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3D printing

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opinion
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Dr George Freedman

Editor-in-chief

3D printing: Embracing innovation

The rapid acceptance of the digital transformation of dentistry is a wonderful example of science driving technology and art. The digital workflow model has captured the dental office protocol. The clinical practice landscape is being reconfigured and transformed, to the great advantage of both patients and dentists. While 3D printing is still in its early stages, just beginning to propel a massive paradigm shift in dentistry, there are other innovative technologies that will be concurrently shaping the dental profession, hopefully for the better.

The increasing use of 3D printing is truly a ubiquitous worldwide phenomenon. The revolution that was forecast to take decades is now expected to develop over a matter of years—or perhaps months. The driving forces are simple:

1. *Economics:* 3D printers and 3D-printing materials cost a fraction of similar milling or traditional laboratory procedures.
2. *Convenience:* same-day and same-appointment restorative and prosthetic procedures are far more attractive to both patients and dentists.
3. *Information:* the internet and dedicated organisations such as the International Academy for Dental 3D Printing (www.iad3dp.org) can educate, inform and train professionals around the globe far more rapidly and effectively than ever before.

As 3D printing is maturing in the dental sphere, further technological advancements are beginning to compete for attention. These innovations are foundational, and they promise to challenge the profession even further. First and foremost is artificial intelligence (AI).

It has long been accepted that experience is crucial to diagnostic ability, which in turn is the basis for the decision-making that guides treatment. Individuals with longer experience, or those with enhanced analytical competence, are more likely to pinpoint the relevant issues and thereby focus the therapy for maximum benefit and minimal intervention.

AI assembles massive numbers of records around a particular condition, technology, treatment or procedure. The information, coming from many sources, is often seemingly unrelated. Fortunately, the sheer volume of data often begins to create a pattern, establishing relationships that may or may not be readily visible to an individual practitioner looking at a far more limited number of personal cases.

While the AI correlations may be causal or not, they offer a far more comprehensive database upon which the scientist and the clinician can conduct systematic analyses to determine causes, cures and optimal therapeutic options. There are some caveats to the use of AI in dentistry: where the database is physically located, who has access to it and to what purposes it is being employed.

There is an organisation, the Dental AI Association, that is beginning to promote the objectives of and standards for the use of AI in dentistry (the association's mission statement appears later in this issue), and we urge those who are participating extensively in 3D printing to become aware of the power of AI in clinical applications. 3D printing and AI are likely to be in the helm of the digital dental revolution for some time to come, and it is essential that the efforts in both fields be integrated to enhance progress in digital dentistry.

Dr George Freedman
Editor-in-chief

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3D printing has an expanding role in implantology

Anisha Hall Hoppe, Dental Tribune International

With a specific focus on guided bone regeneration (GBR), the authors of a new review provide a useful look into the myriad benefits and clinical efficacy of 3D-printed meshes, membranes, synthetic bone grafts and implants. Covering materials, indications and possible challenges for each, the reviewers also note how cutting-edge 3D-printed solutions help improve surgical outcomes and patient satisfaction.

GBR is crucial in ensuring the success of dental implants, particularly in patients who have lost significant amounts of bone owing to trauma, disease or atrophy after tooth extraction. 3D-printed technologies work well towards achieving the goal of GBR. These technologies allow for the creation of highly customised solutions, such as titanium meshes, resorbable and non-resorbable membranes, synthetic bone grafts and implants. Customised 3D-printed products can be tailored to the patient's specific anatomical needs, enhancing the precision of location and improving clinical outcomes.

In the review, the authors discuss how 3D printing has transformed the approach to GBR. The 3D-printing process typically involves three steps: image acquisition, data post-processing and the actual 3D printing. During image acquisition, patient-specific data is collected through methods such as intra-oral scans and CBCT or CT scans. These digital images are then processed using CAD/CAM software, allowing for the creation of customised meshes, membranes, bone grafts and implants, unique to the patient's bone defect.

The 3D-printing technology used for these products employs various methods, including stereolithography and selective laser sintering, methods that also ensure dramatic waste reduction during appliance development. In terms of material, titanium is widely used in GBR owing to its biocompatibility, mechanical strength and resistance to corrosion.

Though clinicians conventionally make use of either resorbable collagen or non-resorbable membranes in surgery, customised 3D-printed membranes are proving an equal or an even better solution due to the science of mixing polymers to achieve desired mechanical properties and enabling clinicians to even control biodegradation. The ratio of the polymers used allows clinicians to meld the benefits of resorbable and non-resorbable membranes into one surgical material that holds the properties of collagen such as biocompatibility, biodegradation and tissue integration with the capacity to maintain space, provide mechanical stability and longevity of non-resorbable membranes. These membranes can be designed with varying pore sizes, and with the inclusion of growth factors and other necessary drugs within the material itself.

It is also possible to produce 3D-printed synthetic bone grafts, often made from materials such as hydroxyapatite or beta-tricalcium phosphate, which serve as scaffolds for osteogenesis. These materials are designed to promote bone regeneration and can be combined with natural bone grafts to optimise outcomes.

