (intra-oral scan) and CBCT data with simplicity. This in turn allows the fabrication of an accurate surgical implant guide that facilitates the placement, in terms of better angulation and accuracy, of single and multiple implant fixtures using a fully guided surgical approach, creating a simplified, accurate and predictable protocol.

For the patient, fully digital workflows in implant treatment planning and surgical workflows have the benefits of reducing the number of patient visits for the procedure and allowing the visualisation, planning and even designing of the prosthetic design (CAD) prior to the patient attending for the surgical phase of treatment.

The following case study demonstrates a scenario in which a complete digital workflow was utilised in the treatment planning, design, implant fixture placement, and implant and natural tooth restorations to rehabilitate the complete maxillary arch.



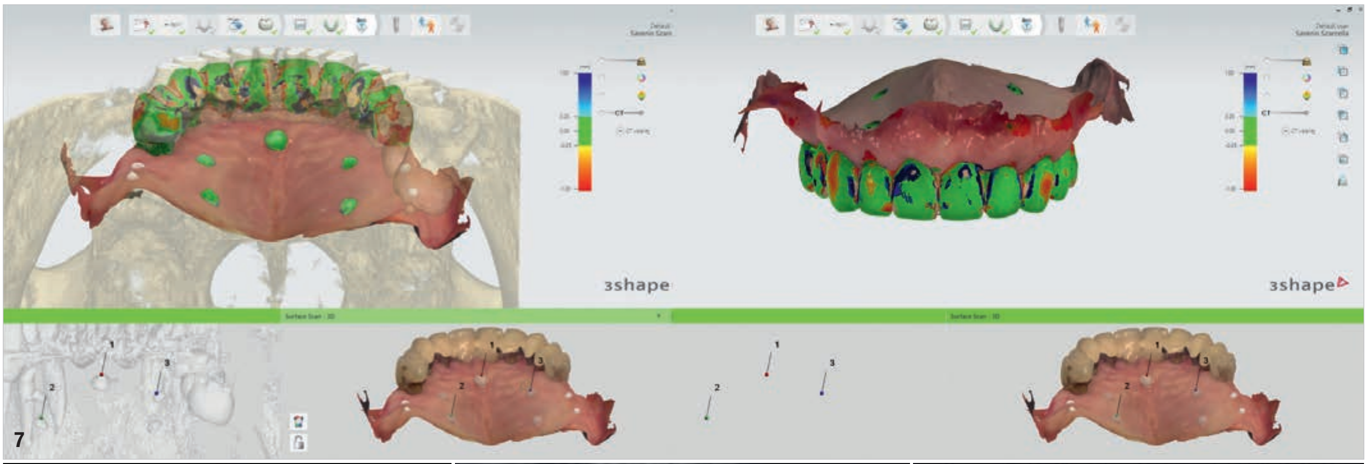


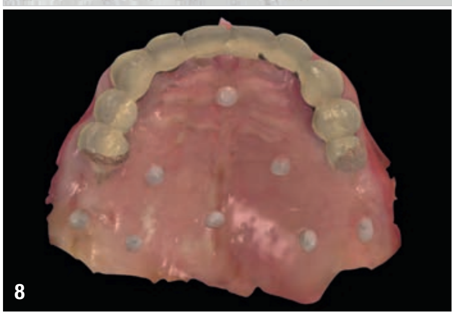


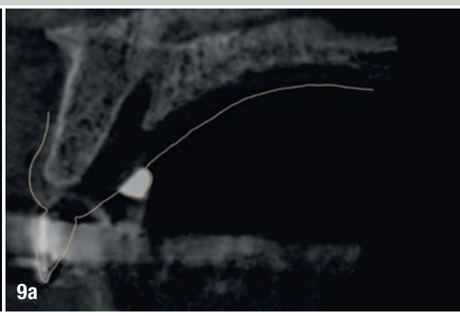
Figs. 4 & 5: Radiographic scatter can lead to the inability to mesh the intra-oral surface scan to the DICOM data. **Figs. 6a & b:** Intra-oral photograph **(a)** and scan **(b)**. Reference markers are utilised in the CBCT scan to minimise radiographic scatter and recorded in the intra-oral scan.

Case report

A 79-year-old patient presented with the chief complaints of mobile teeth and occasional discomfort from the areas around his existing maxillary fixed partial prosthesis. His medical history was unremarkable. The clinical and radiographic exam-







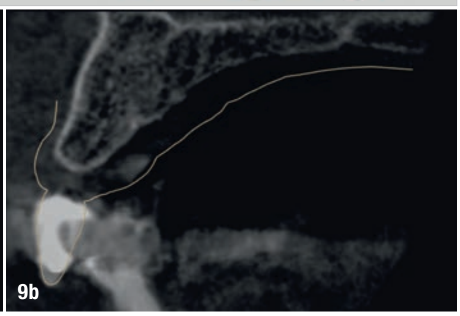
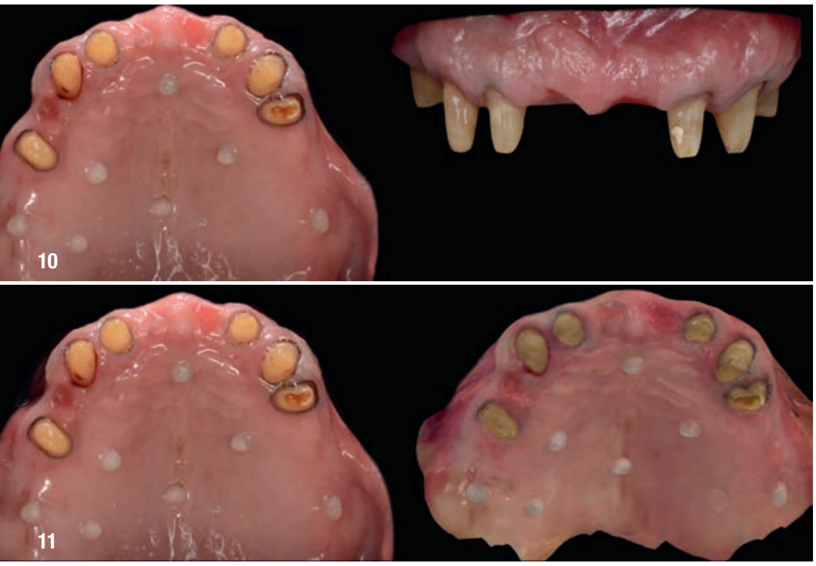


Fig. 7: The differential colour map indicating accurate stitching or meshing of the surface scan and DICOM data. Note that the green areas indicate a < 0.50 µm difference. **Fig. 8:** Better stitching facilitates improved accuracy of implant placement. **Figs. 9a & b:** Verification of the intra-oral scan (yellow line) by superimposition on to the radiographic marker on the CBCT scan.



