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Applications of 3D-Printing Technology in Dentistry

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Abstract;

3D printing has been acclaimed as a disruptive technology which will change manufacturing. The technology has a particular resonance with dentistry. It

has become of great importance with advancement in 3D imaging and modelling technologies such as CBCT, intraoral scanning and CAD CAM in dentistry. Advancement of technology in dentistry have improved the diagnostic accuracy, eased treatment delivery and reduced chair time allowing the dentist to provide more effective treatment.3D Printing allows the dentist to visualise, record hard and soft tissue significantly with precise measurement and print the models.

Uses of 3D printing include the production of drill guides for dental implants, the production of physical models for prosthodontics, orthodontics and surgery, the manufacture of dental, craniomaxillofacial and orthopedic implants and the fabrication of copings and frameworks for implant and dental restorations.

Multiple 3D printing methods such as Stereolithography ,Inkjet based system, Selective laser sintering , and Fused deposition modelling allows us rapid prototyping. Each technology offers specific advantages in the creation of particular type of products. In the dental field SLA and Inkjet based systems are

most commonly used. This review examines the current applications of 3D printing within dentistry, including the fabrication of dental prosthetics, orthodontic devices, and surgical guides. It highlights the benefits of rapid prototyping, customization, and precision that 3D printing offers, thereby improving treatment efficiency and efficacy. Additionally, the review discusses the materials used in 3D printing, technological advancements, and challenges faced by practitioners, such as regulatory compliance and material limitations. Future directions for research and development in 3D printing technology are also explored,

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emphasizing its potential to further transform dental care practices and optimize patient-centered solutions.

Keywords ; 3D Printing, CAD-CAM, Application

INTRODUCTION;

The term “3D printing” is not new. Excel Jon was the first who treated a person using 3D printing in the year 1999, with the material added together typically layer by layer.2 This article explains the significance of 3D printing in dentistry, and in-turn how dentistry helps advancements in 3D printing.**[1]**

3D printing, also referred to as rapid prototyping (RP) or additive manufacturing (AM), involvesthe layer-by-layer construction of objects or structures from materials based on computer-aided designs (CAD) and computer-aided manufacturing (CAM). This innovative approach allows for the development of custom-made products and devices in various fields, notably medicine and dentistry. While 3D printing has been utilized in industrial manufacturing for decades, the techniques and equipment were, until recently, prohibitively expensive and labor-intensive. **[2,3]**

However, significant advancements in technology have transformed 3D printing into a mainstream fabrication technique. Improvements in precision, high-resolution imaging, and the advent of advanced 3D printers have made this method accessible across multiple disciplines. In dentistry, 3D printing's rise has coincided with advancements in CAD systems and enhanced imaging technologies, such as cone beam computed tomography (CBCT) and magnetic resonance imaging (MRI). These innovations enable practitioners to plan and fabricate dental and maxillofacial prostheses with remarkable accuracy, effectively restoring and replacing lost anatomical structures. **[1-5]**

Historically, dental practices were predominantly influenced by subtractive manufacturing, specifically the milling process. This traditional method oftenfailed to account for internal structures and could not reproduce complex models in their entirety. Today, modern CAD software, enriched with sophisticated algorithms and artificial intelligence, empowers clinicians to model any object or tissue with remarkable precision, replicating it exactly as required. **[1-6]**

In dentistry, 3D printing refers to the systematic layer-by-layer application of substance employing digital design files to produce dental models, prostheses, surgical guides, and orthodontic devices. Biocompatible materials that satisfy stringent dental requirements are used in manufacturing, like ceramics, resins, and metal alloys. **[1-7]**

Regarding clinical dentistry, 3D printing optimizes patient-specific therapy customization, improves production, and streamlines workflow. By integrating digital impressions with

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CAD and CAM, precision control is now possible in fabricating restorations such as dental crowns, bridges, dentures, and implants and aligners. Furthermore, 3D printing plays an essential function in developing surgical guides that enable precision and minimize risks during maxillofacial surgery and the insertion of implants. **[2-7]**

Today, dentists can produce printed products with high levels of stability and accuracy via advances in 3D printing techniques, including selective laser sintering (SLS), digital light processing (DLP), and stereolithography (SLA). They provide patients with better and specific treatments while promoting a better and more economical method of dental care. The fabrication of fully functional, biocompatible tissues, along with other advances in materials research, is a possible benefit of 3D printing in dentistry. **[1-7]**

Metal-based printing materials and biocompatible resins have paved the way for developments in dental 3D printing. With such advancements, it is easier to construct permanent dental restorations like crowns, bridges, and implants in no time.12 Enhancements in biocompatibility and durability of dental prostheses have produced wonders. The introduction of CAD/ CAM and its synergy with 3D printing has popularized dentistry to a great extent.13 It has undoubtedly introduced modern dentistry to the world. Such advancements have revolutionized the characteristics of dental procedures and have made them more accurate and efficient. **[4-7]**

The dental sector has been affected positively by a strong synergy of 3D printing and CAD/CAM technology. A precise 3D picture of a patient's dentition can be taken in no time, thanks to CAD/CAM technology. This 3D picture can be given to design a required prosthesis with the help of a 3D printer. This has led to a well-constructed prosthesis that meets the patient's anatomical landmarks. Human error has been reduced, and more accurate dental restoration can be performed with this technology. This has led to a more effective, economical, and readily available dental procedure, thereby modernizing dental procedures to a great extent. **[1-8]**

