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'5D PRINTING' -THE NEW ERA IN DENTISTRY! -A NARRATIVE REVIEW

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Introduction:

3D printing technology has a wide range of applications in various industries. It is widely used to produce complex 3D structures, but it has some limitations such as a limited amount of material, etc., which have been overcome with the introduction of 4D printing technology. In 4D printing, which involves time as a function and the combination of smart materials, this enables properties such as changing form and function.[1]Five-dimensional (5D) printing is a new branch of additive manufacturing (AM) with great potential to solve problems in engineering, medicine, dentistry and other related fields. It is the latest technological advancement used to produce complex and intricately shaped products, implants and devices with much better physical properties than those obtained by three-dimensional (3D) printing. The concept of 5D printing originated from William Yerazunis of the American University of Mitsubishi Electric Research Laboratories (MERL). In 5D printing, the printing plate also moves with the printing head during the printing process. in 3D printing techniques.[1]four-dimensional (4D) printing is the concept of using a smart material that can change the shape of a printed object over time as the temperature changes. [2] One of the advantages of 5D printing is the use of 25% less material than 3D printing. Five-dimensional printing is all about efficiently manufacturing this complex and curved structure with maximum strength. Using computer-aided design (CAD) data to produce super strong dental implants, orthodontic brackets, crowns, aligners, bridges and appliances. This CAD data is created using the dentist's 3D scanner / different design software.[1] 5D printing of **five axes**: [1], 1.X-axis ;2. Y-axis;3. Z axis; 4. Movable print head and 5. Movable printing base.5D printing is an advanced manufacturing technology that builds on the concept of 3D printing and adds customization options and features. While 3D printing requires the creation of three-dimensional objects layer by layer, 5D printing allows additional functions or features to be added to a printable object, often dynamically or responsively. its role in dentistry may be limited due to the newness of the technology.

The key differences between 3D, 4D, and 5D printing:

3D Printing	4D Printing	5D Printing
3D printing, also known as additive manufacturing, involves creating three-dimensional objects layer by layer from a digital model. It typically involves slicing a digital model into thin horizontal layers and then building up the object layer by layer using materials such as	4D printing builds upon the principles of 3D printing but introduces the concept of self-transformation over **time or in response to external stimuli.** Objects are printed using materials that have the ability to change shape, properties, or functionality after fabrication, triggered by factors such as temperature,	5D printing is an extension of 3D printing that adds **additional dimensions of customization and** functionality to printed objects. In addition to the spatial dimensions (length, width, and height) and the fourth dimension of time or environmental response (as in 4D printing).[1,5,6]

plastics, metals, ceramics, or composites. [3]	humidity, light, or other environmental stimuli. [4]	

Applications of 5D Printing Applications in Dentistry:

1. **Custom Dental Implants**: 5D printing can be used to create highly customized dental implants that precisely fit the patient's anatomy. These implants can contain multi-material structures that better mimic the characteristics of natural teeth. Sensors built into implants can monitor factors such as bite force and temperature, providing valuable information to monitor diagnosis and therapy. [7]

2. **Multi-material restorations**: Restorative dental materials can be 3D printed with multiple materials using 5D printing techniques. This makes it possible to create dental fillings with different properties, such as strength, flexibility or transparency, within a single filling. Multi-material fillings match the natural appearance and function of teeth, improving aesthetics and longevity.[8]

3. **Embedded sensors and electronics**: In addition to structural customization, 5D printing allows sensors and electronic components to be integrated directly into dental implants. These sensors can monitor parameters such as bite force, temperature or pH level in the mouth and provide valuable information to monitor diagnosis and treatment.[9,10]

4. **Customization and comfort**: 5D printing enables the manufacture of orthodontic devices. precise adaptation to the unique dental anatomy of the patient. This adjustment increases comfort during treatment by reducing irritation and discomfort caused by ill-fitting appliances. [11]

5. **Integration of smart materials**: 5D printing enables the incorporation of smart materials into orthodontic devices, improving their functionality and responsiveness. Smart materials can respond to environmental stimuli such as temperature, pH or mechanical stress, which improves therapeutic results.[12]

6. **Drug delivery systems**: The integration of 5D printing into dental drug delivery systems offers innovative solutions for the localized and controlled release of drugs or bioactive agents.