Figs. 10 & 11: Sectional removal of the fixed partial prosthesis prior to scanning with the intra-oral scanner avoids the potential of radiographic scatter caused by the metallic components of the prosthesis.

inations indicated moderate to advanced bone loss affecting many of his maxillary and mandibular teeth and secondary decay on the abutments of his fixed prosthesis (Figs. 1–3). Teeth #16, 15 and 28 had a poor prognosis and were planned for extraction. The goal of the treatment was to rehabilitate the maxillary arch with a combination of crowns and implant-retained restorations to provide the patient with a fixed solution.

Diagnostic record collation

After the completion of the clinical examination and with the patient's consent, initial records in the form of a CBCT scan are first taken to obtain the necessary DICOM data and thereafter intra-oral surface scans (digital impressions) are taken. Radiographic scatter can cause problems with assimilating the intra-oral surface scan to the CBCT DICOM data (Figs. 4 & 5). This case shows two different ways to minimise the negative effects that radiographic scatter can have on the accuracy of the assimilation of the CBCT data sets to the intra-oral surface scans.

Use of radiographic markers

Radiographic intra-oral scanning reference markers are placed on the intra-oral surface to be scanned and then captured with the scanner in full-arch intra-oral surface scans of the maxillary and mandibular arches as well as of the patient's occlusion (bite) and these markers are utilised also in the CBCT scan (Fig. 6). These two sets of different data are then imported into the Implant Studio software (3Shape) and assimilated using the three-point alignment of these reference markers. The utilisation of these radiographic markers eliminates the disadvantages and problems that radiographic scatter can cause in assimilating these two sets of data. G-ænial Universal Injectable composite (GC) was utilised as the material for the radiographic reference marker. Having a radiopacity of 250%Al, this material will not result in radiographic scatter during CBCT scans. The accuracy of this merge is confirmed using a differential colour map that shows how close the alignment is visually (Figs. 7–9).

Removal of sources of radiographic scatter prior to CBCT scanning

Sectional removal of the fixed partial prosthesis prior to scanning with the intra-oral scanner avoids the potential of radiographic scatter caused by the metallic components of the prosthesis (Figs. 10–17). Rough preparation

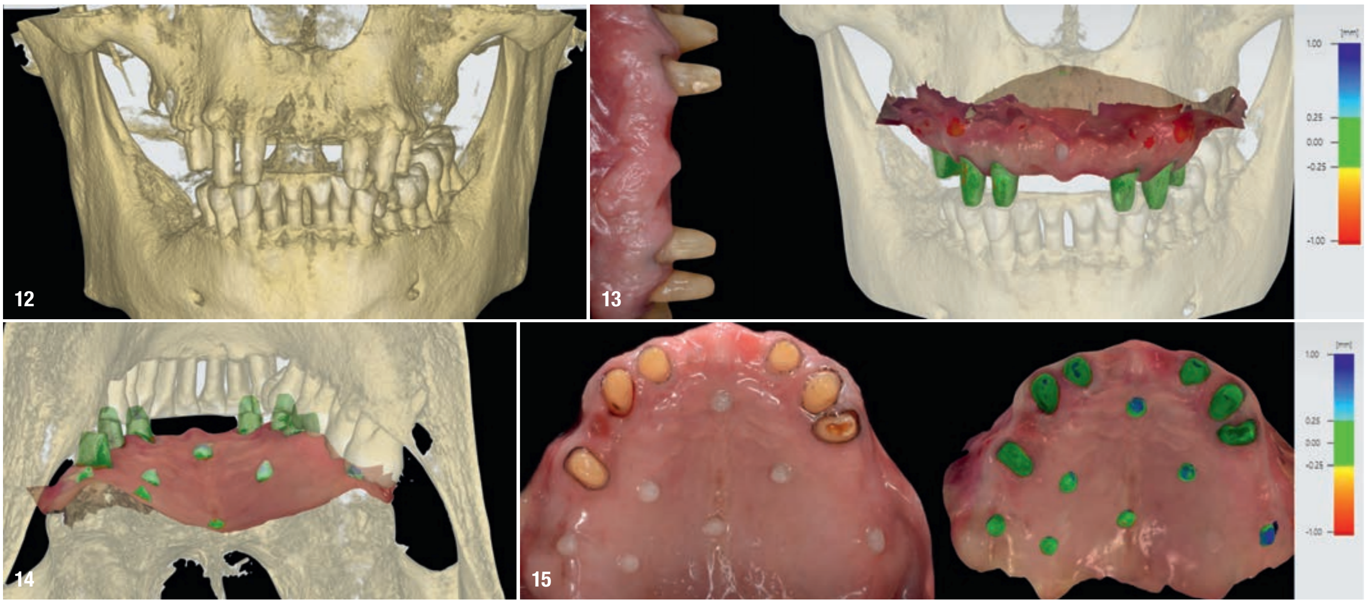
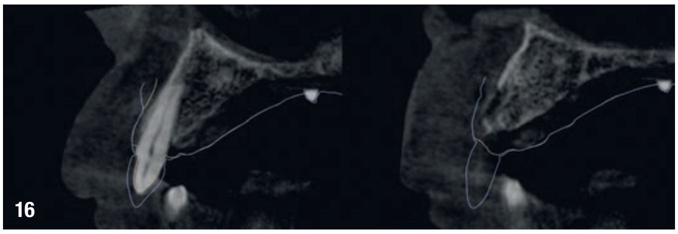
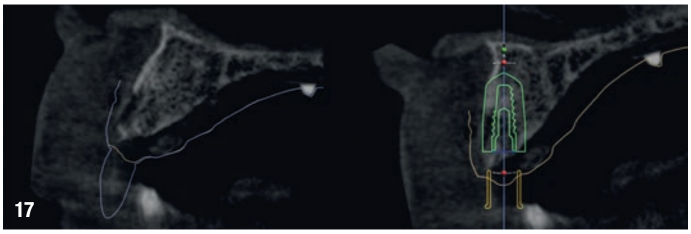


Fig. 12: CBCT demonstrating no radiographic scatter when completed after removal of the porcelain-fused-to-metal fixed partial prosthesis. **Figs. 13–15:** Accurate stitching or meshing of the surface scan and DICOM data in the absence of radiographic scatter on the CBCT scan due to metallic components of the porcelain-fused-to-metal fixed partial prosthesis.