Patient specificity in dental procedures is a great wonder introduced by 3D printing. Additionally, same-day restorations and customized orthodontic devices offer significant benefits to patients. Now, it is easy to make restorations, like crowns and veneers on-site in dental offices.14 Patient visits have undergone a reduction thanks to this. It has brought convenience to patients. Technology has improved orthodontics by introducing customized retainers and clear aligners. Such innovations have benefited both patients and dental practitioners to a great extent. **[1-7]**

An improvement in dental treatment outcomes is observed by integrating CAD/CAM technology. This is because of the ongoing progress in material science and software capabilities. Biofabrication and multi-material printing are new concepts introduced by

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modern dentistry.15 Such concepts have paved the way for more advanced dental solutions like tissue engineering and personalized dental implants. An increase in success rates and patient experiences is also observed by the integration of new technology with dental care, as precision, effectiveness, and accessibility of dental care are enhanced to a great extent. **[1-9]**

Figure 1

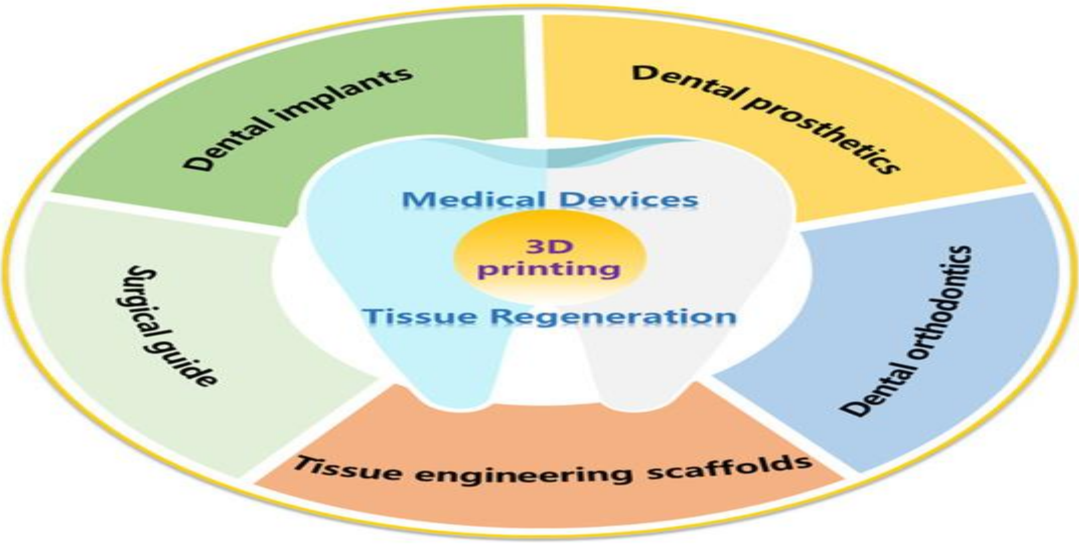

Figure 1. Current applications of 3D printing technology in dentistry.

Types of the additive 3D printing process in dentistry:

1. **Stereolithography and Digital Light Processing:** The oldest and most frequently used technique of 3D printing technique in dentistry is SLA. The principle of SLA is that it is constructed on a layered structure of an entity made of a UV-sensitive liquid monomer which is polymerized and solidified by a laser. Digital-light processing (DLP) is the second method that is generally used. DLP contains a microsystem consisting of a rectangular mirror arrangement called a "digital micromirror device". The angle of the micromirrors can be individually adjusted which acts as light switches and projects the light from the source as individual pixels onto the projection surface. The advantage of DLP technology over the SLA technique is that every single layer can be cured with a single shot of laser exposure by producing patterned laser light rather than scanning separately one after the other with the laser. A high cost of manufacturing is the disadvantage of DLP. **[1--9]**
2. **Photopolymer Jetting and Material Jetting:** In the photopolymer jetting and material jetting processes, the object is built up in layers by a print head with several linear nozzles. The principle can be compared to that of a conventional inkjet printer. Instead of ink, a liquid photo monomer is used for photopolymer jetting, and for material jetting wax

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is used. Afterward, the monomer is cured in layers by UV light or the wax hardens thermally on the building platform. This technique is relatively fast but the high cost of manufacturing is a disadvantage. **[1-12]**

