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"3D PRINTING IN DENTISTRY: REVOLUTIONIZING PRECISION, EFFICIENCY, AND PATIENT CARE"

Dentistry

Dr. L. Krishna Prasada Prof., HOD, Dept Of Conservative Dentistry And Endodontics KVG Dental College And Hospital

Dr. Manisha Rai PG Student Dept Of Conservative Dentistry And Endodontics KVG Dental College And Hospital

ABSTRACT

Three-dimensional (3D) printing has revolutionized modern dentistry by enabling precise, efficient, and customized solutions across various dental disciplines. Originally introduced by Charles Hull in 1986, 3D printing now plays a critical role in endodontics, prosthodontics, orthodontics, periodontology, oral and maxillofacial surgery, and implantology. Guided endodontics enhances the treatment of calcified canals, while computer-aided rapid prototyping (CARP) improves the success rate of autotransplantation. Crown and bridge fabrication benefits from high-resolution 3D-printed restorations, ensuring better fit and reduced material waste. Additionally, 3D printing advances the production of complete and removable dentures, occlusal splints, surgical guides, and custom trays, improving accuracy and efficiency. Emerging technologies, such as 3D bioprinting, offer exciting prospects for tissue engineering in oral and maxillofacial surgery. With ongoing innovations in materials and workflows, 3D printing is poised to become a fundamental component of modern dentistry, enhancing patient outcomes and streamlining clinical procedures.

KEYWORDS

INTRODUCTION

"Through the precision of 3D printing, dentistry transcends traditional boundaries, sculpting not just smiles, but confidence and quality of life."

Charles Hull first presented three-dimensional (3D) printing technology in 1986, and since then, the industry has created a wide range of manufacturing techniques that are used in many different fields. Hull created a 3D printing system and received a patent for stereolithography (SLA) in 1986.

A patent for fused deposition modelling (FDM) was granted to Scott Crump in 1990(1). The field of 3D printing has advanced steadily since then. Its uses in dentistry span from orthodontics, endodontics, and periodontology to prosthodontics, oral and maxillofacial surgery, and oral implantology.

Guided Endodontic Access

Pulp canal obliteration, caused by factors like age-related dentine apposition, caries, orthodontics, systemic diseases, or trauma, presents a clinical challenge. In this scenario, locating canals within narrowing roots becomes crucial.

Research indicates that up to 75% of perforations during attempts to find and negotiate calcified canals are due to pulp canal obliteration. To mitigate this risk, implementing precise strategies for canal access and instrumentation is essential. Numerous international publications have documented research outcomes in the field of guided endodontics since the initial studies.

It is necessary to align the 3D data set and then position the drill's true-to-scale virtual image such that the tip of the drill reaches the visible portion of the calcified root canal. The tooth's apex is selected as the drill's apical target point when the CBCT is unable to show the root canal. A template designer tool is used to create a virtual template once the drill and virtual sleeve position above the incisal edge[2].

Once the template with the integrated sleeve is placed inside the patient's mouth, the bur is guided by the sleeve and pushed a few millimeters down the patient's jaw at a slow speed and pumping motion.

Following the removal of debris, the drilling is resumed if the root canal cannot be navigated at that depth with a hand file. This process is carried out repeatedly until the bur reaches the sleeve's mechanical stop. Conventional root canal therapy can now begin if the canal has been identified successfully[2].

Steps Showing Guided Endodontics:

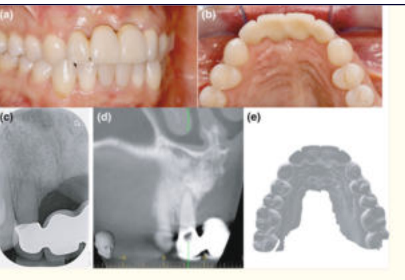

FIGURE 1

Clinical situation from buccal (a) and palatal (b), 2D imaging performed by the general dentist shows no apical lesion (c), CBCT image shows a severely calcified root canal and a lateral lesion (d), palatal view of intraoral scan (e)