Clinical studies reviewed in the paper show promising results for 3D-printed GBR materials, particularly in terms of bone regeneration and implant success. 3D-printed titanium meshes have demonstrated effectiveness in vertical and horizontal bone regeneration, and 3D-printed polymeric membranes show potential in combining the advantages of conventional resorbable and non-resorbable membranes.

However, while early results are encouraging, the authors recommended more clinical trials involving human participants. Most available data comes from animal studies and *in vitro* research, and more human studies are required to assess the long-term success of these technologies, particularly regarding peri-implant bone volume after implant loading. Furthermore, at the present time, the use of 3D printing in GBR presents a significant cost factor, both financially and regarding the amount of time required for training, reducing access to these novel treatments.

Editorial note: The study, titled "Customized 3D-printed mesh, membrane, bone substitute, and dental implant applied to guided bone regeneration in oral implantology: A narrative review", was published online on 25 September 2024 in Dentistry Journal.

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“Try to make a 3D-printed shell complete denture for a complete arch reconstruction”

An interview with Dr Francisco X. Azpiazu-Flores

Anisha Hall Hoppe, Dental Tribune International

Dr Francisco X. Azpiazu Flores.

A new case series has documented the testing and use of 3D-printed shell complete dentures as a diagnostic tool in implant planning and provisional restoration fabrication to expedite full-arch restoration. Dental Tribune International spoke with lead researcher Dr Francisco X. Azpiazu-Flores of the Department of Prosthodontics of the Indiana University School of Dentistry in Indianapolis in the US about how the research highlights the potential of this approach to simplify and streamline the process and to save clinical and laboratory time, offering enhanced aesthetic outcomes and functional results.

Dr Azpiazu-Flores, what are 3D-printed shell complete dentures?

The 3D-printed shell complete denture is a diagnostic appliance. Its main purpose is to define the position of the future artificial teeth at the desired vertical dimension in centric relation, all indispensable elements for a successful full-mouth restoration with dental implants. The anterior tooth position is defined with the shell complete denture, and the incisal edge position can be modified digitally in the 3D-modelling software during the design stage by using intra-oral and extra-oral photographs as a reference, or if needed, it can be adjusted chairside using dental composite to achieve the aesthetic outcome the patient wants. After defining these parameters and validating them intra-orally, patient satisfaction should be optimal.

Can you elaborate on the accuracy of 3D-printed shell dentures in replicating aesthetic and functional features such as incisal edge position, midline alignment and occlusal plane orientation?

The shell complete denture can preserve the aesthetics of the patient’s existing prosthesis if these are adequate, and if changes to the artificial teeth are required for either functional or aesthetic purposes, they can be modified digitally or chairside. The incisal edge position, midline and occlusal plane orientation can be adjusted by adding or removing material as needed to this diagnostic appliance. Since this appliance is only meant to help visualise and define the desired prosthetic contours, the clinician can adjust extensively without concerns about the adjustments affecting its long-term durability.

What challenges have you encountered with the digital workflow when creating 3D-printed shell dentures for full-arch restoration? Are there specific cosmetic considerations or adjustments that are more difficult to manage compared with traditional methods?

A possible limitation of the shell complete denture is that, if it is made from a complete denture with

3D printing has opened up endless possibilities for dramatically improving current dental restoration processes.

unstable posterior occlusion or deficient anterior tooth relationships and the clinician is not able to identify and adjust this digitally or chairside, these unfavourable elements can transfer to the shell complete denture and subsequently to the planning of the dental implants, leading to imprecise implant planning and placement. Additionally, learning how to use the modelling computer program requires time. However, most dentists nowadays are very familiar with using such software, so the learning time shouldn't be too great.

How do 3D-printed shell complete dentures affect facial and lip support compared with the conventional method? Are there specific techniques you use to ensure optimal aesthetic outcomes for soft-tissue support?
Facial and lip support are important parameters whenever rehabilitating edentulous patients. Traditionally, flangeless complete dentures or artificial tooth arrangements are used to evaluate these parameters. With the 3D-printed shell complete denture, once the artificial tooth position has been defined and validated intra-orally, a 3D-printed flangeless appliance can be created using the contours of the artificial teeth of the shell complete denture. This requires an additional appointment; however, it is a required step for full-arch restoration of the maxilla.

"The shell complete denture can preserve the aesthetics of the patient's existing prosthesis [...]."

Is there anything else you would like our readers to know about this case series or any other research you are working on?
I would like to encourage them to try to make a 3D-printed shell complete denture for their next full-arch restoration with dental implants! It is a straightforward method that will make their work easier. Also, I encourage them to expand the applications of this technique by customising the design of the appliance to fit their clinical scenario!

Currently, I'm working on other protocols to accelerate restoration with multiple or single implants. If readers are interested in checking them out, they can refer to my ResearchGate profile.

Editorial note: The study, titled "3D-printed shell complete dentures as a diagnostic aid for implant planning and fabricating interim restorations for complete arch rehabilitations: A case series", was published online on 22 July 2024 in the Journal of Prosthodontics*, ahead of inclusion in an issue.*