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# 3D PRINTING TECHNOLOGY POTENTIAL TO GENERATE NEW DENTAL MATERIALS

**Zinovia Surlari[1] , Dana Gabriela Budală[2*] , Oana Țănculescu[1] Cristina Iordache[2]**
**Calenciuc Simona Gabriela [3] ,Dragoș Ioan Virvescu [1]**

1"Gr. T. Popa" U.M.Ph. - Iași, Romania, Faculty of Dentistry, Department of Odontology-Periodontology, Fixed Prostheses
2-"Gr.T.Popa"U.M.Ph. -Iași, Romania, Faculty of Dentistry, Implantology, Removable Dentures, Dental Technology
3-"Gr.T.Popa"U.M.Ph. -Iași, Romania, Faculty of Medicine, student

* Corresponding author; Dana Budală *e-mail:* danab1978@yahoo.com…

## ABSTRACT

**Introduction**: In order to provide insights on the application of 3D technologies in objects conservation and restoration, a state of the art was presented on the use of 3D models in conservation and restoration work. The most common concern is the uncertainty about the suitability of the 3D printing materials. The required prior knowledge, the applicability, ethical considerations, required work and costs, managing and storage of data, and the achieved results are other important points of attention.

**Keywords**: CAD-CAM, 3D printing , biomaterials, additive manufacturing etc.
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## INTRODUCTION.

Nature has devised numerous brilliant solutions to many complex challenges during billions of years of evolution.

Nature has since been transformed into a source of inspiration by today's cutting-edge technologies, allowing the extrapolation and application of its various ways to attempt to address contemporary engineering challenges [1].

In recent years, the method has acquired a variety of labels in scientific research, including biomimetics, bio-inspiration, bionics, biomimicry, nature-based solutions, and so on [2,3].

Schmitt OH, an engineer and physicist, used the word "biomimetics" in 1957 to characterize a biological approach to engineering [4,5].

Biomimetics is now defined as the "... interdisciplinary cooperation of biology and technology or other fields of innovation with the goal of solving practical problems through the function analysis of biological systems, their abstraction into models, and the transfer into and application of these models to the solution" under International Organization for Standardization (ISO) standard no.18458:2015 [3].

Nonetheless, nothing prevents any technological development from being labeled as "bio-inspired," as long as there is compelling evidence of an existing biological model generator [6].

In many cases, attempting to replicate a biological composite exactly is still futile: even with today's advanced technology, replication of intricate micro/nanostructures, such as those observed in biological composites such as bone or nacre, is not yet conceivable.

However, the ultimate aim of 'biomimetics' remains, and contemporary methods continue to pursue it by drawing on fields such as biology, physics, and technology [7].

Without a doubt, it will only be possible to solve technical difficulties through the abstraction, transfer, and application of knowledge derived from biological models by employing an interdisciplinary approach and thereby combining not just various approaches but also distinct ways of thinking.

**OVERVIEW**

The outstanding physical performance of the complex architectures and structures found in natural composite materials is one topic that scientists are interested in. Some natural hard tissues, for example, have combined physical qualities that are orders of magnitude greater than the sum of the individual components [8-10]

The nacre of a mollusc shell, for example, is largely composed of a fragile mineral component; nonetheless, despite the expectation that this structure would be highly brittle mechanically – given its high mineral content – it is actually 3000 times harder than the minerals from which it is composed. [11].

Another example is mammalian teeth, which are remarkably resilient structures [12,13]. Even though they are composed of only brittle mineral and weak organic phase, they are able to tolerate the high forces generated by a person chewing thousands of times a day [14,15].

Tooth enamel is a hard, extracellular tissue composed of 96 vol % mineral phase, 4 vol % organic material, and water [16,17], with hierarchical organization ranging from the nano- to the macro-scale [18,19].

Prisms are the microscale building pieces that make up the second hierarchical level of enamel organization. There is an ultra-thin (1mm) sheath-like structure known as enamel 'tufts' at the border between the prisms and the interprismatic material, which is formed of a non-collagenous, organic matrix [22,23].

Natural dental material fractures are said to develop suddenly at a crucial tensile stress.

However, after studying tooth fracturing from a minor fissure to a catastrophic splitting it is clear that nature's method for ensuring tooth survival follows far more sophisticated laws [24].

Ceramics are employed in a variety of applications due to their exceptional qualities, including the chemical industry, manufacturing, electronics, aircraft, and biomedical engineering. High mechanical strength and hardness, good thermal and chemical stability, and feasible thermal, optical, electrical, and magnetic performance are some of the qualities that make them such adaptable materials.

Ceramic components are often molded into the appropriate forms from a powder mixture with or without binders and other additives using traditional technologies such as injection moulding, die pressing, tape casting, gel casting, and so on [25].

The advent of three-dimensional (3D) printing technology, also known as additive manufacturing (AM), is often recognized as an industrial revolution. 3D printing is a group of sophisticated manufacturing technologies that are used to create physical parts in a discrete point-by-point, line-by-line, or layer-by-layer additive manner from 3D CAD models that have been digitally sliced into 2D cross sections.

3D printing is a distinct manufacturing philosophy that allows for the flexible preparation of very complex and precise structures that would be difficult to realize using standard fabrication methods such as casting and machining [26].

As a result, since its inception in the 1980s, 3D printing has swiftly acquired traction in the scientific and engineering sectors [27].

The use of 3D printing into ceramic component manufacturing opens up totally new avenues for addressing the aforementioned issues and challenges. Ceramic 3D printing was initially reported in the 1990s by Marcus et al. [28] and Sachs et al. [29].

Computer-aided design and computer-aided manufacturing (CAD/CAM) technologies for the fabrication of dental restorations have rapidly spread worldwide. Currently, the most prevalent CAD/CAM procedures in dentistry are subtractive: computer-controlled milling machines drill a block of material to produce a particular morphology [30].