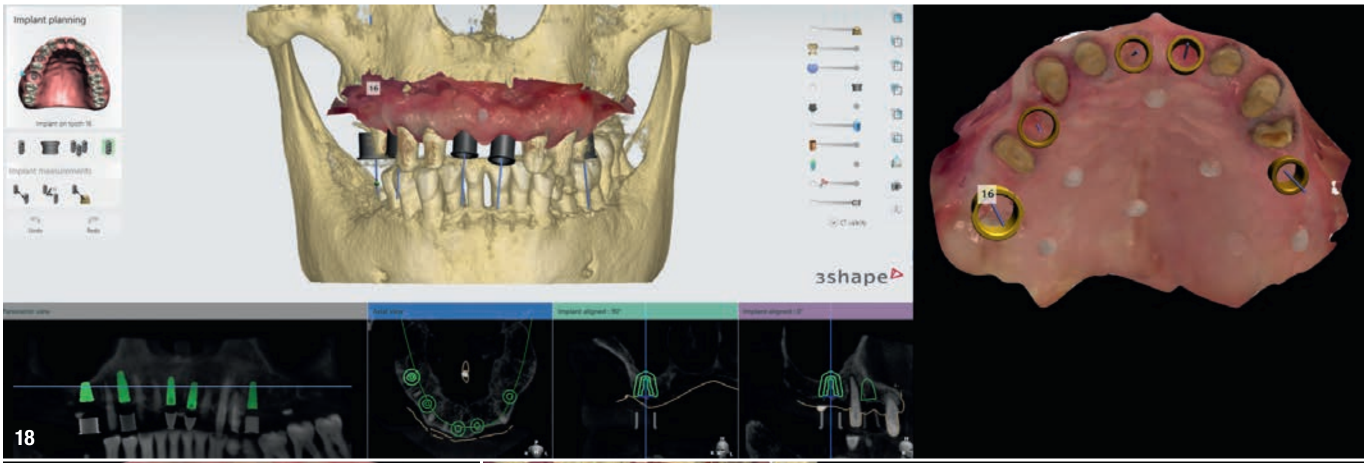



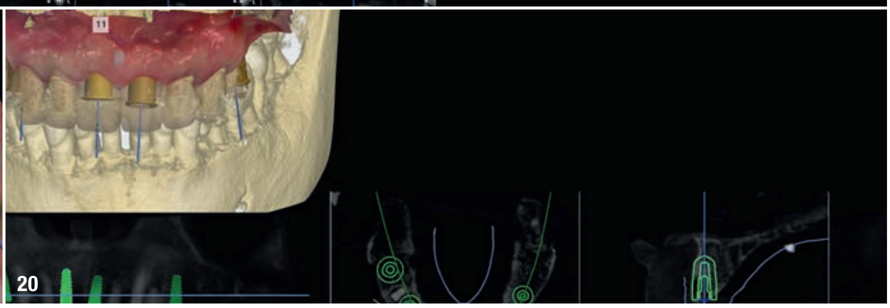
Figs. 16 & 17: Intra-oral surface scans before and after removal of the original porcelain-fused-to-metal fixed partial prosthesis superimposed on to the CBCT scan. This facilitated the planning of implant placement from a restorative perspective.

of the tooth abutments was also completed prior to the acquisition of the subsequent intra-oral scan. Intra-oral scanning of the prepared natural tooth abutments at this phase allows the scans to be utilised for the 3D printing of a surgical guide for fixture placement and a temporary prosthesis prior to the surgical phase of treatment. The confirmed file merge will then create an accurate virtual rendering on which the digital planning of the implant placement from a restorative perspective can be performed. There is an extensive library of all major implant brands and guide sleeves incorporated into Implant Studio. A digital BioHorizons implant fixture and the associated digital library were used for the planning of this case.

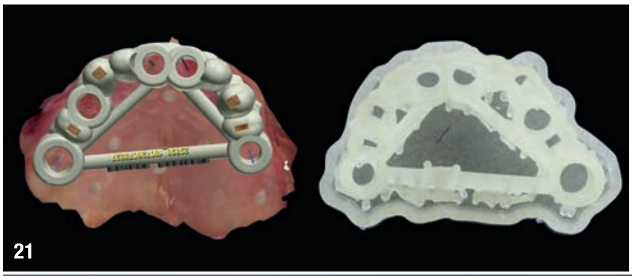
Treatment planning

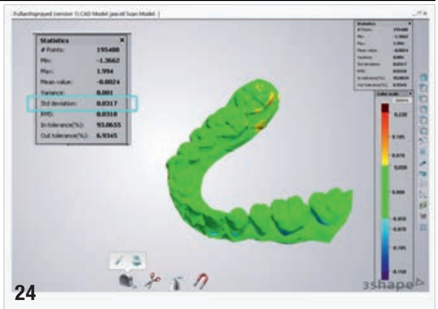
After collation of the information, the initial treatment plan was formulated. It would involve guided surgical placement of implant fixtures in sites #16, 14, 11, 21 and 25. A bone graft was planned for site #11 owing to bony defects, and a two-stage surgical protocol would be utilised during the integration phase for the implants in sites #11 and 21. Immediate provisionalisation of the maxillary arch after implant surgery would be performed with a 3D-printed temporary prosthesis manufactured using the Asiga MAX UV 3D printer (Asiga) and GC Temp PRINT resin (GC). A copy of the existing shape and contours of the failing prosthesis would be superimposed to create a temporary prosthesis that was almost an exact copy. A second phase of provisionalisation after implant integration would allow for soft-tissue development, extraction of tooth #15, and verification of the aesthetics and occlusion, that is, a trial smile. The plan was to deliver this phase of treatment utilising individual temporary restorations on implants and natural abutment teeth, 3D-printed using the Asiga MAX UV and GC Temp PRINT. Finalisation of the rehabilitation would be performed with a combination of lithium disilicate-based and monolithic zirconia restorations on both the natural teeth and implant abutments.



Figs. 18–20: Planning of implant placement. A surgical guide was designed based on the desired implant position (five planned implant fixtures, virtual position and angulation, and planned position of access).



