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Review Article

3 D Printing a Boon in Dentistry and Medical Care: An Analysis

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Received: December 28, 2023; **Published:** January 09, 2024

Abstract

3D printing is gaining prominence in the healthcare industry due to its ability to create unique products tailored to specific patient anatomy. This technology uses additive deposition or fusion of material, allowing for creative freedom. Large language models (LLM) and generative AI are used in healthcare to produce coherent, constructive, and cogent output. ChatGPT and GPT-4 from OpenAI improve human interactions and close communication gaps in the medical field. These models are used for data analysis, report creation, clinical decision assistance, educational support, patient communication, and clinical decision making.

***Keywords**: 3 D Printing; Chat GPT; CHAMP; Technology; Alveolar Bone; COVID 19*

Introduction of 3 D Printing

Additive manufacturing, or 3D printing, is becoming a more significant force in the healthcare industry. In general, the fabrication technology does not require large numbers to break, even in contrast to traditional manufacturing, and it particularly lends itself to the clinical necessity to produce one-of-a-kind goods suiting specific patient anatomy. In order to create three-dimensional things, additive deposition or fusion of material is used in 3D printing procedures, layer by layer. This paradigm of additive manufacturing allows a lot of creative freedom and makes the technology perfect for creating gadgets or anatomic models tailored to a patient's individual anatomy, which usually involve intricate geometries. A CAD model is frequently needed as the input for 3D printing software. The CAD model is then "sliced" into 2D layers and printed one at a time to create the 3D object [1]. Tumors, periodontitis, car accidents, and genetic factors can all result in defects in the craniofacial region, which includes the alveolar bone. Periodontitis ranks as the sixth most common disease globally and is the primary cause of tooth loss, with cavities and trauma following closely behind. The inability of existing clinical treatments to repair the deterioration of alveolar bone and restore the functionality of periodontally affected teeth presents a challenge for treating cases of periodontitis. Furthermore, the size and shape of the osseous defects have a major role in the selection of the best course of action, including guided tissue production and bone grafting. Furthermore, it could be difficult to restore the function of the mouth cavity in a significantly resorbed alveolar bone with dental implants [2]. Large Language Models (LLM), which are used in further AI generation for the healthcare business in comparison to Generative AI, are intended to produce cohesive, constructive, and cogent output. They achieve this by producing the most statistically likely word combination given an input. Generative AI is highly regarded, and there have been numerous papers on how these technologies might enhance medical education. The reason the models are "large" is that they employ massive text collections to create predictive models with trillions or even billions of parameters. ChatGPT (chat-based Generative Pretrained Transformer) and GPT-4 from OpenAI (OpenAI, San Francisco, CA, USA) have the ability to improve human interactions and close communication gaps. The medical field may find use for these algorithms. With the usage of a transformer neural network, which ChatGPT integrates, replies to user requests are produced through successive layers of attention and prediction that are adjusted by Reinforcement Learning from Human Feedback (RLHF). GPT-3, the model from which ChatGPT was derived, included 175 billion parameters and 96 such layers. It is especially optimised for the development and comprehension of conversational discourse. It's essentially a chatbot that has been educated on a vast amount of online text. It can provide text responses that are human-like thanks to natural language processing. Input from the user can be processed, and reactions to the input can be modelled and output. The positive aspects of the output are enhanced based on user feedback, and the negative aspects are modified to conform to user expectations. GPT-based models are being used more and more for data analysis, report creation, clinical decision assistance, educational support, patient communication and consent, and clinical decision making. They have the potential to completely transform the radiology industry. More creative applications of LLMs and GPT-based models in radiography are probably going to be created as these models get better, which will present both opportunities and constraints. When it came to providing accurate answers to non-expert questions on lung cancer, ChatGPT was compared to Bard (Google LLC, Mountainview, CA, USA) and Bing (Microsoft Corporation, Redmond, WA, USA). While ChatGPT's results were more accurate than those of other AI LLMs, none of them could consistently provide accurate answers to every query. Moreover, LLMs are frequently utilised to enhance readability and streamline medical writings for readers who are not medical professionals. For frequently asked patient queries on lung cancer and screening, three LLMs (ChatGPT, GPT-4, and Google Bard) enhanced readability and ease of use; Bard showed the biggest improvement while maintaining clinical appropriateness [3].