For starters, it allows for more accurate restorations while saving time [31]. Second, complicated models can be constructed more quickly than using traditional methods [32].

This technology has considerably benefited dentistry.

Third, the use of monolithic blocks also means fewer internal defects, which are usually present in handmade restorations and which compromise their strength [33].

Despite these benefits, subtractive techniques are not without limitations:

►they lose raw resources. The material milled from blocks is difficult to recycle and is frequently discarded. Furthermore, milling tools wear quickly and must be replaced on a regular basis.

►milling techniques still necessitate hand finishing, which necessitates more time.

In reality, the bare surfaces of restorations must always be polished after production to remove the roughness left by the burs. A one minor flaw caused by a bur could endanger the entire restoration.

►a milled restoration's monolithic chromaticity does not usually result in excellent aesthetic outcomes.

As a result, incorporating a restoration from an aesthetic standpoint sometimes entails colour change, either simply by painting the surface or by adopting a more sophisticated layering structure.

►modern CAD/CAM ceramic and resinous materials have significantly greater mechanical characteristics than natural tissues and are theoretically strong enough to sustain physiological loads.

In the light of these limitations and considerations, it seems opportune to reconsider the choice of computer-assisted manufacturing approach, and to think about future alternatives.

Additive manufacturing (AM), or three-dimensional (3D)- printing, is a process that enables the creation of three dimensional objects from digital data using the layer-by-layer deposition of material [34].

We can already see a broad variety of AM applications across several industries, including biomedicine and dentistry.

Furthermore, 3D printing appears to be a very promising technique that may lead the way for the development of novel clinical strategies for major bone defects in bone regeneration surgery.

Additive manufacturing has different advantages when compared to the subtractive approach. First, the waste material is reduced by around 40%, and the residue can be more readily recycled [35].

Second, the resolution of an additive process is much higher than with the subtractive approach. The precision of a 3D-printer depends on the kind of technology employed and on the thickness of the layers printable by the machine.

However, modern 3D-printers are able to stratify layers in the range of 10– 20mm, enabling the production of smooth surfaces and precise margins [36].

Furthermore, preliminary in vitro studies have revealed that restorations created utilizing stereolithography (SLA) technology displayed similar or higher accuracy marginal and internal adaptability than milling-based restorations.

The SLA technique is believed to be the most prominent and popular 3D printing technology and has been extensively used worldwide.

SLA is a process in which a light source of a certain wavelength (usually in the ultraviolet range) is used to selectively cure a liquid surface in a vat containing mainly photopolymerisable monomer along with other additives in very small amounts, particularly photoinitiators.

The SL of ceramics proceeds with the addition of fine ceramic particles, down to micro/nanometre size, into the photocurable medium, which can be aqueous or non-aqueous.

The liquid becomes a ceramic suspension after it has been well dispersed in the medium with the aid of essential surfactants and additives. Similarly, polymerisation only takes effect in the organic monomer phase under light irradiation as ceramic particles are inert to light emission.

The ceramic particles are then uniformly surrounded by the cross-linked organic network being polymerised to form the pre-designed shape of each layer until the entire 3D ceramic part is built up.

The digital light processing or digital light projection (DLP) technique is in fact a mask-based SLA, in which an integral image is transferred to the photopolymerisable liquid surface by exposing the light source through a patterned mask once only.

Despite these benefits, the usage of printed things in dentistry is still constrained in a variety of ways. Due to a shortage of acceptable materials, the production of conclusive restorations is not yet possible.

Indeed, future research into the application of 3D-printing technology in dentistry should concentrate on increasing the mechanical properties of tooth-like materials, which might be accomplished by generating novel 'bio-inspired' microstructural arrangements inside a material.

For these reasons, future research could try to duplicate the composition and meso-scale organization of natural tooth tissues in order to get similar toughening mechanisms. In other words, by focusing on the design of micro-scale assemblies made up of one or more basic materials, it will be possible to affect macro-scale material qualities to match current needs in dental restorations. [38].

Regenerative tissue engineering aims to restore the function of injured tissue and organs through the production of cells and bioactive agents.

Extending these regeneration methods to tooth would offer new and innovative approaches to the widespread problem of edentulism.

The biggest challenge for 3D bio-printing, however, is that the printing process must be cytocompatible and capable of reproducing in vitro a microenvironment that most closely represents the conditions of the tissue observed in vivo [39].

In recent years, there has been an increasing demand for nanoscale fabrication of 3D microstructures, particularly in the fields of nano biomedicine, nanoelectronics and nano mechanics. Growing advances in materials chemistry and laser optics have made it possible to develop novel nanofabrication techniques.

Among them is two-photon polymerisation (TPP), in which the polymerisation is activated by the simultaneous absorption of two photons (TPA) of a near-infrared (780 nm) or green (515 nm) laser, only taking place at high laser intensity within a spatially localised focal spot in the corresponding photosensitive resin [40].

## CONCLUSIONS

1. In recent decades, research challenges and industrial needs have promoted ceramics massively to be an exciting new area of application for 3D printing technologies.

2. Ceramic components with highly complex structures that are impossible to be fabricated using conventional manufacturing methods can now be prepared via 3D printing techniques, thus demonstrating their great potential and value.

3. It is suggested that the integration of the 3D printing process with appropriate feedstock preparation and required post-treatments (such as infiltration and isostatic pressing) offers a unique possibility for further enhancing the properties and performance of the parts, although these steps in the operation lead to increased production times and costs.

4. Although many arguments were provided, it is important to bear in mind that this is merely a start to provide full, valid solutions and these concerns should therefore be the topic of future research.

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