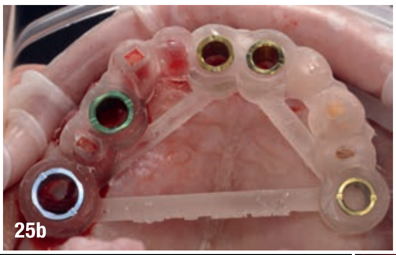


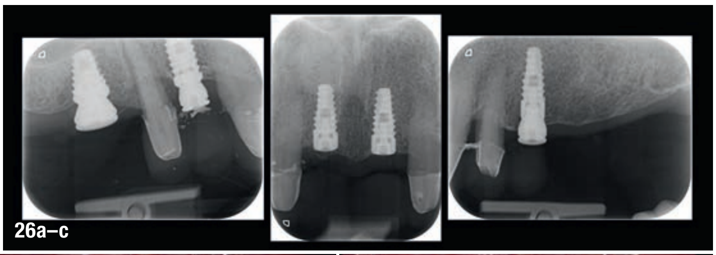
Figs. 21 & 22: Design of the surgical guide with cross-arch support for guide stability. **Fig. 23:** 3D-printed composite temporary restoration. **Fig. 24:** The restoration was 3D-printed on an Asiga MAX UV in DentaMODEL resin, scanned using a 3Shape scanner and validated in 3Shape Convince software.

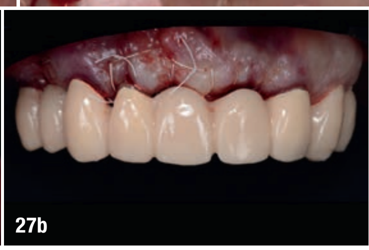
Digital implant planning and surgical guide fabrication

The number, position, angulation and access position of the implant fixtures were virtually planned based on a restoratively driven protocol (Figs. 18–20). Once the position of the implants had been planned and established in the planning software, a surgical guide with the planned implant positioning was designed on Implant Studio (Figs. 21 & 22). The use of virtual windows and additional bars allows for better visualisation and reinforcement of the 3D-printed surgical guide. The virtually planned surgical guide was then manufactured with 3D printing. Once the guide had been post-processed, the master sleeves from the BioHorizons guided surgical system was placed and fixed to the printed guide. The design of the previous porcelain-fused-to-metal fixed partial prosthesis was copied and replicated in the digital planning of the provisional prosthesis. From the CAD, the temporary prosthesis was then printed using the Asiga MAX UV and GC Temp PRINT (medium) set at 50 µm on the 3D printer (Figs. 23 & 24).

It should be noted that optimised settings for Asiga 3D printers are now factored into Implant Studio. These optimised settings allow for easy workflow integration between Implant Studio and Asiga 3D printers. In addition, the printing accuracy of the Asiga 3D printers has also been tested and proved. 3D scans of full-arch dental models printed in DentaMODEL (Asiga) have demonstrated that over 93% of data points are within 50 µm of the original CAD file with a standard deviation of 31 µm.







Figs. 25a & b: Five implants were placed using a fully guided surgical protocol. Intra-oral situation without **(a)** and with the surgical guide **(b)**. **Figs. 26a–c:** Post-op radiographs after immediate implant placement. **Figs. 27a & b:** Immediate post-op photographs after guided implant surgery and temporary cementation of the provisional fixed partial prosthesis, palatal **(a)** and labial view **(b)**. **Figs. 28a & b:** View at ten days **(a)** and four months after implant surgery **(b)**.

Guided implant surgery and bone grafting phase

A flap was raised in regions #11 and 21. This allowed visualisation of the surgical site. The implant fixtures were placed utilising the digitally planned surgical guide and the BioHorizons fully guided surgical protocol (Figs. 25 & 26). Owing to existing bony defects, bone grafting with bovine cancellous particulate was done. This was then covered with a porcine collagen membrane, and primary closure was achieved with PTFE sutures after a relieving incision. Primary stability of the fixtures were then confirmed. Healing abutments were placed on the other implant sites, implants #16, 14 and 25. The printed provisional prosthesis was then cemented with GC Fuji TEMP LT (GC; Fig. 27). A delayed healing protocol was employed, and osseointegration was confirmed after a period of 16 weeks (Fig. 28). During the healing phase, tooth #24 developed signs and symptoms of pulpal necrosis. Endodontic treatment was initiated and subsequently completed. The treatment plan for the next phase of treatment would be finalisation of the preparations and fabrication of single-unit provisional crowns for teeth #13, 12, 22, 23 and 24. Thereafter, single-unit implant-retained provisional crowns for

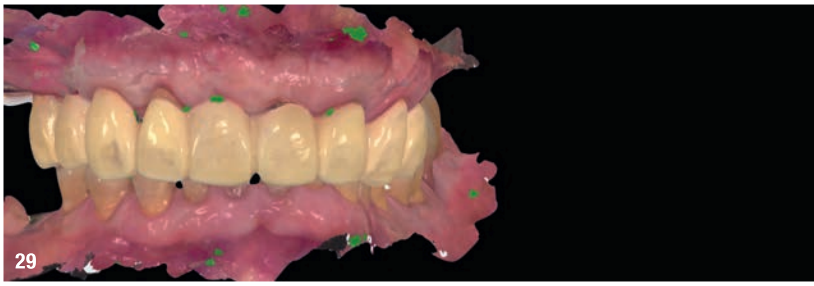
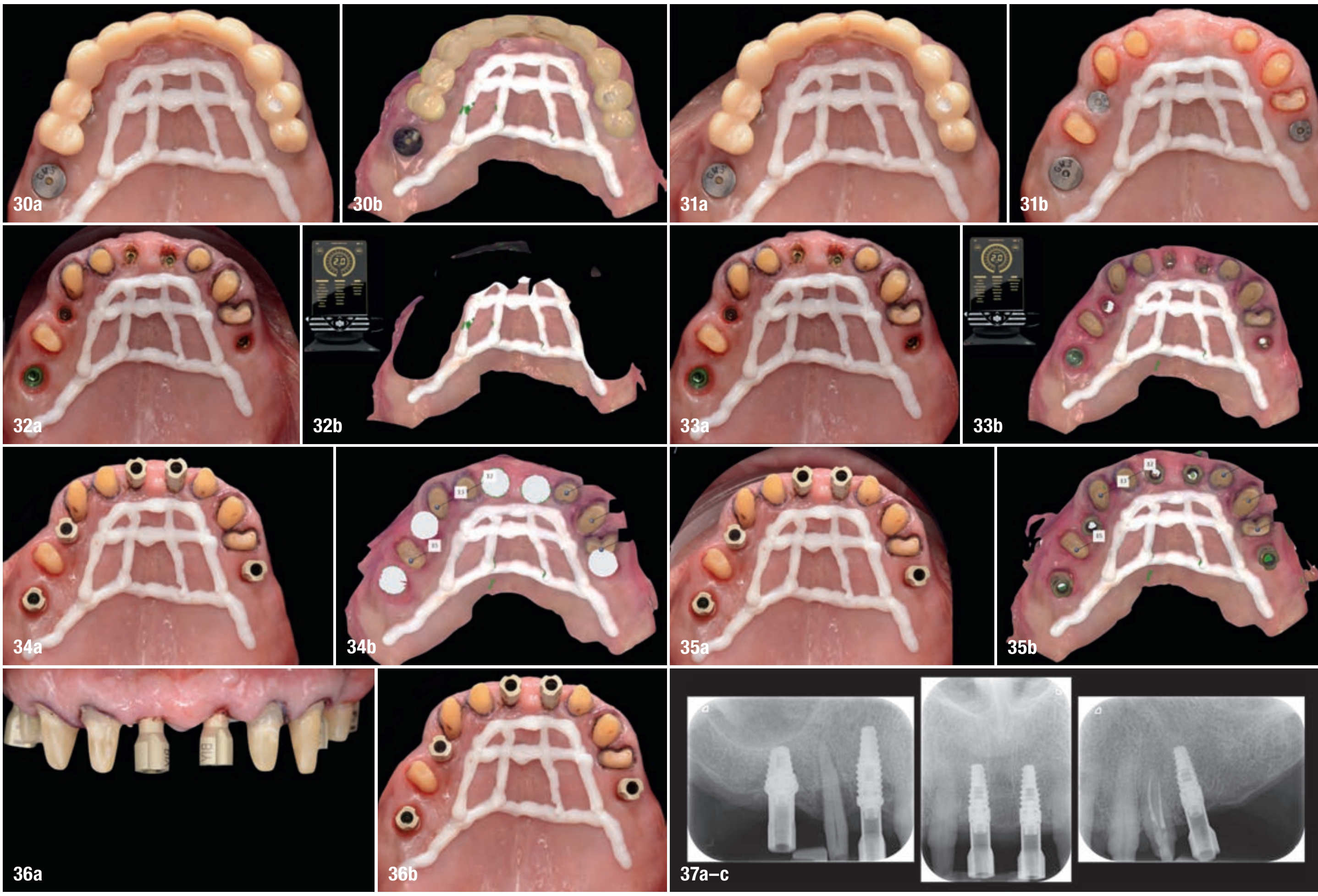


