EasyChair Preprint

№ 3442

Additive Manufacturing Applications in Medical Field like Cardiology & Dentistry: A Review

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May 19, 2020

Additive Manufacturing Applications in Medical Field like Cardiology & Dentistry : A Review

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ABSTRACT

Intensive research over the past two decades, significant progress has been achieved in the development and commercialization of new and innovative AM processes, and the applications in automotive, energy sectors, aerospace, biomedical, and other fields as well. AM processes are useful to produce 3D parts directly from CAD models by joining materials layer by layer which offers beneficial ability to build parts with geometric and material complexities that could not be formed by subtractive manufacturing processes. 3d printing has been used pre-operatively for surgical planning and for resident or patient education. It has also found its way to the operation theatre where it is used to fabricate customized surgical tools or patient-specific implants . This paper reviews the main applications of 3d printing or AM in cardiology as well as in dentistry .

INTRODUCTION

Additive manufacturing technologies are used to print 3D physical object from 3D digital file. A virtual design file is created from the CAD file using 3D modelling program/scanner or other scanning technologies like computed tomography (CT), magnetic resonance imaging (MRI).

Further, Data is converted into a 3D physical model by using various AM technologies. The print material creates . 3D model layer by layer, and this process is also called rapid prototyping . (1 ,2)For preoperative evaluation, it is a promising tool that helps in medical education and hemodynamic simulation. It increases operative success and reduces operative risk .(3 , 4) . In patient-specific anatomies, it is used to evaluate stent placement. 3D printed models have some advantages over conventional platforms. In printing methods and materials; there is a rapid pace of advancement of principal drivers in the development .(5 , 6)

NEED OF STUDY

In today's globalised world, every industry needs customization and innovation in products and services. In this study, we analyse and describe how the surgeon and patient can benefit by implementing this technology in the management of cardiovascular diseases as well in dentistry . It has opened a new path to improve the golden hands of a Surgeon . In medical field , customisation is necessary because the data of all human being are not same. We need to be identifying the different scanning technologies and creation of a 3D physical model by adopting 3D scanning.

There is a need to undertake study for determining how 3D scanning helps to fulfil various requirements by using additive manufacturing technologies in lesser time with lower costs (22) .

1) additive manufacturing in cardiology -

Regarding diseases, one of the biggest killers is cardiovascular disease, and millions of people required help in the issue of cardiovascular every year. Additive manufacturing helps to provide a better quality of life and speedy recovery of these patients.1 It is an emerging and crucial adjunctive tool which can help cardiologists and cardiac surgeons for intervention and surgical planning, monitoring and analysis. Current applications of this technology are in device innovation, teaching tools, procedural planning and functional flow models .(7 , 8). Additive manufacturing has been revolutionizing cardiovascular surgery, as in the new study taken by Texas A&M University; it combines Virtual reality (VR), high-resolution CT scan, vascular robotics systems and 3D printing for proper implementation in cardiology. This technology is used to provide a better standard of care and saves money. It supports treatment and creates holistic treatment plans (9 , 10). AM gives an idea about stabilising heart muscle during operation, short development time and care for the patient. It provides a good co-operation between surgeon and suture. This technology provides a possibility of physical manipulation of the cardiac model in vitro which improves safety and may reduce operating time for complex cardiac surgeries. It provides knowledge of customised cardiac valves and helps its printing using biological/ adaptable materials. Doctors can check the status of an outer and inner layer of the heart wall and quickly determines the health of the heart .

Benefits of using additive manufacturing in cardiology

I. Tangible heart model and its components are easily printed by AM technologies that are useful for the patient to review the heart and vessel anatomy.

II. For a complicated case, the benefit of 3D printed model is to see the anatomy of the heart from different angles and understand the anatomical positions of the vessels.

III. For explaining the planned procedure to patients, the anatomical 3D model is also beneficial to understand much better during invention that what will happen.