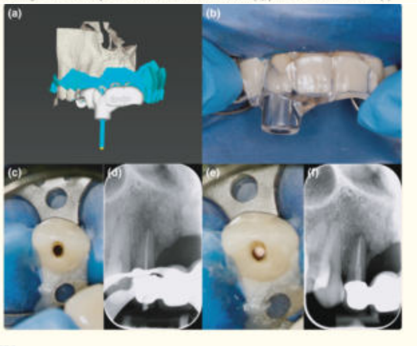

FIGURE 2

Virtual planning of the access cavity (a), tension-free insertion of the template (b), minimally invasive access cavity (c), masterpoint radiograph (d), root canal filling before placement of a post (e), final radiograph of root canal filling with fibre post (f)

Autotransplantation

Autotransplantation, a surgical procedure where a tooth is moved within the same individual, relies on preserving the periodontal ligament (PDL) cells and ensuring proper adaptation. Extra-oral time and PDL trauma significantly impact outcomes. Conventional methods involve using the transplanted tooth as a template for recipient site preparation, which can be time-consuming and risky. Improving autotransplantation outcomes could enhance the procedure's effectiveness and acceptance[3].

Recent advancements, such as **computer-aided rapid prototyping (CARP)**, have improved autotransplantation procedures. CARP enables the creation of tooth replicas, allowing manipulation of recipient bone sites before extracting transplanted teeth. By minimizing repeated insertion and removal, CARP reduces damage to the **periodontal ligament (PDL)** and increases the chances of successful autotransplantation. In simpler terms, autotransplantation involves moving a tooth within your mouth, and its success relies on

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careful handling and adaptation. Dentists' opinions on this procedure vary, but innovations like CARP may enhance its reliability and widespread use.

Crown And Bridge Dentures

1. **Precision**: 3D printing allows for high-resolution, layer-by-layer fabrication, resulting in crowns that precisely match the contours of the prepared tooth.
2. **Predictability**: By utilizing digital scans of the patient's mouth, the entire process becomes more predictable, ensuring a snug fit and reducing health risks

When it comes to creating crown and bridge dentures, **resin-based 3D printing** methods like SLA or DLP offer several advantages. Unlike traditional milling techniques, 3D printing minimizes material usage, resulting in **minimal material waste**. In simpler terms, 3D printing is efficient and resource-friendly for crafting dental restorations[5].

Complete Dentures

1. **Precision**: 3D printing allows for high-resolution, layer-by-layer fabrication, resulting in dentures that precisely match the contours of the patient's mouth .
2. **Predictability**: By utilizing digital scans of the patient's mouth, the entire process becomes more predictable, ensuring a snug fit and reducing health risks .

In simpler terms, 3D printing enhances the accuracy and fit of complete dentures, making the process more reliable and effective.

Denture base strength is crucial to withstand real-life wear and tear.

CAD/CAM Materials: Research by Aguirre et al. suggests that CAD/CAM materials exhibit higher flexural strength compared to compression-molded denture base materials .

1. **Thermal PMMA**: Ayman and Pacquet found that thermally polymerized PMMA (polymethyl methacrylate) has higher bending strength than CAD/CAM milling denture base material[6] .
2. **3D Printing**: However, 3D printing materials used for denture bases generally have inferior mechanical properties compared to most milling denture base materials and thermally polymerized acrylic resin[6] .

The choice of material and manufacturing method significantly impacts the strength and durability of denture bases.

Removable Partial Dentures

Integration Of 3d Printing: The integration of **3D printing technology** in producing RPD frameworks has become a clinical routine. Two primary additive techniques are commonly used:

- **Selective Laser Melting (SLM)**: Direct printing of the metal framework.
- **Digital Light Processing (DLP)**: Framework printing in castable resin, followed by casting and processing

2. **Advantages And Uncertainties**:

- **Faster And Advanced**: SLM is a faster and technically more advanced procedure.
- **Substitution Of Traditional Casting**: However, the complete substitution of traditional casting techniques for RPD fabrication remains uncertain

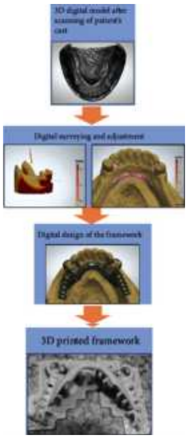

Figure 3- The computer-aided design (CAD)/computer-aided manufacturing (CAM) process of constructing a partial prosthesis framework. (Images from the study of Harb et al[7].