Fig. 29: Pre-op intra-oral surface scan.



Figs. 30a & b: Pre-op intra-oral photograph **(a)** and scan using the Mak optimised scan strategy and spaghetti technique **(b)**. **Figs. 31a & b:** Pre-op intra-oral photograph before **(a)** and after removal of the initial provisional splinted prosthesis **(b)** at the start of surgery to uncover implants #11 and 21. **Figs. 32a & b:** Surgery uncovering implants #11 and 21 utilising a GEMINI diode laser **(a)**. Once completed, the remaining healing abutments were removed and a soft-tissue scan was performed. By utilising the Mak optimised scan strategy and spaghetti technique, an accurate scan can be achieved even in the absence of hard-tissue (tooth) landmarks **(b)**. **Figs. 33a & b:** Intra-oral photograph **(a)** and implant soft-tissue scan **(b)** after uncovering of implants #11 and 21. **Figs. 34a & b:** Intra-oral photograph **(a)** and digital cut-out in preparation for intra-oral scan with the use of implant scan bodies **(b)**. **Figs. 35a & b:** Intra-oral photograph **(a)**. Complete maxillary arch intra-oral scan with the utilisation of 3Shape scan bodies **(b)**. The scanning accuracy was improved and scanning was simplified with the use of the Mak optimised scan strategy and spaghetti technique. **Figs. 36a & b:** The 3Shape scan bodies *in situ*, frontal **(a)** and palatal view **(b)**. **Figs. 37a–c:** Periapical radiographs to verify the seating of the digital scan bodies.

Fig. 38: Second set of provisional restorations. Figs. 39a & b: Intra-oral photograph (a) and digital model manufactured using DentaMODEL resin printed with the Asiga MAX UV (b). Fig. 40: Completed provisional crowns, implant-retained crowns and fixed partial prosthesis characterised with OPTIGLAZE color (GC; Bradley Grobler, Oral Dynamics).

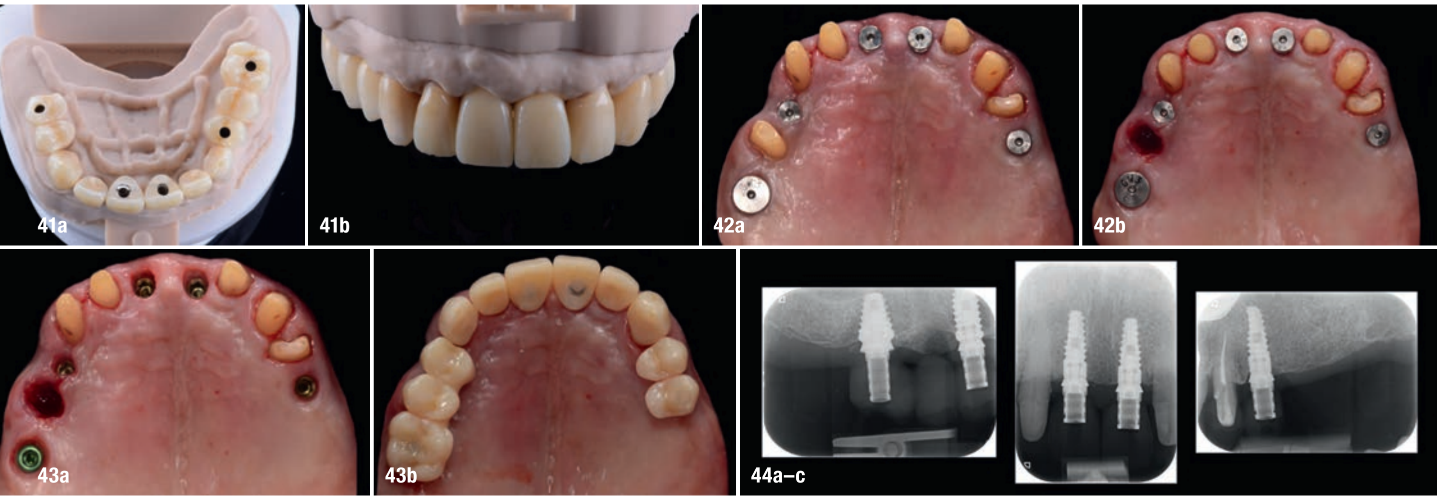
implants #11, 21 and 25 would be fabricated and tooth #15 extracted. Next, an implant-retained three-unit provisional fixed prosthesis from implant #16 to 14 was to be fabricated, and the soft-tissue emergence profile and contours of regions #15, 11 and 21 would be developed.