3. **Binder Jetting:** It is a type of photopolymer jetting where an adhesive is applied to a powdery substrate using pressure nozzles. Additional support structures are not necessary, as the printed entity is completely bounded by a supportive substrate. If metal and glass powders are used, the object can be exposed to a sintering process in which the adhesive is burned out. Due to high adhesive content, the resulting items exhibit high sinter shrinkage and porosity and should be infiltrated subsequently. Due to the complicated geometries in dentistry, the binder jetting process using powder/adhesive is restricted mostly to surgical planning models. **[1-12]**
4. **Selective Laser Sintering/Laser Melting:** In the laser melting process all powdery materials that can be sintered or melted by laser radiation and solidified after cooling can generally be used. The material used can range from plastics and metallic materials to ceramic materials. In dentistry, these methods are used mainly for metals. The terms ‘‘laser sintering’’ and ‘‘laser melting’’ are understood conflictingly. The two processes are further divided into numerous subgroups, some of which represent the brand names of certain companies (eg; laser CUSING). However, the basic printer building principle is alike. Low cost is the advantage and high maintenance is the disadvantage of laser melting. **[1-12]**
5. **Fused Filament Fabrication:** The melt layer process was developed over 20 years ago by the founder of Stratasys (Edina, MN, USA) and protected by the trade name ‘‘fused deposition modeling.’’ The process is called fused deposition modeling. The non-patented term is ‘‘fused filament fabrication (FFF)’’ which works according to the principle of strand extrusion. Thermoplastic materials, like polylactides, acrylonitrile butadiene styrene, and waxes, are provided as semi-finished products in various strand thicknesses to the extruder, where they are melted in the hot end and applied to the building board with the aid of a die at the respective x-y coordinate. Heated construction chambers are used to diminish heat distortion in cases of uneven cooling. After completion of one plane, the next plane (z-axis) is started. Low cost is the advantage and low accuracy is the disadvantage of this method. **[1-12]**
6. **Bioprinting:** Bioprinting employs the use of biomaterials, cells, or cell factors as a “bio-ink” to fabricate tissue structures. Parameters like biocompatibility, cell viability, and 13 cellular microenvironments of the biomaterial can greatly alter the printed product. The goal of this method is to design 3D artificial tissues that consist of a scaffold, cells, and an environment that is similar to the real environment of the human body. 3D bioprinting attains these three essential constituents as it is an extremely effective and precise method to create artificial tissue in-vitro. Materials used are alginate, fibrin, collagen, PLGA

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(poly lactic-co-glycolic acid), tricalcium phosphate, chitosan, and hyaluronan. It creates structure with living cells, soft and hard tissue scaffolds, 3- dimensional hydrogels, ceramics, and hydrogels. **[1-12]**

MATERIALS USED IN 3-D PRINTING;

Various materials that can be used for 3D printing include metals, ceramics, thermoplastics, hydrogels, resins, and polymers. **[12-14]**

A wide range of materials used for regenerative procedures are referred to as bio-inks such as bio ceramics (hydroxyapatite and betatricalcium phosphate) and hydrogels. Hydrogels are considered as an ideal material for 3D-printing and these may be natural (collagen and gelatin) or synthetic [polyacrylamide (PAM), polyethylene glycol (PEG), poly (2-hydroxyethyl methacrylate) (PHEMA) and polyvinyl alcohol (PVA)]. Resin based materials are used for manufacturing biocompatible permanent crowns, splints, retainers, removable denture bases, impression trays, prosthodontic and orthodontic models, indirect bonding trays and dental surgical guides. High precision stone-like rigid plastic materials can be used to produce dental models. **[12-16]**

More recently, thermoplastic materials such as PEEK (Polyether Ether ketone) and PMMA (Polymethylmethacrylate) are used for production of 3D printed objects. Metals and metal alloys like Co-Cr and titanium are used for manufacturing copings, bridges, partial dentures, and implants. **[17-19] Figure 2**

Applications Of 3D Printing;

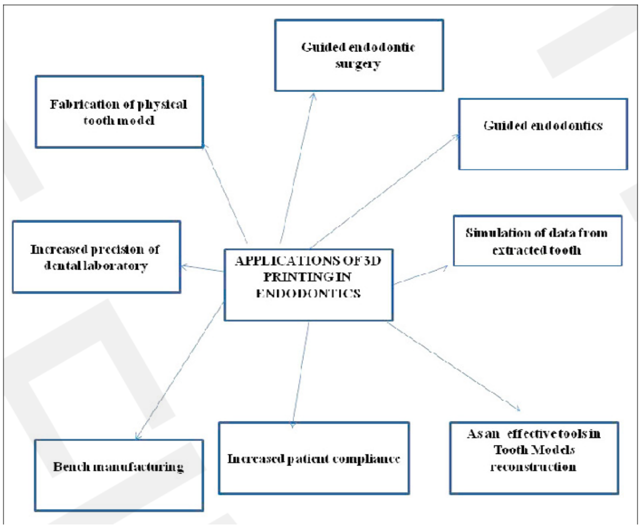

Figure 2. Applications-of-3D-printing-in-endodontics

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-PEDIATRIC DENTISTRY;

Pediatric dentists routinely deal with child patients who face fear and anxiety in a dental set up, three-dimensional printing is emerging as a promising technology with a wide scope in this eld with respect to achieving patient cooperation. Use of this

technology helps reduce chairside time and number of visits, reduced gag reflex, fear and anxiety, and improved patient comfort. It is particularly beneficial in the management of children with Special Health Care Needs (SHCN) as well as Cleft Lip and Palate patients. **[19]**

The most common applications include fabrication of spacemaintainers, custom trays, xed and removable appliances, pediatric crowns, occlusal guards and guided endodontics.3D Printed Space maintainers provide higher level of detail, faster

fabrication and eliminate the extensive laboratory work, involved in fabrication of conventional space maintainers.[**10,20]**

Sangho et al fabricated resin crowns for primary teeth using this technology**.[20]**

Custom Pediatric Appliances: 3D printing enables the production of custom-fit dental appliances for children, such as space maintainers and habit-breaking devices, with enhanced comfort and efficacy.