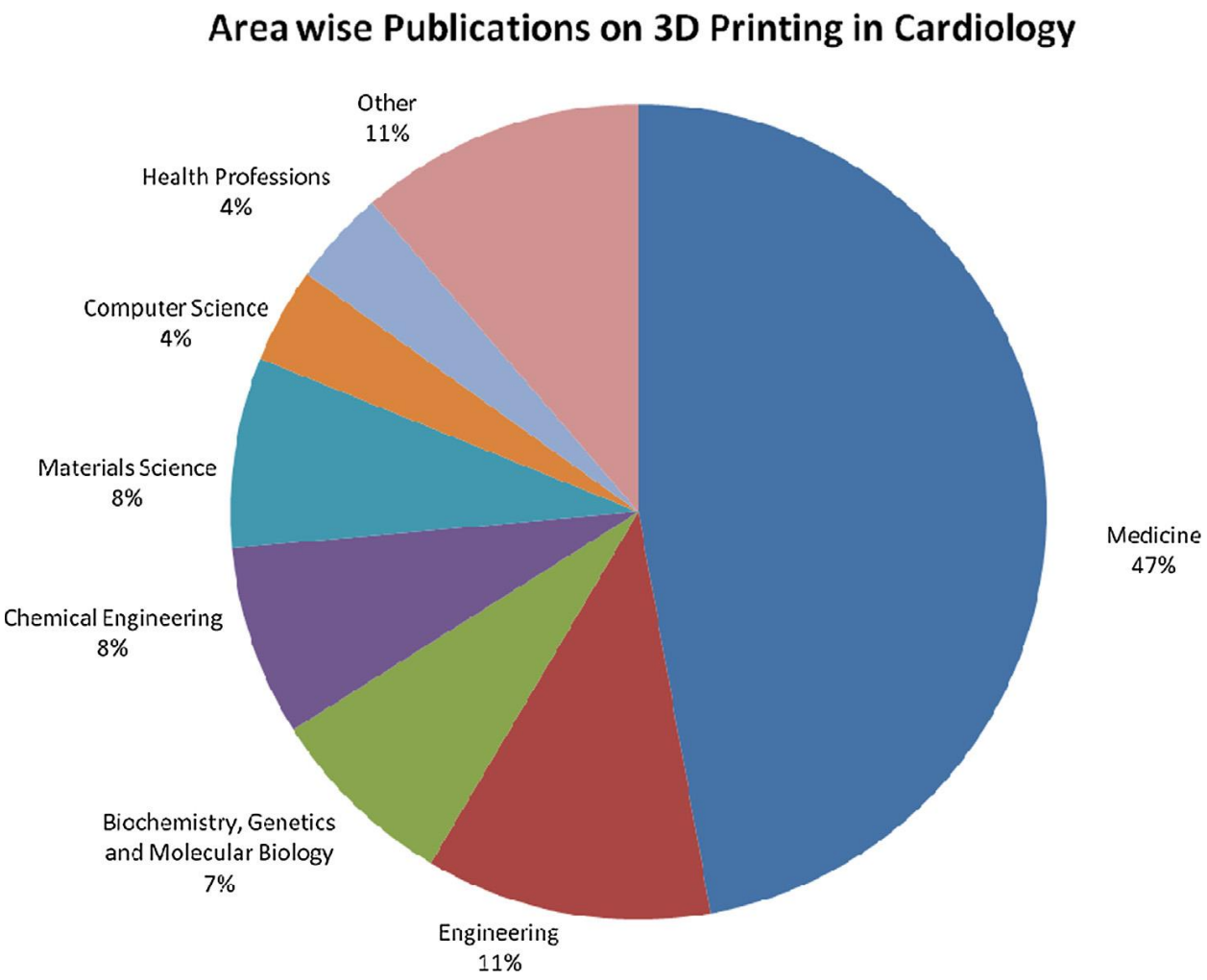
IV. In teaching, the 3D printed model becomes more accessible to explain. They can touch and turn it around. It is a most important educational tool because it gives more information as compared to 2D or 3D images on a screen (11) .

V. 3D printed model is also beneficial for pre-surgical training which saves lives, improving outcomes and offering new treatments.