Occlusal Splints

These are removable artificial surfaces that affect the relationship between the mandible and maxillae. They serve various purposes, including managing discomfort from occlusal discrepancies, orofacial pain, bruxism (teeth grinding), and obstructive sleep apnea.

1. **Traditional Fabrication vs. 3D Printing:**

- **Traditional Fabrication**: Conventional methods involve impression materials, dental stone, cast fabrication, trimming, designing, processing, and finishing. However, this approach can be time-consuming and result in variable quality and consistency.
- **3D Printing**: Using digital workflows and 3D printing, dentists and laboratories can create occlusal splints more efficiently and with better precision.

2. **Workflow for 3D-Printed Occlusal Splints:**

Start by scanning the patient's maxillary cast using an intraoral scanner.Use computer-aided design (CAD) software to design the occlusal splint based on the patient's specific needs.Employ a 3D printer (such as the Formlabs Form 2) and biocompatible resin (e.g., Dental LT Resin) to directly 3D print the splint.Post-process the printed splint needs to be finished to ensure a smooth surface and proper fit.

3. **Benefits of 3D-Printed Occlusal Splints:**

- **Control**: The digital workflow allows precise control over design and fit.
- **Efficiency**: Less labor-intensive compared to traditional methods.
- **Biocompatibility**: Using appropriate materials ensures patient safety.
- **Consistency**: 3D printing results in consistent appliance quality

Surgical Guide For Oral Implantology

3D printing allows for precise virtual planning of implant placement using software programs.These guides are specially designed for each patient's implant site and manufactured using 3D printing technology.By incorporating cone-beam computed tomography (CBCT) scans and cast models, surgical guides can be tailored to the patient's unique anatomy. The use of 3D-printed surgical guides enables more accurate procedures compared to conventional techniques. Dentists can achieve a high level of predictability in implant placement.

1. **Advantages**:

- **Accuracy**: Statistically significant differences exist between virtually planned implant positions and actual implant positions, with minimal deviations.
- **Predictability**: Implants can be better positioned, reducing operating time and patient discomfort.
- **Reduced Risk**: Surgical guides minimize damage to adjacent structures (teeth, sinuses, bone cortices).

3- Dimensional Printed Custom Trays

Accurate implant impressions are crucial for successful prostheses. Custom trays play a key role in achieving accurate impressions.Stable trays ensure uniform thickness and adequate space for impression materials.Accurate trays contribute to good support, retention, stability, and functional restoration.3D printing provides precise custom trays.Shorter processing time compared to traditional methods.CAD programs and 3D printers allow customized tray production.

1. **Clinical Impact**: 3D printing streamlines the process of creating custom trays for implant-supported dentures in edentulous patients.3D-printed custom trays offer controlled space for impression materials, improving accuracy and reproducibility. Custom trays show better accuracy and uniform 3D space compared to traditional hand-made trays[8].

Applications of 3D Bioprinting in Oral and Maxillofacial Surgery:

- Autografts (using a patient's own tissue) have been the go-to solution for soft tissue or hard tissue defects. The advent of **3D bioprinting** has expanded horizons for surgeons, physicians, and bioengineers.

- **What Is 3D Bioprinting?**:
- It's a technique that allows precise printing of tissues with pre-defined arrangements of cells, complete with their own vascularization.While accessibility remains a challenge, 3D bioprinting holds immense potential for reconstructive surgeries in oral and maxillofacial areas[10].

3D Printing of Dental Prostheses:
Three-dimensional printing enables rapid fabrication of complex dental prostheses layer by layer.

Recent Advances in 3D and 4D Printing:
Dentists can custom design and print surgical drill guides, temporary and permanent crowns, bridges, orthodontic appliances, orthotics, implants, and even mouthguards for drug delivery.

Educational Models And Clincial Simulation
In dental education, various materials have been used for preclinical exercises. Extracted teeth, human cadavers, and commercially available resin teeth all have limitations. Tooth prototypes, including 3D-printed replicas, offer advantages over extracted teeth. These models enhance training for endodontic procedures.