Diagnostic Models: Precise 3Dprinted models of the dental structures of pediatric patients are helpful for treatment and diagnosis planning, especially in complex cases requiring careful evaluation.

-ORTHODONTICS;

3D Printing has gained relevance in the eld of orthodontics for designing intraoral appliances such as retainers, splints, functional appliances, arch expansion appliances, clear aligners, sleep apnea appliances etc., dramatically reducing fabrication time. **Figure 3**

Al Mortadi et al digitally designed Andersen and sleep-apnea devices and 3D printed them. Both these appliances had an excellent t and accurate thickness**.[21]**

In contrast to thermoformed aligners, digitally dened aligners can be fabricated with higher precision leading to better fit and higher effectiveness, as reported in a

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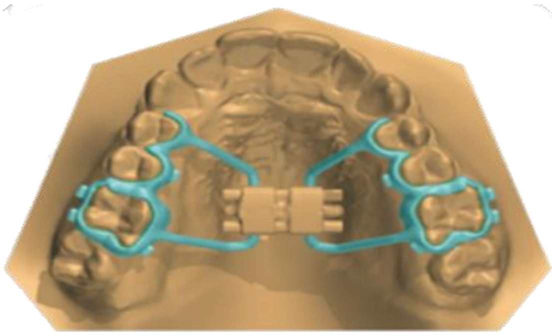

Figure 3. 3D Printed Orthodontic Appliances

study by Jindal et al. **[22]**Patient specific orthodontic brackets can be printed, and their accurate positioning can be achieved using 3D printed indirect bonding

trays. In a study by Yang et al, 3D printed customized ceramic brackets proved to be a favorable strategy, with optimized esthetics and biomechanics. **[23]**

This technology makes it possible to produce diagnostic models using digital impressions offering high reliability and reproducibility. Czajkowska et al conducted a study to compare 3D printed diagnostic models and dental stone models and reported that the former had higher mechanical properties and more longevity. **[24]**

3D-printed guides can be used as a template for precise determination of the nal position of an orthodontic miniplate prior to the surgical procedure, reducing the time needed for surgery and simplifying the process. Ryu et al reported satisfactory results after using digitally printed customized guides andminiplates for treatment of a 6-year old male patient with Class III malocclusion, presenting maxillary undergrowth and mandibular prognathism. **[25]**

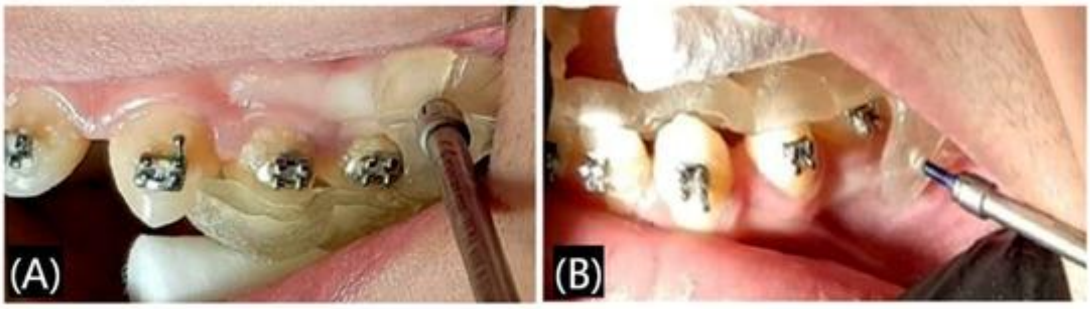

Figure 4. A case of bimaxillary alveolar protrusion treatment with a 3D printed surgical guides. (A) Upper jaw. (B) Lower jaw.

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The placement of Temporary Anchorage Devices (TADs), particularly mini-implants can be planned using a 3D-printed insertion guide or in some cases, the digitally printed TAD-borne appliance itself serves as the guide for insertion, as a time-efifcit treatment option. **[25-30]**

Figure 4

Figure 5. Implant Surgical Guide

Clear Aligners: 3D printing creates customized clear aligners with precise digitized scans of thepatient's teeth. Due to technological advances, a set of Invisalign that slowly shifts teeth into the correct positions can be made.

Brackets and Wire Bends: Customised braces and archwire bends can be printed to fit specific treatment plans, improving the accuracy of orthodontic interventions.

Dental Model;

1. Study Models: Accurate, lifelike models of a patient's teeth can be printed for study and treatment planning. These models aid in visualizing the treatment plan and communicating it effectively to the patient.

2. Diagnostic Model: Dentists can use printed models for diagnosis and to simulate treatment approaches. They can provide better analysis and prediction of treatment outcomes.