Research status

Research status of additive manufacturing in cardiology Search using the keyword as ‘‘additive manufacturing” ‘‘cardiology”, identified only six published articles. Three articles of 2017

and again three articles till August 2018 are published. Different Journals Academic radiology, Annals of biomedical engineering, International journal on interactive design and manufacturing, Journal of biomechanics, Netherlands heart Journal, Trends in biotechnology published one article each. Engineering and medical fields have an equal contribution of 30%. Biology field contributes 20%, chemical engineering contributes 10%, and Mathematics field again have the equal contribution of 10%. Additive manufacturing employs different 3D printing technologies to accomplish different types of requirements. In Cardiology, application of 3D printing is proliferating and is subject of intense research. We explored the research material using Scopus on the use of 3D printing in cardiology. Around 38 research articles were identified by searching keywords as ‘‘3D printing” ‘‘cardiology”. The first article was published in 2000. Again, after a long gap, three articles were published in 2014, In the year 2015, one article published, and there is an increment of research publications in 2016 where eight articles are published. Sixteen articles published in 2017 and till August 2018, six articles were published in this ongoing year as JACC cardiovascular imaging journal has highest publications of two articles and rests various other journals published one research articles by each. A Research study on cardiac patient – specific three dimensional Models as Surgical Planning tool was carried in feb 2020 in volune 167 , Issue 2.



Major finding during literature review

Additive Manufacturing provides a useful contribution in the area of cardiology, starting from imaging to clinical translation, it has a useful role, and the same is presented below:

i. Research on applications of this technology in cardiology is increasing; Search of the literature showed that medicine is the most common field where research on AM is rapidly progressing.

ii. AM helps converting a predesigned virtual model into a physical object and acts as an efficient, supportive tool for medical education that reduces operative risk.

iii. Additive manufacturing follows five steps in cardiology by its application, i.e. image acquisition, segmentation, computer-aided design, rapid prototyping and clinical translation to create an artificial 3D heart.

iv. 3D printed model provides excellent communication between patient and health professionals. The patient can understand the illness better and take a more informed . (11)

v. AM helps provide a walk-through planning tool to the cardiac surgeon before complicated surgery that can make the procedure safer and faster.

vi. AM helps the surgeons to create a customised action plan which gives an idea of what to expect by studying patient's accurate replica of cardiovascular tissue.

vii. AM can potentially help in designing an artificial heart that will closely resemble the human heart. It is at a nascent stage and requires innovation in medical tools/ devices to fabricate customised artificial heart rapidly.

viii. Additive manufacturing has various applications in Aortic pathology, Atrial septal defect closure, proper patients for pulmonary valve implantation, procedural planning, teaching tool and device innovation.

ix. Due to various attributes of AM such as design, colour, efficiency, speed, cost and accuracy, it has the potential to revolutionise the practice of cardiac intervention and surgery .

Additive Manufacturing in Dentistry

AM technologies fulfil the complex challenges in medical aswell as in dentistry. These technologies are now available to improvepatient outcomes. The two leading technologies prominent in the area of dentistry are stereolithography (SLA) generally used for alignerfabrication, and another is direct metal laser sintering (DMLS) which is capable of producing high-quality metal dental crown and appliance frames. (12 , 13) . Implant surgeries are performed mostly by hand. During this procedure, dentists first scan the patient's jaw and drill the patient's mouth by taking help of scanned image. This technique works on imagination so it is not so accurate.(14 , 15). Additive manufacturing is a sophisticated method for pinpointing the best location to drill. It improves the accuracy of surgery by correctly creating an entire set of denture that comfortably fit in the patient's mouth. AM technology is now becoming accessible. It provides better health care and offers needful information for diagnosis and treatment to the dentist. It also has different applications in medical areas during performing of complex surgery which is helpful to improve patient outcome.(16 , 17)

Benefits of additive manufacturing in dentistry

.Faster and accurate service

• Cost-effective

• Determine depth and width of teeth

• Easily fabricate customised implants

• Reduce fabrication time

• With its digital storage, there is considerable inventory reduction of

physical models

• Rapidly produce custom design

• Accurate sizing for implants

Additive manufacturing is used to manufacture patient specific eruption guidance appliances, thereby increasing patient comfort and reducing overall cost of the model.(18)