Materials Used For 3-D Printing
The Top Resins For 3D Printing In Dentistry, Include:
1. **ONX Tough 2.0:** Known for its industry-leading fracture toughness, multiple color choices, and esthetic properties. It is recommended for All On X restorations.
2. **Tie-Rodin Sculpture and Ceramic Crown:** These resins are suitable for crowns, inlays, and onlays due to their high glass filler particle content, multiple color choices, and radiopacity.
3. **Tie-Rodin Sculpture and ONX Tough:** These resins are recommended for veneers due to their radiopacity, multiple color choices, and the ability to be printed 300 microns thin.
4. **Tie-High Impact Denture and Lucitone:** These resins are suitable for dentures due to their multiple color choices and high impact formulation.
5. **Graphy Tera Harz Flexible Denture:** This resin is recommended for partial dentures due to its high elongation at break and flexible base material.

The best overall 3D printer is the SprintRay Pro 55s with Crown Kit and Arch Kit. This printer is recommended as the best overall option based on its performance and capabilities[9].

The Future Of 3D Printing –
“The digital revolution that is transforming every aspect of our world is also impacting dentistry and medicine in a multitude of ways, from electronic record-keeping and data analysis to new diagnostic tools, novel prevention methods—and revolutionary treatment options **'The future is wide open,'** says Emmott.”

The future of 3D printing in dentistry is bright. The upcoming innovations in 3D printing technology, including new high translucency resins highly filled with ceramic, as well as ultra-high-strength materials. These innovations are expected to blur the line between porcelain and resin further while solidifying 3D printing as a definitive solution for indirect restorations. Additionally, the document mentions that companies are pushing new and exciting workflows to the market that are geared towards same-day dentistry, indicating a trend towards faster and more efficient 3D printing processes.

CONCLUSION
3D printing technologies have brought favorable circumstances to the manufacturing of complex equipment in various fields, including dentistry. The summary of the clinical applications of 3D printing in dentistry, including working models and specific applications in Endodontics, prosthodontics, oral and maxillofacial surgery, and oral implantology is discussed.3D printing technology holds a promising future for, highlighting its ability to meet complex and personalized needs in dental applications.

REFERENCES

1- Gross B. C., Erkal J. L., Lockwood S. Y., Chen C., Spence M. D. Evaluation of 3D printing and its potential impact on biotechnology and the chemical sciences. Analytical Chemistry. 2014;86(7):3240–3253. doi: 10.1021/ac403397r.
2- Connert T, Weiger R, Krastl G. Present status and future directions - Guided endodontics. Int Endod J. 2022 Oct;55 Suppl 4(Suppl 4):995-1002. doi: 10.1111/iej.13687. Epub 2022 Feb 4. PMID: 35075661; PMCID: PMC9790195.
3- Srivastava S, Gupta K, Dubey S, Singh A. Guided autotransplantation of tooth: An innovative approach. Natl J Maxillofac Surg. 2022 Aug;13(Suppl 1):S136-S139. doi: 10.4103/njms.NJMS_169_20. Epub 2022 Aug 20. PMID: 36393944; PMCID: PMC9651230.
4- Anderson J, Wealleans J, Ray J. Endodontic applications of 3D printing. Int Endod J. 2018 Sep;51(9):1005-1018. doi: 10.1111/iej.12917. Epub 2018 Mar 23. PMID: 29486052.
5- Abduo J., Lyons K., Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. International journal of dentistry. 2014;2014:15.783948 [
6- Prpic V., Schauperl Z., Catic A., Dulcic N., Cimic S. Comparison of mechanical properties of 3D-printed, CAD/CAM, and conventional denture base materials. Journal of Prosthodontics. 2020;29(6):524–528. doi: 10.1111/jopr.13175.
7- Harb I. E., Abdel-Khalek E. A., Hegazy S. A. CAD/CAM constructed poly (etheretherketone) (PEEK) framework of Kennedy Class I removable partial denture: a clinical report. Journal of Prosthodontics. 2019;28(2):e595–e598. doi: 10.1111/jopr.12968.
8- Chen H., Yang X., Chen L., Wang Y., Sun Y. Application of FDM three-dimensional printing technology in the digital manufacture of custom edentulous mandible trays. Scientific Reports. 2016;6, article 19207
9- Walley,Michael 3D printing in restorative dentistry-3rd edition .
10- Sharma, P., Dadwal, H. & Thind, G.B.S. Applications of 3D Bioprinting in Oral and Maxillofacial Surgery: An Insight. J. Maxillofac. Oral Surg. (2023). https://doi.org/10.1007/s12663-023-02063-7