Applications of 3D dental imaging from various angles

In today's paradigm of surgical training, there is a growing recognition of the necessity of practising operations outside of the operating room and the role that simulation plays in filling this gap. Surgical simulation has many advantages, such as cost-effectiveness, safety, education, and outcome-based benefits. Tree-dimensional (3D) printing makes it possible to quickly design and produce task trainers that offer easily accessible training-a perfect addition to the conventional surgical training paradigm. Rhinoplasty is a very popular and intricate procedure that requires technical proficiency as well as a deep understanding of anatomy. With 3,52,555 procedures completed in 2020, it is the most popular cosmetic procedure in the US. Additional procedures are being performed for functional reasons, trauma reconstruction, and revision rhinoplasty. Although nasal osteotomy is a crucial part of the process, there are a number of possible side effects that might arise from it, including as mucosal tears, scarring, periorbital edema and ecchymosis, and middle vault collapse that impairs breathing. This stage is challenging to teach and understand because it involves a reliance on tactile feedback and a soft tissue envelope covering critical structure. Although nasal osteotomy task trainers from the past have been documented, in this study we not only discuss our model, but also how we went about creating our task trainer. Both high fidelity and low fidelity models provide learning experiences, according to the literature; however, high fidelity models may have a greater impact on learning. The authors examined a variety of materials to find the one that most closely resembled bone in this anatomic location, and this was one of the reasons they did so. Our techniques could be used to develop task trainers for additional challenging steps in the procedure. There are now a number of 3D printing materials available that purport to mimic bone, but there is little research addressing how well each material performs in certain usage situations [4].

Applications of 3D bioprinting in periodontics

3D bioprinting technology is becoming more widely used in dentistry for a variety of purposes, including successful patient treatment choices (Patel R., *et al*. 2017). In the subject of periodontology, we briefly address the regeneration of the periodontal complex in this article. According to Vaquette C., *et al*. (2018), periodontology involves complexly organised periodontal tissues that necessitate multilayered biomaterial structures in order to restore both structural and functional integrity at the bone-ligament interface. According to Gaviria L., *et al*. (2017), periodontitis is an inflammatory disease that develops in response to periodontal infections and damages the periodontium, resulting in tissue death. Consequently, there is a growing need for periodontal regeneration techniques. In order to help those with periodontitis repair the destroyed periodontal structures, numerous clinical studies in the field of 3D bioprinting are currently underway. Because of their complicated form, periodontium structures call for specialised technical knowledge during the printing process. Because the periodontal structures accurately bioprint the structures and display varying porosities. However, because additive manufacturing technology allows for the use of line thickness, resolution altering features, and good mechanics, it also makes it possible to print structures with correct porosities (Rasperini G., *et al*. 2015). This was the first time a customised 3D printed scaffold was employed in the field of periodontics, as demonstrated by a case study conducted by Rasperini G., *et al*. that used a 3D printed bioresorbable scaffold to correct a periodontal deficiency (Asa'ad F., *et al*. 2016). Unfortunately, this example failed at the end of the thirteenth month, necessitating the surgical removal of the scaffold. This resulted from the researchers' exclusive use of PCL, which had a poorer cell affinity and slowed the pace of tissue breakdown, which led to ineffective tissue regeneration (Ausenda F., *et al*. 2019). As a result, the scientists concluded that either the PCL should be integrated with long-lasting devices like titanium screws, or they should employ bioinks with a higher rate of resorption (Carrel JP., *et al*. 2016). However, it is quite likely that this work has opened up new avenues for investigation into the field of oral regenerative medicine in order to develop more customised 3D bioprinted structures [5].

