Current and future trends in odontology and dental surgery

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ABSTRACT

Dental Surgery is an ever changing and ever evolving field of medical science, dentistry has seen tremendous advances in recent years. Research and advancement in field of Modern dentistry/odontology will make possible the use of artificial intelligence, virtual reality, biotechnology including tissue engineering. Tissue engineering is a novel and highly exciting field of research that aims to repair damaged tissues as well as create replacement (bio artificial) structure of cranio-maxillo-facial region viz part of skull, ear, nose, hard and soft palate etc. Practical implications are advancement in field of artificial intelligence, virtual reality, information technology, biomaterials, tissue engineering, biosensing, tele-dentistry, 3D printing technologies, application of advance laser in field of dental surgery, nanodentistry and controlled drug delivery system hold great promise to transform the clinical and surgical practice. Advancement in these technologies have the great potential to improve patient's treatment outcome, reduce treatment cost and increase access to dental and oral health care, it will be really interesting to witness the great evolving trend of dental surgery in the future.

Keywords: artificial intelligence, virtual reality, biomaterials, tissue engineering, 3D printing, CAD/CAM, laser, nanodentitry and drug delivery system.

I. INTRODUCTION

Dental surgery or odontology subject to constant evolution, with new technologies continuously advancing and redefining the way dental and oral healthcare is practiced and delivered. There is a plethora of interesting advancement topic in field of dental surgery, hence, this communication aims to provide an overview of a few emerging trends in dentistry Table 1 shows Artificial intelligence (AI), biomaterials, teledentistry and 3D printing. Herein, is a brief presentation and discussion of the potential applications of such evolving technologies and their implications for the future of dental surgery or odontology. In dental surgery several digital workflow for production processing have already been integrated into treatment protocols, particularly in the rapidly evolving branch of computer-aided designed /computer aided manufacturing (CAD/CAM) and rapid prototyping (RP).

New technology like radiological image process by AI and machine leaning (ML). Augmented and virtual reality is the technological based on superimposition of various imaging files creating virtual dental patients and non-invasive simulations comparing different results before any clinical intervention. Recent advancement in the field of information technology help in tremendous advancement in field of research regarding oral and dental surgery.

Table 1: Evolution and Trends in dentistry.

Emerging Trends in Dentistry (Technologies / Applications)		Key features
Nanotechnology	nanoparticles, nanotubes, nanofibers, nanocomposites	High surface area-to-volume ratio, tuneable physicochemical properties, enhanced mechanical and biological properties
Controlled Drug Delivery	Nanocapsules, hydrogels, liposomes, micelles	Controlled release of drugs, improved bio-availability, targeted drug delivery

Tissue Engineering	Scaffolds, hydrogels, layer-by-layer films, cell sheets	Mimic extracellular matrix, provide mechanical support, promote cell adhesion and proliferation
Regenerative Medicine	Stem cell therapy, gene therapy, tissue engineering	Replace, restore, repair, or regenerate damaged tissues or organs
BioFilm Control	Anti-microbial peptides, Silver/Copper nanoparticles, coatings, enzymes	Prevent biofilm formation, disrupt established biofilms, and reduce antibiotic resistance
bio-Sensing	Biosensors, nanosensors, microarrays, lab-on-a-chip	Detect biomolecules, monitor physiological parameters, diagnose diseases
bio-Imaging	Optical imaging, MRI, CT, PET, SPECT	Visualize anatomical structures, track cellular processes, diagnose diseases
Lasers	Erbium lasers, CO_2 lasers, diode lasers, Nd: YAG lasers	Cut, ablate, coagulate, and sterilize tissues, promote *in situ* wound healing
Note: This is not exhaustive and is only meant to provide examples in current or emerging areas.		

II. ARTIFICIAL INTELLIGENCE (AI)

The term "artificial intelligence" (AI) refers to the idea of machines being capable of performing human tasks. A subdomain of AI is machine learning (ML), which "learns" intrinsic statistical patterns in data to eventually cast predictions on unseen data. Deep learning is a ML technique using multi-layer mathematical operations for learning and inferring on complex data like imagery. This succinct narrative review describes the application, limitations and possible future of AI-based dental diagnostics, treatment planning, and conduct, for example, image analysis, prediction making, record keeping, as well as dental research and discovery. AI-based applications will streamline care, relieving the dental workforce from laborious routine tasks, increasing health at lower costs for a broader population, and eventually facilitate personalized, predictive, preventive, and participatory dentistry. However, AI solutions have not by large entered routine dental practice, mainly due to 1) limited data availability, accessibility, structure, and comprehensiveness, 2) lacking methodological rigor and standards in their development, 3) and practical questions around the value and usefulness of these solutions, but also ethics and responsibility. Any AI application in dentistry should demonstrate tangible value by, for example, improving access to and quality of care, increasing efficiency and safety of services, empowering and enabling patients, supporting medical research, or increasing sustainability. Individual privacy, rights, and autonomy need to be put front and centre; a shift from centralized to distributed/federated learning may address this while improving scalability and robustness. Lastly, trustworthiness into, and generalizability of, dental AI solutions need to be guaranteed; the implementation of continuous human oversight and standards grounded in evidence-based dentistry should be expected. Methods to visualize, interpret, and explain the logic behind AI solutions will contribute ("explainable AI"). Dental education will need to accompany the introduction of clinical AI solutions by fostering digital literacy in the future dental workforce.