In dentistry, there are various requirements for the patients; such as crown, implants and bridges. Various AM technologies are beneficial for dentistry. Binding jet technology is used to manufacture dental prostheses. Various parameters are taken such as drying powder level, binder amount, drying time and powder spreading speed. The shows that it provides an accurate implant with low cost and better strength.(19). Micro-computed tomography is used to scan the existing framework for obtaining a 3D printed model. The result shows that it helps to achieve more than 99% density with controlled shrinkage at a lesser cost. It is highly compatible to produce complex shape dental implant with exact dimensions.(20). The comparison of the accuracy of dental restoration manufactured through additive manufacturing and subtractive

manufacturing method using wax or zirconia milling is undertaken. The result shows that the accuracy of dental restorations manufactured by additive manufacturing technique is higher than that of subtractive methods .(21) .

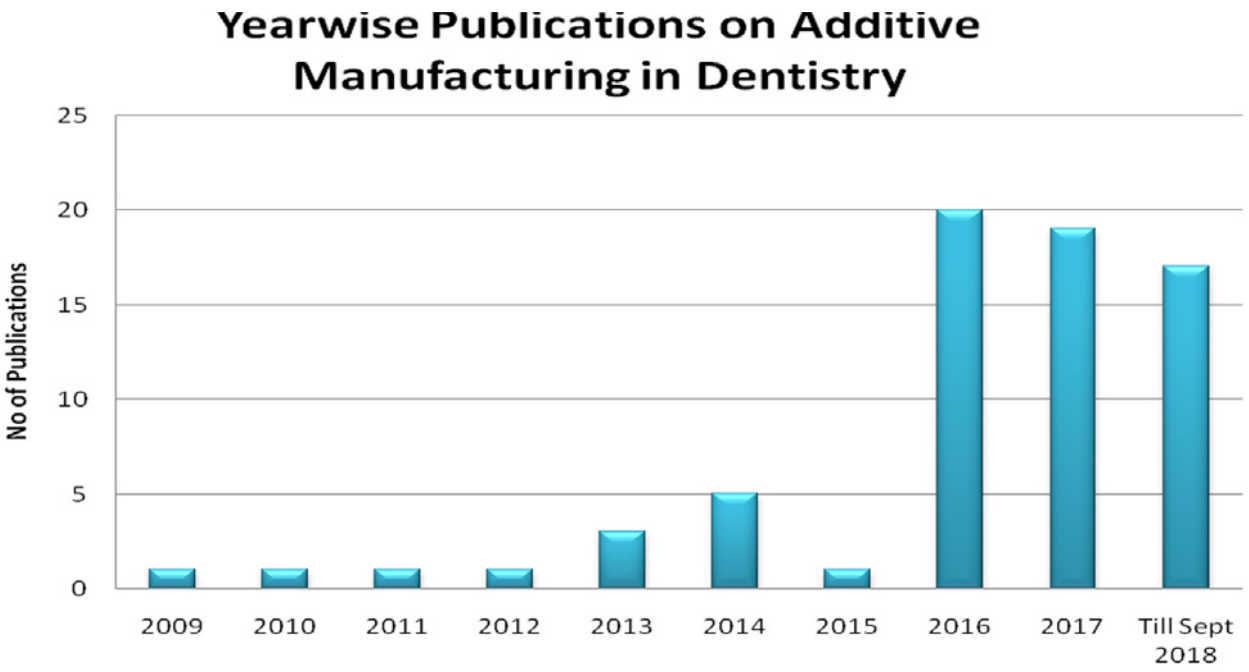
Research status on additive manufacturing applications in dentistry

Identified research article related to this area through Scopus database till September 2018 by searching keywords as “AdditiveManufacturing” Dentistry” and found 70 research articles published in this field. Here we observed from the data, that first paper got published in 2009, and now the number of publications has risen. year-wise publications from 2009 to September 2018.(22). Journal of Prosthetic Dentistry have highest publications of nine in this field by the application of AM. Dental Materials journal have two publications is at position 2. Biomed Research International, Rapid

Prototyping Journal, Journal of Dental Research and various other journals have one each. By the application of AM in the field of dentistry, engineering area has maximum utilisation of 27%. However,