The creation of multiphasic scaffolds for periodontal regeneration-which comprises the periodontal ligament, cementum, and alveolar bone-is the primary goal of study. Following a number of investigations, the authors recommended employing a range of biomaterials, apart from PCL, for periodontal regeneration in animal models. Bioceramics may be used to successfully treat sinus and bone augmentation treatments, according to a study by Rasperini G., *et al*. (Ausenda F., *et al*. 2019). A 3D printed scaffold composed of biphasic ceramic [5] hydroxyapatite and alpha-tricalcium phosphate was utilised in the research work by Carrel JP., *et al*. in a sheep animal model for vertical bone augmentation method. It was compared to the bovine bone and particulate beta-tricalcium phosphate. It was discovered that the biphasic ceramic was better and that it offered good mechanical integrity without requiring membranes (Sahranavard M., *et al*. 2020). Collagen is a suitable biomaterial for regeneration in non-stress bearing zones, and the use of bioceramics is advised for alveolar bone regeneration (Ausenda F., *et al*. 2019). Because chitosan is biocompatible, biodegradable, anti-bacterial, and hydrophilic by nature, it is regarded as one of the best bioinks for regenerative treatments (Tayebi L., *et al*. 2018). The membrane, which is composed of gelatin, elastin, and sodium hyaluronate, was 3D printed in a recent study by Tayebi L., *et al*. it was found to be biocompatible and bioresorbable, and it also provided mechanical integrity and the necessary surgical characteristics, like suturability, for its application in guided tissue regeneration procedures (Amada P., *et al*. 2018). Therefore, it is more intriguing to develop improvements in periodontal regeneration methods today employing 3D bioprinting techniques and the availability of a large range of biomaterials.

3D printing for the regeneration of dental alveolar tissues

For most people, oral health is a daily concern and an essential component of overall health. Dental alveolar tissues, which include gums, blood vessels, nerves, periodontal ligament, teeth, alveolar bone, and dental pulp, cooperate to support normal physiological mastication and digestive function on a daily basis (Ma., *et al*. 2019). Tissues vary from soft to hard due to their varied mechanical characteristics and ordered, complicated spatial structure, which are facilitated by the engagement of many cell types (Goudouri., *et al*. 2017). They could sustain a variety of injuries, such as bone abnormalities, periodontitis, gingivitis, cavities, and tooth loss. It is quite difficult to restore teeth completely. Nonetheless, a number of methods have been developed to repair these tissues [6].

In the realm of regenerative medicine, the hardest tissues and organs-such as the bones, teeth, and cartilage-are the most actively researched and quickly evolving. The extracellular matrix of hard tissues and organs mineralize to endure pressure and weight, which is one of their distinguishing characteristics. Many different 3D printing technologies have been applied to organ and hard tissue engineering over the past 20 years. Other names for 3D printing include solid free form fabrication, layered manufacturing, rapid prototyping, and additive manufacturing (AM). What is the reason behind the recent surge in popularity of 3D printing? The digital manufacturing technologies have been adopted by the dental profession. The final touches of restorations are the only tasks that still need to be done by hand because the majority of laboratory work that was formerly completed by artisan methods is now done digitally. Large amounts of digital data are becoming a familiar sight to dental technicians and modern dentists. For dental CAD software, 3D printing provides a type of "output" device that enables the materialisation of complex objects and components in a range of materials. 3D printing methods are often more advanced, versatile, and mechanised than traditional tissue engineering techniques. The production processes can be greatly streamlined by using 3D printers. Porous scaffolds for hard tissue engineering have been produced by numerous industrial 3D printers during the past ten years [7].