Surgical Guide;

1. Implant Surgical Guides: 3D printed guides are designed based on a digital workflow that includes imaging such as CBCT scans. These guides help ensure precise placement of dental implants, improving surgical accuracy and reducing procedure time. **Figure 5**

2. Bone Grafting Guides: In complex procedures, surgical guides can help in positioning bone graft materials accurately.

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-IMPLANT DENTISTRY;

3D printed surgical guides prepared using intraoral and CBCT scans can be used for verifying proper location and angulation prior to implant placement. This can help achieve increased longevity and viability of an implant-based restoration. Studies

indicate that 3D-printed surgical guides can be as statistically accurate as milled guides for guided-implant surgery with higher accuracy, ease of fabrication, less material wastage, and reduced laboratory time compared to subtractive techniques. **[34,35]**

Figure 6. Surgical Guides

This technology can produce custom-built, patient-speci□c implants for replacement of single or multiple teeth. In a case series by Mangano et. al, custom-made 3D printed subperiosteal titanium implants were used for the prosthetic restoration of the atrophic posterior mandible of elderly patients. The implants were fabricated by the DMLS technique which proved to be an accurate and effective method, as amsuitable alternative for invasive regenerative therapies in such cases, with fewer post- operative complications**.[36] Figure 6**

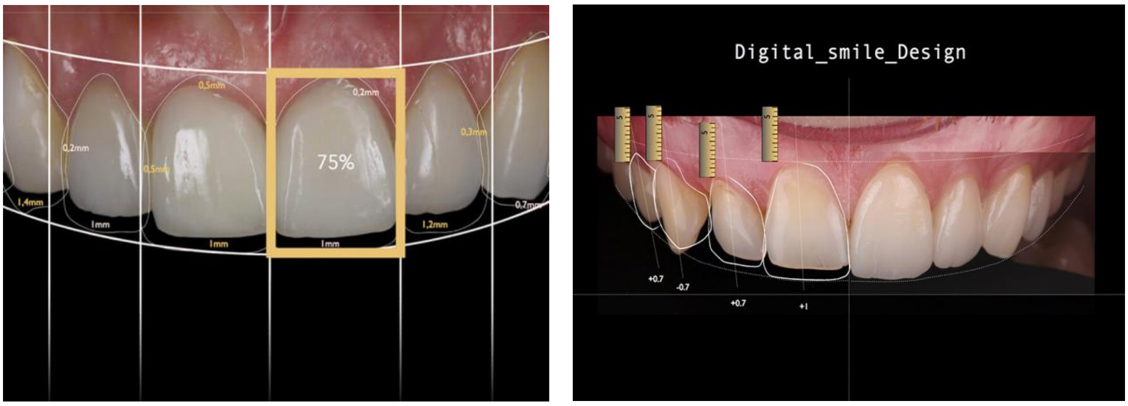

Figure 7. Digital Smile Dentistry

Custom implants: 3D printing makes fabricating dental implants tailored to every patient's exact anatomy and jawbone possible, improving integration and functionality.

Bone Grafting Templates: Precisely forming & placing grafts via 3Dprinted templates enhances success rates of regenerative medicine procedures.

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-3D printing in surgery:

The development of 3D imaging has enabled us to attain a more precise diagnosis and improved treatment planning . **[37]** 3D models of detailed replicas of the skull and jaws of patients serve as anatomical models which have been beneficial in presurgical planning and also serve as a reference during surgery . **[38]**

Surgical guides , augmentation of bone defects and creating replicas of jaws that could serve as study models for students, fixation plates etc can be 3D printed and used for Oral and Maxillofacial and Orthognathic surgeries . **[39,40]**The absent parts of the external ear caused due to birth defects or disorders when tried to restore, demands for a very clear understanding of the complex anatomy. 3D printing could serve the purpose. **[19,41] Figure 5,6**

Surgical Guides: 3D-printed surgical guides are essential for precise implant placement and other procedures. Initial digital imaging and planning are the basis for these guidelines, ensuring accurate drilling and implant placement.

Prosthetic Reconstruction: 3D printing makes it possible to create customized prosthetic models and tools for reconstructive procedures, which aid in preoperative planning and postoperative recovery

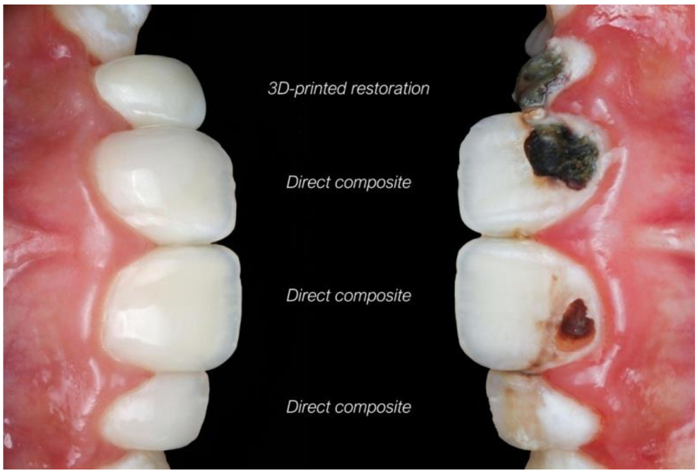

Figure 8. 3D-printed Crown and Direct Composite Restorations in Anterior Teeth

Restorative dentistry;