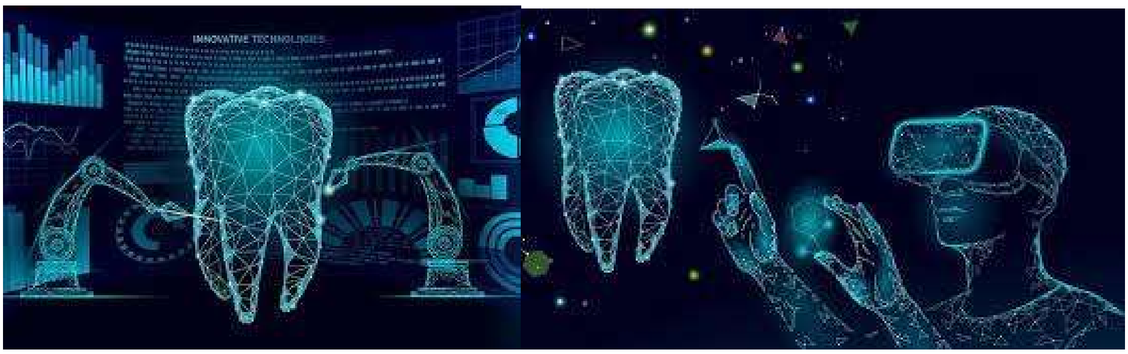


Figure 1: Artificial intelligence and Augmented reality in dental surgery.

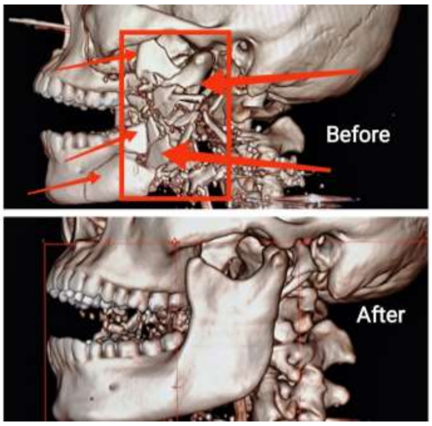


Fig 2: AI generated 3D reconstruction image of 2D Computed tomography image for treatment planning for fracture mandible.

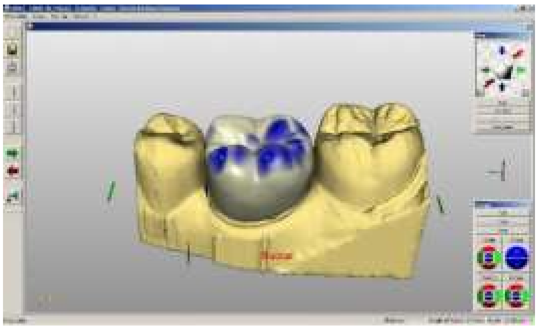


Figure 3. Computer aided Design

Figure 4. Computer aided wet milling

Figure 5. Computer aided dry milling

Figure 6. Dental crown fabricated by CAD/CAM manufacturing technology

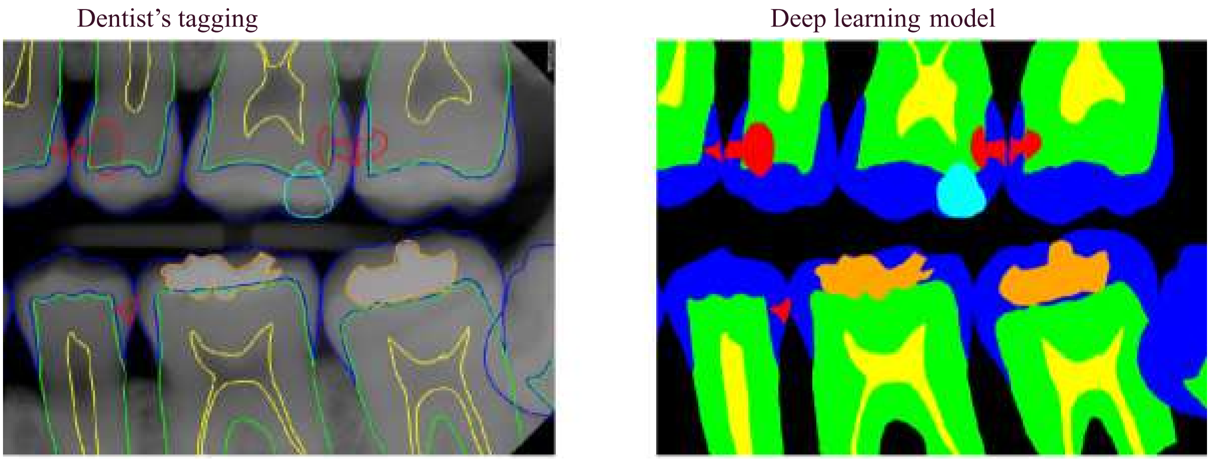


Figure 7. Artificial intelligence for detection of dental caries
Caries (red), enamel (blue), dentin (green), pulp (yellow), metal restoration (orange), restoration (sky blue), gutta percha (brown), background (black)