The patient approved and was happy with the shape and occlusion of the initial printed provisional prosthesis. The plan was to replicate the aesthetic and occlusal scheme in the second phase of provisionalisation.

Implant uncovering surgery (teeth #11 and 21) and master intra-oral digital impression

Once the 16-week healing phase was complete and the fixtures had integrated, the restorative phase was initiated, commencing with the uncovering of the implant fixtures in sites #11 and 21. All the tooth preparations were finalised and remarginated, and the process to allow the fabrication of a second set of provisional restorations was undertaken. A master digital impression using the Mak optimised scan strategy was used to acquire the master digital intra-oral scan. It should be noted that the preoperative scan was accomplished using the Mak optimised scan strategy and spaghetti technique. This novel scan strategy allows the accurate stitching of the images taken in an intra-oral scan in soft-tissue areas, where the availability of landmarks is often limited. This also leads to optimised image acquisition by the intra-oral scanner, thereby improving and providing the *most* accurate of scans. There is an abundance of literature and evidence showing that the accuracy of intra-oral scans is largely dependent on the experience of the operator and the minimisation of soft-tissue capture in the scans. With this approach, a pre-preparation scan with the healing abutment and temporary prosthesis *in situ* was taken first (Figs. 29 & 30).

Implant uncovering surgery at sites #11 and 21 was then completed using a soft-tissue diode laser, the GEMINI (Ultradent Products), and the cover screws were removed (Fig. 31). The healing abutments were then removed and an emergence profile scan was taken immediately thereafter to record gingival contours around the implants before any collapse of the



Figs. 41a & b: Completed provisional restorations fitted on to the printed models to allow the refinement of the contact points and occlusal contacts, palatal (a) and labial view (b). Figs. 42a & b: After removal of the provisional fixed partial prosthesis from the first provisionalisation phase before (a) and after extraction of tooth #15 (b). Figs. 43a & b: After removal of the healing abutments (a) and placement of the second set of provisional restorations (b). Figs. 44a–c: Periapical radiographs to verify the seating of the implant-retained provisional restorations.

Fig. 45: Immediate post-op photograph of the inserted provisional restorations, frontal view. **Figs. 46a & b:** Immediate post-op photograph of the inserted provisional restorations, labial view **(a)** and smile **(b)**. **Fig. 47:** Immediate post-op photograph of the inserted provisional restorations, palatal view.

tissue (Figs. 32 & 33). The implant position scan was thereafter taken with 3Shape scan bodies (Figs. 34–37). The corresponding 3Shape scan body was fixed to the implant, and the seating of the scan body was confirmed radiographically before the scan was completed. The use of 3Shape scan bodies allows the laboratory to use different CAD libraries for the specific implant system. This feature remains an advantage that is unique to 3Shape presently. The use of 3Shape's scan bodies also provided a fast, easy and accurate acquisition of the digital fixture-level impression and the seamless transfer of the digital information to the Dental System software (3Shape) for the design process of the planned restorations. All other prosthodontic records, including bite registration and the opposing arch, were also captured with the intra-oral scanner. All the digital data was then sent to the ceramist through the 3Shape Communicate portal for the fabrication of the second set of provisional restorations as planned.

Fabrication of the second set of provisional restorations

The provisional restorations were printed with GC Temp PRINT and the Asiga MAX UV (Figs. 38–41). BioHorizons temporary cylinders were utilised as the abutments for the implant-retained restorations. The contours of pontic #15 and the provisional restorations for implants #11 and 21 were designed and fabricated to allow the contours to be modified to facilitate the development of the soft tissue.

Insertion of the second set of provisional restorations

After removal of the splinted provisional restoration, all the abutments were cleaned and tooth #15 was extracted (Fig. 42). All the 3D-printed temporary restorations were cemented utilising a provisional cement (GC Fuji TEMP LT). The provisional implant restorations, fabricated with direct screw access, were torqued to the manufacturer's recommendation (Figs. 43–47). The soft tissue was prosthetically shaped and allowed to heal for a period of three months before finalisation of the rehabilitation with the definitive restorations.

Conclusion

The case presented illustrates how advances in digital technologies can provide clinicians with the tools for diagnosis, treatment planning, and execution of dental restorative procedures in a truly transformative way. Simplification of clinical protocols, increased accuracy over conventional analogue techniques, and improved patient comfort and outcomes are compelling reasons for the use of a fully digital workflow in the field of restorative and implant dentistry.

about

Dr Anthony Mak obtained his dental degree at the University of Sydney in Australia and then went on to complete his postgraduate diploma in oral implantology. He graduated with multiple awards and has worked with some of Sydney's most renowned practitioners. His interests lie in dental technologies and advances in materials and techniques. He has a unique understanding of CAD/CAM dentistry and currently owns two practices in metropolitan Sydney focusing on comprehensive and implant dentistry. Dr Mak has a thorough understanding of direct versus indirect dental restorations and has lectured internationally on the topics of aesthetic and digital dentistry. He is a sought-after speaker and a key opinion leader for several global dental companies.

Dr Andrew Chio graduated as a dentist at the top of his year from the University of Melbourne in Australia in 1995. On graduation, he undertook his dental internship at the Bendigo Base Hospital in Australia before spending the next one and a half years working in a rural hospital in Nepal. He is the principal dentist of Arawatta Dental Centre in Carnegie in Australia and an active member of various dental associations. He is a lecturer and gives advanced hands-on training to dentists in specific areas of restorative dentistry.

New age of digital dental practices

By DentaFab, Turkey

Who are we?

Established in 2013, DentaFab develops and manufactures 3D printers and photopolymer resins for the dental industry. In 2017, we established our dental 3D-printing and materials research and development (R & D) centre. Since then, we have developed a broad range of dental resins, including biocompatible resins, under our brand PowerResins.

Our company has offices in five locations and employs over 80 R & D and technical support engineers. Through our reseller partners, our 3D printers and materials are used in more than 26 countries by thousands of dental professionals around the world.

Creating the new digital ecosystem

Intra-oral scanning, CAD/CAM, digital design and 3D printers have changed the way dentistry is practised. We also support the development of digital dentistry by collaborating with leading experts in the industry. Our aim is to create an ecosystem where dental laboratories and dentists can produce more easily, quickly and at low cost.

We continue to develop and diversify our professional 3D printers and biocompatible dental materials every day through the feedback of our customers and the results of clinical studies. With its proprietary Internet of Things technology, DentaFab also provides remote control and support services for its high-speed precision 3D printers.

Why DentaFab 3D printers?

Accuracy, fit and consistency are essential in digital dentistry. Our customers need to get the same result over time without any failure. We have optimised 3D-printing technology in order to get the most accurate and consistent outcome. Our fast DLP technology provides very high-speed printing capabilities for dental professionals.