Since photopolymerization has long been used in dentistry, 3D printing approaches based on UV or visible light. Therefore, resins are commonly used in 3D printing, but have shown some contraction due to their light-activated and mechanical polymerization properties. Therefore, 3D technology is used.9 While fabricating restrorations, customary CAD/CAM

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processing frameworks give various focal points to clinicians and patients, including accuracy. Be that as it may, there are additionally hindrances to subtractive generation strategies. Milling the restoration from a ceramic block, for example, wastes some of the raw

material. In addition, exposure to tooling during production presents the possibility of microscopic cracks in the ceramic surface. These shortcomings could be minimized or even eliminated with 3D printing. **Figure 7,8**

Crowns and bridges: High-accuracy crowns and bridges can be produced rapidly via 3D printing. Precise CAD models are made from digital prints and printed with biocompatible ceramics or resins. As a result, prostheses may precisely imitate the fit and structure of natural teeth.

Inlays and Onlays: By designing custom inlays and onlays that suit each patient's unique tooth contours, occlusal fit and lifespan can be increased.

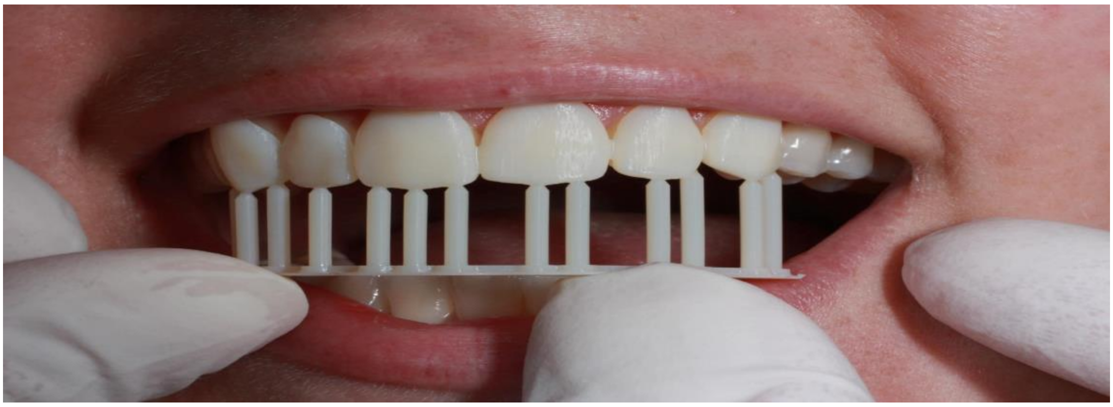

Figure 9. Additive mock ups can be printed directly from EXOCAD for try-in

-Periodontology;

3D printed guides are all the more ordinarily utilized in periodontology for esthetic gingival reconstruction. **[42]**

Persistent explicit careful guides are used for gingivectomy and smile planning.12 The utilization of 3D printing innovation in Regenerative periodontology is still under research. Studies are being done to assess the utilization of 3D printed biphasic platforms to help

in tissue recovery of defects and in healing process. **[42]**

This procedure is called as added substance biomanufacturing. A CT scan of the defect helps in creation of a wax mold from which is intended to make a scafofold that will help in guided tissue recovery. **[19,43]**

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Surgical Templates: To assure precise tissue management and regenerative material placement, customized surgical plans can be made for periodontal operations like flap surgeries or guided tissue regeneration.

-Prosthodontics;

With the use of cobalt- chromium alloy it is possible to fabricate a perfect fit removable partial framework. Thereby opening the way for the construction of the removable framework without the need for the investment and casting procedures using 3D printing technology. **[44]** A 3D printing fabrication method called "Robocasting" is used for the fabrication of the fixed partial dentures. With the help of Inkjet printing technology, it is possible to build up high strength zirconia restorations with a density of 96.6%.**[45]**This technology is superior to the CAD/CAM milling as it overcomes the issues like wastage of the materials and accuracy. **[46] Figure 9**

-Oral and Maxillofacial;

Additive manufacturing technology has been used for three decades in the oral and maxillofacial field of dentistry for model fabrication, diagnosis, surgical planning, surgical guide and template fabrication, and custom implants manufacturing **[47,48].** Similar to the 3D-printed surgical guide for implant surgery, surgical guides and templates are designed based on the obtained CT image and CAD software analysis of the maxillomandibular defect. A 3D printed guide in combination with a

3D-printed patient-specific titanium template provides stability during the operation and ensures the precise placement of bone segments **[49]**. In addition, these guides and templates result in less defects, higher accuracy, better margin control, and bone compromises **[47].**

The capability of 3D printing technology to design and print complex geometries has been used to fabricate custom dental implants. 3D printers, such as SLS and SLM, have the ability to print in titanium or in implantable polymer, particularly polyether ether ketone to fabricate dental implantswith adjustable porosity and mechanical properties **[50].**

However, 3D printing technology is still often used in conjunction with conventional pressing and milling technologies to fabricate implants, because pressing and milling have their advantages as well, such as reduced post-processing, fast production, and predictable use of uniform andhomogenous materials **[1-7].**

Often, maxillofacial defects are complex in shape and size, and 3D printing technology can be extremely beneficial in fabricating prostheses for these defects due to its ability to print complex geometrics. A combination of scanning technology and 3D printing is more comfortable for patients and provides a prosthesis with higher accuracy and better fit to the defect area [**47,51**]. Other benefits