The capacity to cultivate human tissues in three-dimensional (3D) cultures has shown benefits for tissue development as well as regenerative medicine. Systems for cultivating "organoids" have been created for a variety of human tissues, including the kidney, brain, stomach, and intestines. Compared to traditional 2D systems, three-dimensional systems facilitate the creation of tissue-mimetic designs and more realistic physiological responses. A previously unidentified layered 3D culture system has been reported to test the migration and maturation of neural progenitor cells (NPCs) derived from human induced pluripotent stem cells (iPSCs). The results show that the effects of methyl-CpG-binding protein-2 (MeCP2) dysfunction on iPSC-derived neuronal migration and maturation in 3D layered hydrogels are genotype-specific [8].

Additional applications in dentistry [9]

- A dental 3D printing material with groundbreaking versatility.
- Effortlessly 3D print indirect bonding trays in house.
- Revolutionize direct composite restorations.

Some applications of 3D printing in the medical field

The COVID-19 pandemic

All facets of healthcare were obliged to adjust by the COVID-19 pandemic in order to continue operating safely [1]. Personal protective equipment (PPE) for respiratory precautions and other care-related items became scarce in the spring of 2020 [2,3]. When supply chain interruptions occurred, organisations looked for other ways to keep supplies sufficient. Some of these methods included refurbishing old equipment and using additive manufacturing (3D printing) to create replacement parts when feasible. The Children's Hospital Additive Manufacturing for Paediatrics (CHAMP) Lab is an in-house additive manufacturing resource run by the Department of Radiology at Children's Hospital of Philadelphia (CHOP). It serves the entire hospital and is responsible for designing, quickly prototyping, and 3D printing surgical models, training aids, and clinical and research devices. The COVID-19 pandemic-related supply chain difficulties increased the burden on the CHAMP lab to assist in bridging gaps in the shortages. The CHAMP lab was called upon to generate backup supplies for ventilators, nasopharyngeal swabs, and personal protective equipment in addition to our current project burden. s. A significant number of requests were urgent, and some had their specifications altered after the project started due to irregular or disorganised stakeholder communication and changes in the availability of materials [10].

3D printing is an affordable option for mastoidectomy education

For learning temporal bone surgery, where excellent training is essential to guarantee patient safety, cadaveric temporal bones continue to be the gold standard. However, there is now more interest in alternatives to cadaveric dissection due to the shortage of training cadavers and the growing demand for high-quality instruction. A number of promising technologies, collectively referred to as additive manufacturing or 3D printing, have been put forth to create physical models for temporal bone surgery training that is based on simulation. Although it is widely believed that 3D-printed models have enormous potential for use in otology surgical training, there is little evidence of their systematic integration into surgical curricula and less information on their effectiveness as an educational tool. The notion that practising mastoidectomy on 3D-printed models enhances novices' surgical performance (i.e. transfer of skills) during cadaveric dissection has just lately been reported. However, there are significant obstacles to implementation, including low physical similarity and expensive expenses [11].

Advancements in technology for creating 3D printed anatomical models for preoperative planning of comminuted fractures

Surgeons can now observe and simulate the fracture reduction processes prior to surgery when preoperative planning for comminuted fracture repair is carried out utilizing 3D printed anatomical models. However, because certain fractures are complex, creating these models can be difficult, especially when it comes to accurately arranging multiple bones, conserving fine detail in bone fragments, and keeping the location of misplaced fragments. In order to prepare 3D printed anatomical models for preoperative planning of comminuted fractures, this study outlined numerous important technical factors. A more accurate depiction of the fracture was achieved by developing an improved segmentation process that maintains minute details in bone pieces. To further preserve the accuracy of the digital model, struts were manually added [12].

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Conclusion

Due of its potential to make custom items for patient anatomy, 3D printing is growing in healthcare. This technology allows creativity through additive deposition or fusion. Healthcare uses Large Language Models (LLM) and Generative AI to produce cohesive, constructive, and cogent output. OpenAI's ChatGPT and GPT-4 improve medical communication. These models aid data analysis, report development, clinical decision making, education, patient communication, and decision making.

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Volume 23 Issue 1 January 2024