Why PowerResins?

PowerResins is DentaFab's photopolymer resin brand and bears the CE mark. PowerResins are compatible with all LCD and DLP 3D printers. We provide our customers with all relevant printing settings and technical support to optimise their printing quality. All settings are also available on our website, powerresins.com.

Biocompatible resins with the CE mark

All of our biocompatible resins bear the CE mark for Class IIa medical devices and are free of methyl methacrylate. We have applied for U.S. Food and Drug Administration clearance as well as clearance for other specific countries. In the meantime, our R & D department is working closely with dental professionals for new materials suitable for dentistry.

Same-day delivery is available now using PowerResins Temp

The new digital dentistry revolution—3D-printing technology has been revolutionising all aspects of our life, including dentistry. Among CAD/CAM systems, 3D printers have become indispensable in the industry in order to offer solutions for many dental applications with a single device.

Consider the example of a patient who is to undergo implant treatment. The dental clinic can plan and place the implants using 3D-printed surgical guides with maximum accuracy. The prosthesis can be simulated using PowerResins mock-up resin. While the patient is in the chair, a temporary prosthesis can be produced with DentaFab 3D printers in 9 minutes and placed in the patient's mouth. To prepare the definitive restoration, the dental technician can 3D-print the dental model in 20 minutes with a perfect implant analogue fit. The entire process from start to finish can be achieved within the same day!

V-Print splint comfort

Photopolymerising resin for the generative production of thermo-flexible therapeutic splints

Whether for bite elevations, whitening treatment or bruxism, dental splints are being used in increasing numbers for various purposes, and the requirements in respect of splint materials must satisfy the wishes of the dental and laboratory teams as well as of patients. Flexibility, longevity, stability, workability and transparency are only a few attributes of V-Print splint comfort.

It is not just that elaborately designed therapeutic splints are manufactured efficiently, reliably and in a reproducible manner in 3D-printing processes. Dental technicians also wish for an almost odourless, easy-to-process printing material.

Complaints due to chipping, cracks or improper fit are immediately reduced to a minimum thanks to the flexible material properties of V-Print splint comfort. Its inherent memory effect allows for recovery after deformation or heat effects, as may happen with steaming in the laboratory, for example. The finished splint may be quickly ground and polished in the dental practice, if required.

Its high abrasion resistance makes V-Print splint comfort an ideal therapeutic tool for use for occlusal splints. But also its level of classification as a medical device is relevant in terms of long-term therapy. The classification of V-Print splint comfort as a Class IIa medical device allows an unlimited period of wear.

For patients, however, the focus is more on comfortable wear and suitability for daily use. V-Print splint comfort produces very durable, thermo-flexible splints that react to heat. The splint nestles against the tooth structures. It can be comfortably inserted and removed, requiring no effort.

As a result, we obtain a customised splint that fits tension-free, without any bothersome pressing or pulling. Its high transparency makes for an inconspicuous splint, underscoring the aesthetic claim of the material. The neutral taste makes it more acceptable for the patient to wear and thus contributes to the success of the therapy. The smoothly polished surfaces are easy to clean for the wearer and very resistant to discoloration.

With V-Print splint comfort, dental laboratories and practices receive a product that meets all the requirements of splint therapy while achieving the highest levels of customer satisfaction. At market launch, V-Print splint comfort will be available for Asiga and Rapid Shape printers, alongside the SolFlex printers with PowerVat. You can find a comprehensive current list of all our printing partners at www.voco.dental/3dprintingpartners.

www.voco.dental

Quality medical products

FREEPRINT—30 high-performance 3D-printing resins

DETAX is one of the world's leading manufacturers of high-quality medical products, including a full range of 3D-printing materials. The FREEPRINT line offers more than 30 high-performance 3D-printing resins for all dental applications.

All FREEPRINT medical devices have been certified in accordance with the EU medical device regulation. Certain products, for instance FREEPRINT denture and FREEPRINT temp, have already received U.S. Food and Drug Administration clearance. DETAX 3D-printing materials are validated for standard printers and post-curing devices. The validation portfolio currently includes 30 devices and is being expanded continuously (see www.detax.com for the latest validation list). This ensures permanently reproducible printing results and the highest product quality.

www.detax.com

A small footprint but large capability

The new VOCO SolFlex 170 HD printer

Whether splints, models, denture bases or surgical guides, additive fabrication with SolFlex 3D printers brings numerous advantages. In addition to reducing material and labour costs, it leads to higher clinical quality and consistency throughout the production process. In order to offer optimal solutions, VOCO is continuously expanding its range of printing resins as well as 3D printers. Brand new to the portfolio is the SolFlex 170 HD 3D printer.

SolFlex 170 HD

With its build platform of 121 × 68 mm, several objects can be printed in parallel—and that with a space-saving, small printer base. The compact new addition uses a high-definition projector, which realises prints of extremely precise and almost continuous surface structures. With long-lasting DLP ultraviolet technology, the large build area is exposed in its entirety with high precision and reliability, saving time. This means that the desired restorations can be produced quickly on the SolFlex 170 HD, at up to 120 mm per hour. The rigid material vat of the SolFlex 170 HD—the PowerVat—permits practical material storage in the vat, simplifying the handling and enabling further prints at a later time. The material vat is non-wearing and therefore extremely durable. If required, only the cost-effective foils are exchanged. To further facilitate work, the intuitive touch screen can also be operated with gloves. In addition, the standard STL file can be easily transferred to the printer via USB, LAN or Wi-Fi. The SolFlex 170 HD is adjusted perfectly to all VOCO V-Print printing resins—for precise results.

www.voco.dental

3D-printed permanent restorations

VarseoSmile Crown plus from BEGO—definitive, fast, aesthetic

From now on dental professionals and patients will benefit from an even wider range of applications for the permanent 3D-printing material VarseoSmile Crown plus, which makes the desire for fast, inexpensive, aesthetic and durable restorations a reality.

At the beginning of last year, BEGO presented VarseoSmile Crown plus, the world's first tooth-coloured ceramic-filled hybrid material approved as a Class IIa medical device for 3D-printing permanent single crowns, inlays, onlays and veneers. The already broad range of applications for the biocompatible material, which is offered in seven VITA classical shades (A1, A2, A3, B1, B3, C2 and D3), was expanded in several respects in the middle of this year and confirmed by extensive scientific studies conducted by renowned universities and institutes. Recent studies have also demonstrated the material's suitability for veneers on metal frameworks—an application option that revolutionises the efficiency of veneering combination restorations.