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of implementing 3D printing technology include reduced manufacturing time, decreased number of appointments, and repeatability allowing multiple prostheses **[52].**

-Educational approach;

To prepare dental students for their first living patient, extensive hands-on training is required in a preclinical setting. With computerized dentistry becoming an essential fragment of dental learning and dental practice, 3D printing has started to enhance components of dental Education. **[53]**

Regardless of progress in 3D printing, only straightforward tooth models have been available for dental students to enhance their manual skills,

Provides excellent chances for students and practitioners to learn how to execute various maxillofacial procedures by accurately duplicating orofacial anatomy and complex geometry. Intraoral scans of patients are used to produce 3D

models that are tailored to each individual patient. **[53,54].**

These 1923ustomized models are used to teach dentists how to prepare veneers and crowns in prosthodontics**[53].**

Advantages of 3D Printing in Dentistry;

1. Customization: Solutions tailored to individual needs lead to better-fitting and more comfortable devices.

2. Speed: The reduction in turnaround times for producing dental restorations significantly enhances patient satisfaction.

3. Cost-Efficiency: Lower material waste and reduced manual labor contribute to more economical practice operations .

4. Enhanced Accuracy: Precision in digital scanning, modeling, and printing results in superior outcomes and minimizes the need for adjustments.

Disadvantages;

The benefits from high material utilization might in some cases diminish when contrasted with the drawbacks due to its extended postprocessing duration. Other shortcomings include its high cost, the occurrence of staircase effect (created by layered deposition), inconsistent reproduction and requirement of support materials (that is difficult to remove postprocessing). Ceramics, one of the most popular materials used in dentistry lacks the ability to be 3D printed due to the high porosity caused during fabrication.

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Limitation of 3D Printing;

1. The initial investment in 3D printers and related software is high, often posing a significant barrier for smaller dental practices. Furthermore, effective use of this technology requires specialized training for dentists and technicians, necessitating a commitment to skill development.

2. Regulatory issues add another layer of complexity, as dental 3D printing must meet stringent quality control and certification standards, making compliance a daunting task. While the materials available for 3D printing are diverse, not all are suitable for long-term dental applications or have the desired aesthetic qualities, presenting limitations. Additionally, technical issues such as printing errors can occur, leading to potential delays and complications in the treatment process.

4D Printing- the future;

4D printing is an upcoming technology that has immense possibilities. Skylar Tibbitt's and his co-workers designed self-folding structures that reshape under certain environmental conditions. They converted the steady 3D printing materials into actively changing objects by this approach. Thus, 4D printing helps in the making of materials that shape-shift over a certain time or space. 4D-printed materials can move in different directions as programmed before they are constructed. Regulating the track of the motion of 4D-printed materials in restorative dentistry can eradicate the use of dental etching and bonding systems as they rely more on retention via mechanical means and not chemical aids. **[53-55].**

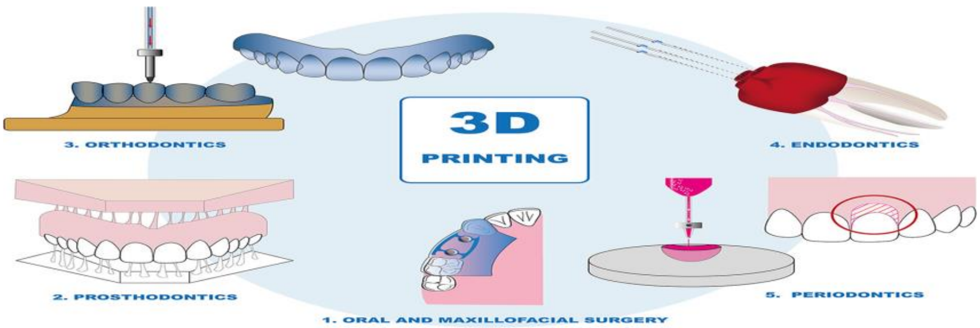

Figure10. Schematic representation of possible applications of 3D printing

A new technological innovation, 4D printing is providing higher capabilities to change the restorative dentistry. Nowadays it is predicted that 4D printed products will replace 3D printed products. 4D printing concept was introduced in 2012 and created an attracted interest in processes and materials. A 4D printing technology allows the printed model/product to change its shape and function concerning time effected external condition like heat, water, light and electricity. This technology provides added capability of embedded transformation in product from one shape to another. **[53-58]. Figure 10**

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The research in the 4D printing in dentistry will be increasing as to produce smart bridges, elaborate dental crowns, aligner, surgical templates, and orthodontic braces adjusted as per requirement of the individual patient after temperature change. It brings an innovative revolution in dentistry. It will improve the quality of patient life and efficiently solve the problem in dentistry. The dentist can convert need/idea into a reality which provides a comprehensive opportunity to manufacture smart dentistry tools and devices as per the requirement of the patient. **[53-60]. Figure 11**