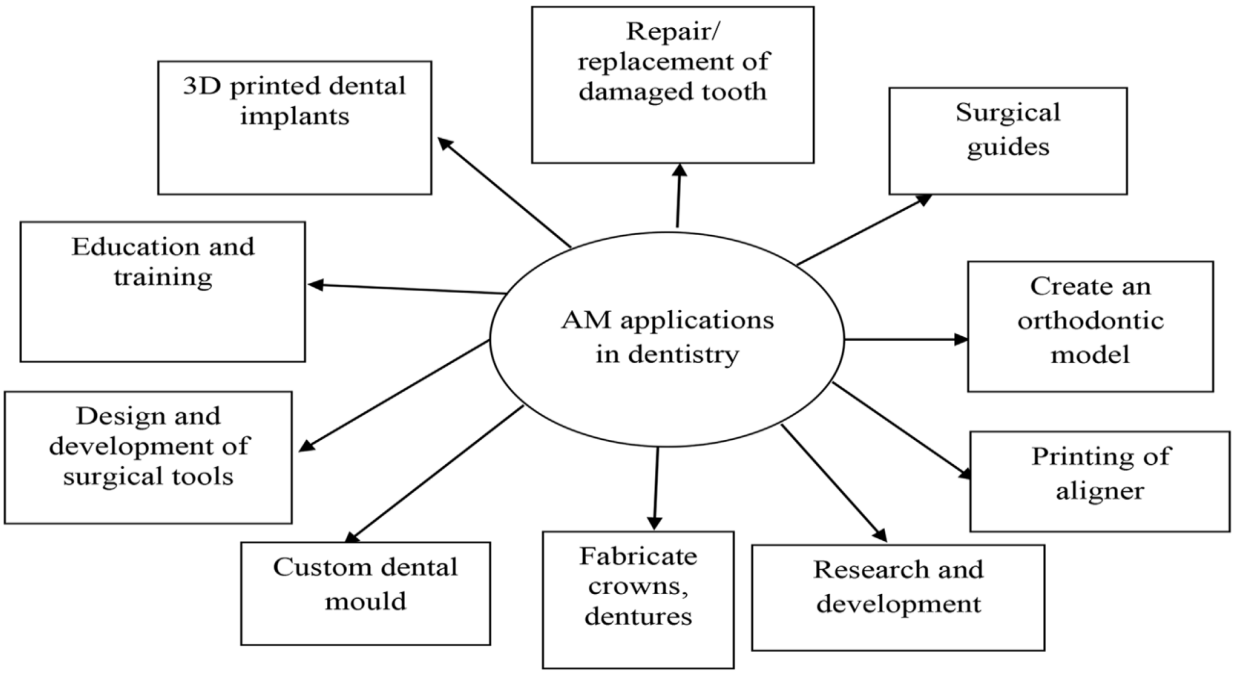
dentistry contributes 23%, Materials Science 16%, Biochemistry, Genetics and Molecular Biology 11%, Medicine 5%, Computer science 3% and other areas also contribute 14%. From Scopus data, it has analysed that applications of additive manufacturing are increasing in the area of dentistry. Thus these

technologies/machines are becoming commercially viable and acceptable in the field of dentistry.



A literature based review done by Mohd. Javid , Abid Hallen in journal of Oral Biology and Craniofacial Research , Volume 9 , Issue 3 , July sep 2019 . AM of ceramics for dental applications , review by Raquel , Galante , Celio G Figueieedo etc in Dental Materials , Volume 35 , Issue 6 in June 2019 .

Applications of AM in dentistry



CONCLUSION

Additive manufacturing technologies provide innovation in the manufacturing of complex and mass customised dental implants with negligible wastages. Easy scanning of the Patient-specific dental parts

by the dental 3D scanner assists quick printing of personalised dental model with high accuracy and It easily fabricates a three dimensional physical model of the heart of a specific patient in a short time, using various specialised technologies from previously acquired scanned virtual image. Three-dimensional scanned images created by CT and MRI can be examined in the form of a realistic and tangible object. This can be used to examine the complexity of diseased anatomy in a given patient. This technology easily fulfils various requirements of cardiology and dentistry due to its flexibility in design and manufacturing of specific patient 3D models .

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