Further innovations relate to the aesthetics of the printed restorations: thanks to an extended formulation, the fluorescence of the restorations is now similar to that of natural teeth. Furthermore, in addition to the individualisation of the end-polymerised printed objects with stains, this is now also possible with commercially available veneering composites. The possibility of adapting or repairing already printed objects with VarseoSmile Crown plus outside the patient's mouth if necessary, while maintaining stability of the restorations, is another advantage in practical use.

Over the last few months, the range of compatible 3D printers for which the use of VarseoSmile Crown plus is approved, has also been expanded. "We want to make our innovative material available to as many users as possible—including those who do not own a 3D printer from the BEGO Varseo printer family. The list of compatible printers is growing continuously based on our partnerships with well-known 3D printer manufacturers such as Formlabs and Asiga," reported Thomas Kwiedor, head of business development for 3D printing at BEGO. Kwiedor continued: "SprintRay users with Pro series printers in the EU can also benefit from the many advantages of our material."

Thanks to the full integration into the digital workflow and the low material costs of about €2 per crown, a fast supply option with an excellent price–performance ratio is made possible. Patients can be restored immediately in just one session with print times of less than an hour, depending on the printer.

You can find all the information on 3D printing of permanent restorations from VarseoSmile Crown plus and on how to order free VarseoSmile Crown plus test sample crowns, as well as an overview of the compatible 3D-printing system components and a summary of the scientific studies conducted at www.bego.com/3d-printing/materials/varseosmile-crown-plus.

www.bego.com

More shining smiles with the help of the AccuFab-L4D

New L4D dental 3D printer from SHINING 3D

SHINING 3D, a complete-solution provider in digital dentistry, has announced a further addition to its line-up of dental additive manufacturing solutions, the AccuFab-L4D. This large-platform L4D 3D printer has been developed to further the popularisation of digital treatment solutions.

"SHINING 3D is the full-solution provider helping dentists and dental technicians to efficiently and effectively conquer digital dentistry. We are happy to announce that, with the AccuFab-L4D, we are able to grant even more flexibility and versatility to everyone who wants to fully digitalise their dental workflow processes," said Kevin Ping, product manager of the dental line at SHINING 3D.

The AccuFab-L4D impresses with a large printing platform while simultaneously convincing with a small and compact body. The simple but modern and lightweight design enables easy and user-friendly operation, providing users at all stages of digital dental experience a smoothening of their respective printing application.

Large format and high quality

The 192 × 120 mm print layout, with 4K high resolution, meets the needs of dental users for efficiency and detail at the same time.

Minimal investment and maximum upgrade

Unlike many large-platform 3D printers, the AccuFab-L4D weighs only 19 kg. The AccuFab-L4D has been designed to become dentists' and dental technicians' lightweight, compact and economical companion, helping them to achieve digital transformation and an upgrade to their workflow with minimal investment.

User-friendly and easy to operate

The AccuWare printing software, independently developed by SHINING 3D, helps the user to navigate easily and independently through the entire digital manufacturing process from planning to printing. The software is designed to support intelligent layout, one-click support generation and one-click printing, empowering even 3D-printing newbies to confidently start manufacturing their dental projects in-house.

Wide range of materials and applications

SHINING DENT, SHINING 3D's self-developed range of dental 3D-printing materials, provides a wide range of options for a broad array of dental 3D-printing applications.

The AccuFab-L4D supports the printing of working models, implant guides, orthodontic models and individual trays and other types of professional dental applications, improving the efficiency of denture making and realising efficient treatment in one visit.

In order to popularise the digital treatment and production process, the AccuFab-L4D incorporates a number of user-friendly features, including nesting, slicing and equipment maintenance operations. The AccuFab-L4D is designed to make it easy to print even for first timers, thus creating an impactful appeal of 3D-printing technologies in the dental industry.

SHINING 3D provides fully integrated 3D digital dental solutions, from obtaining 3D data with 3D scanners for laboratories and intra-oral 3D scanners for clinics, then designing with professional dental CAD software, to printing dental products, including working models, orthodontic models, implant models, surgical guides, wax-ups and partial frameworks.

www.shining3d.com

International events

Formnext

16–19 November 2021
Frankfurt, Germany
www.formnext.com

ADF—Conference and Exhibition

23–27 November 2021
Paris, France
www.adfcongres.com/en

GNYDM—Greater New York Dental Meeting

28 November–1 December 2021
New York, US
www.gnydm.com

TIPE 3D Printing Conference

18–20 January 2022
online event
www.tipe3dprinting.com

AEEDC—International Dental Conference and Arab Dental Exhibition

1–3 February 2022
Dubai, UAE
https://aeedc.com

The 6th Additive Manufacturing Forum

14–15 March 2022
Berlin, Germany (hybrid event)
https://am-forum.eu/

3D PRINT—Congress & Exhibition

5–7 April 2022
Lyon, France
www.3dprint-exhibition.com/en

The 5th International Dental Symposium

16–17 April 2022
Tokyo, Japan
www.gcdental.co.jp/100thsymposium/index.html

DENTAL SALON 2022

25–28 April 2022
Moscow, Russia
https://en.dental-expo.com/dental-salon-en

EAS—The 2nd Spring Meeting

22 May 2022
Porto, Italy
www.eas-aligners.com

How to send us your work

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.

Text length

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 fewer 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.

Text formatting

We also ask that you forego any special formatting beyond the use of italics and boldface. If you would like to emphasise 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.

Any formatting contrary to stated above will require us to remove such formatting before layout, which is very time-consuming. Please consider this when formatting your document.

Image requirements

Please number images consecutively throughout the article by using a new number for each image. If it is imperative that certain images are grouped together, then use lowercase letters to designate these in a group (for example, 2a, 2b, 2c).

Please place image references in your article wherever they are appropriate, whether in the middle or at the end of a sentence. If you do not directly refer to the image, place the reference at the end of the sentence to which it relates enclosed within brackets and before the period.

In addition, please note:

- We require images in TIF or JPEG format.
- These images must be no smaller than 6 x 6 cm in size at 300 DPI.
- These image files must be no smaller than 80 KB in size (or they will print the size of a postage stamp!).

Larger image files are always better, and those approximately the size of 1 MB are best. Thus, do not size large image files down to meet our requirements but send us the largest files available. (The larger the starting image is in terms of bytes, the more leeway the designer has for resizing the image in order to fill up more space should there be room available.)

Also, please remember that images must not be embedded into the body of the article submitted. Images must be submitted separately to the textual submission.

You may submit images via e-mail or share the files in our cloud storage (please contact us for the link).

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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An abstract of your article is not required.

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Questions?

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