A. Local drug delivery: 5D printing enables the production of dental devices with built-in drug delivery systems that can release drugs or bioactive agents directly at the site of use, such as dental implants or removable dentures.[13]

B. Controlled Release Mechanisms: With 5D printing, drug delivery systems can be designed to release drugs in a controlled manner over time, enabling sustained therapeutic effects and improved treatment outcomes.[14]

C. Tailored therapies: 5D printing enables drug delivery systems to be adapted to the specific needs of patients, such as the release of antimicrobial agents for periodontal treatment or growth factors for tissue regeneration.[15]

7. **Biocompatibility and safety**: 5D printing allows the production of drug delivery systems from biocompatible materials, ensuring safety and compatibility with oral tissues.8. Smart dentures, shape memory materials in dentures:The incorporation of 5D printing into smart dentures and the use of shape memory materials in dentures offer promising advances in dentistry.

A). Smart prostheses: 5D printing can be used to make smart prostheses with adaptive and responsive features. Smart materials can be integrated into the denture base or framework to improve fit, stability and comfort. [5,17]

B). Shape memory materials in dentures: Shape memory materials such as shape memory alloys or shape memory polymers can be used in dentures to create dental devices that adapt to temperature or changes in temperature. mechanical stress.[18]

C). Improved stability and comfort:9. Smart prostheses made with 5D printing and shape memory materials provide better stability and comfort to the wearers of the prostheses. These materials can adapt to changes in oral conditions, providing a better fit and reducing the risk of discomfort or irritation.[19]

10. **Personalization and customization**: 5D printing enables the manufacture of dental fillings precisely tailored and adapted to the patient's unique dental anatomy. The multi-material design allows different materials with different properties to be combined, which improves the aesthetics, durability and functionality of the restorations.[20]

11. **Multi-material properties**: 5D printing makes it possible to make dental fillings with multi-material designs, allowing the combination of materials with different properties such as strength, flexibility and transparency in a single filling. This versatility allows the creation of restorations that closely mimic the natural appearance and function of teeth.[21]

12. **Improved functionality and durability**: 5D printed multi-material dental restorations can provide improved functionality and durability by combining materials with complementary properties such as ceramics, polymers and metals. These fillers resist compressive forces and provide long-term stability and longevity.[22]

Materials used for 5D printing: Biocompatible polymers: Biocompatible polymers, such as dental resins, are commonly used in 5D printing to make dental prostheses, including crowns, bridges, and dentures. These materials offer excellent biocompatibility and aesthetics.[23]

a). Ceramics: 5D printing uses ceramic materials such as zirconium oxide and lithium disilicate to make dental crowns, veneers and bridges. These materials offer excellent aesthetics, strength and biocompatibility.[24]

(b). Metal alloys: Metal alloys such as cobalt chromium and titanium are used in 5D printing to make dental implants and removable dental frameworks. These materials offer excellent strength, durability and biocompatibility.[25]

c). Hydrogels: Hydrogels are emerging as promising materials for 5D printing in dentistry, especially in applications such as drug delivery systems and tissue engineering. These materials offer adjustable properties and excellent biocompatibility.[25]

Limitations: Due to recent development, the cost of two axes, moving head and bed is added and skilled operators are required.

Conclusions: In the future this technology will facilitate the work of the clinic with significantly better reliability and minimal side effects. It can be well applied to the printing of dental implants made of various biocompatible materials. Five-dimensional printing technology becomes the ideal solution for all curved products such as stents, bones, prostheses and other dental tools and equipment. To reduce the cost of implants, 5D printing is preferred over 3D printing technology, as the former produces less material waste.

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