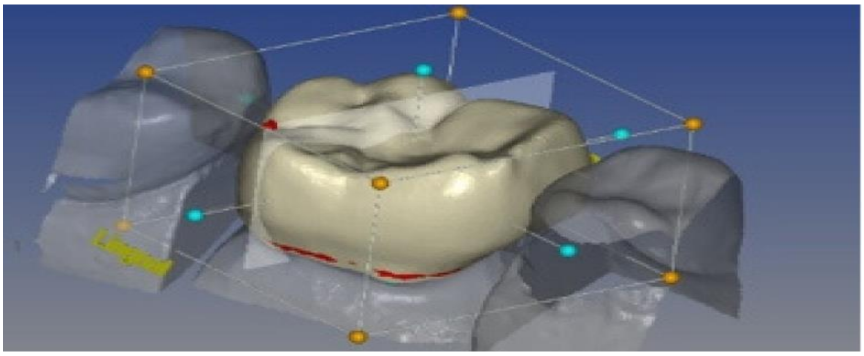

Figure11. 3D Crowns Printed in 10 Minutes

Future applications can include:

1. 4D-printed restorative materials in dentistry that can alter their shape as well as position from the center to the margins in a known time and can prevent fracture or marginal leakage.

2. Designing orthodontic appliances with a controlled, self-folding motion to move the teeth in the required direction and angulation is possible. This amazing technology if made use of, can progress similarly to CAD-CAM and 3D printing and thus change the scope of dentistry.

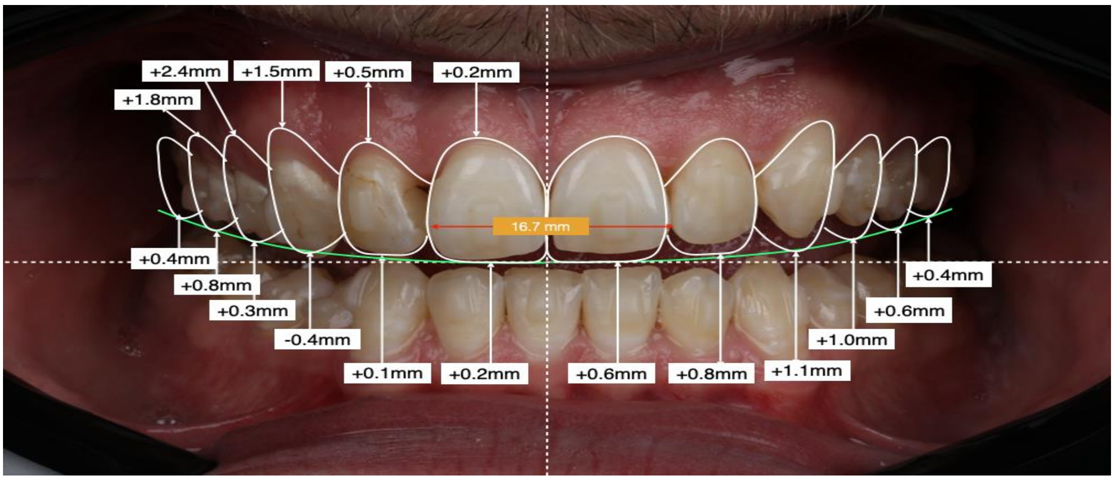

Figure12. Digital-Smile-Design-Treatment-Process-Scans-

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Additive printing technology can revolutionise dentistry. Currently, it is mainly used in surgical planning and indirect implant preparation or aligners for orthodontic correction. As technology advances, creating new heights every day, 3D printing has the capacity to modernise other aspects of dentistry as well. It can be used in the preparation of crowns as newer biocompatible printable materials are developed every day. Ongoing research for 3D printed molecules of intra-canal medicaments with greater healing potential or the discovery of a growth factor delivery system in the periapical region has the potential to transform dentistry. **[60-65] Figure 12**

4D printed can create dental implants with properties as good as natural teeth. Patient's denture could be redesigned to adjust with new shapes as per the eating habits and also take care of humidity and temperature in the mouth. 4D printed dental implants possess characteristics of dimensional changes that could help to avoid marginal leakage. Smart orthodontics implants enhance the function of ligature and wires that help teeth to moves in the desired direction. These implants can adjust the situation without any need for human control. **[64,65]**

In future, 4D printing can print low-cost, smart, functional dentures using multiple biocompatible materials. It can provide a perfect solution for the production of various types of smart, customised dentistry model that can grow as patient teeth grow. Now, 4D printing can solve various problems which are the limitation of 3D printing technologies. This technology has the potential to grow as rapidly as digital dentistry . **[65]**

Conclusion:-

"3D printing**"** or **"**Rapid prototyping**"** technology is a boon to the field of dentistry. It increases the confidence and satisfaction of the patient towards the treatment to be done thus improving the patient dentist relationship. It acts as an important tool for educating dentist**,** students and patients about the treatment plan. It reduces the risk of failure and complications by guiding the dentist in a proper way before implementing the procedure into the patient. It helps the dentist to design the instrument according to the need of the treatment. It requires special skill and saves the valuable time of the dentist and patient during the treatment. Along with all these advantages health and safety protocols should be strictly followed. Thus**,**the combination of scanning**,** visualization**,** CAD**,** milling**,** 3D printing technology and skill makes the dentistry curious and creative. In the future 3D printing has huge scope in the field of research and treatment planning.

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