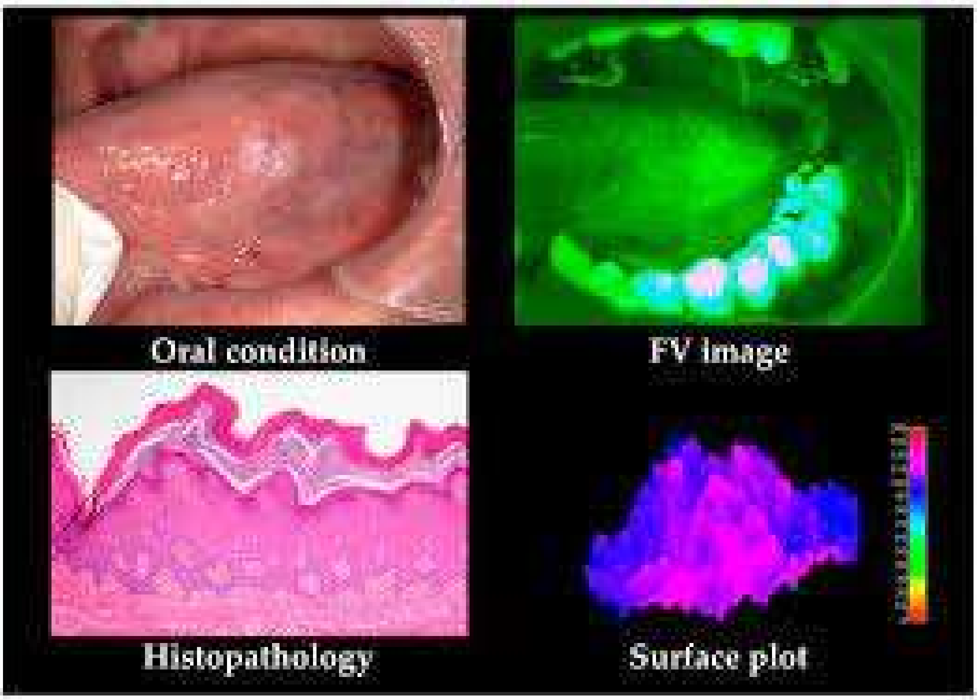


Figure 8. AI for detection of oral cancer.

AI, the artificial simulation of human intelligence, is rapidly advancing in many fields, including dentistry and oralsurgery. AI has the potential to revolutionize many aspects of oral and dental healthcare, from diagnosis to treatment planning to predict and simulate patient outcomes. For example, AI-powered imaging software can help dentists detect dental caries earlier, leading to more effective treatments and better patient outcomes [1]. The global occurrence of oral cancer (OC) has increased in recent years. OC that is diagnosed in its advanced stages results in morbidity and mortality. The use of technology may be beneficial for early detection and diagnosis and thus help the clinician with better patient management. The advent of artificial intelligence (AI) has the potential to improve OC screening. AI can precisely analyze an enormous dataset from various imaging modalities and provide assistance in the field of oncology. This review focused on the applications of AI in the early diagnosis and prevention of OC. A literature search was conducted in the PubMed and Scopus databases using the search terminology “oral cancer” and “artificial intelligence.” Further information regarding the topic was collected by scrutinizing the reference lists of selected articles. Based on the information obtained, this article reviews and discusses the applications and advantages of AI in OC screening, early diagnosis, disease prediction, treatment planning, and prognosis. Limitations and the future scope of AI in OC research are also highlighted AI can also help us create more personalized treatment plans that take into account the unique needs and preferences of each patient. Additionally, AI can assist oral and maxillofacial surgeonsin the detection and diagnosis of oral cancer [2]. As AI’stechnological abilities, readiness, and accessibility continue to advance, it is likely that its utility in the oro-dental and cranio-maxillo-facial complex will only continue to expand.

III.BIOMATERIALS

With advances in materials science and nanotechnology, dental biomaterials are constantly evolving. Briefly, biomaterials are materials designed for use in the body; an area of rapid innovation in dentistry, oral surgery, and cranio-maxillo-facial reconstruction, regeneration, and repair. New biomaterials, such as anti-bacterial coatings and smart/ intelligent formulations that respond to changes in the oral environment, are being developed for use in practice. These have the potential to improve patient outcomes, reduce the risk of infection, and improve the longevity of dental restorationsand implants. Additionally, biomaterials that can support *in situ* tissue regeneration, leading to improved healing after dental and/or surgical procedures are being developed. Calcium phosphate bioceramics remain some of the most widely used biomaterials for bone regeneration, particularly because of their long clinical track-record and well studied mechanisms. Both natural and synthetic polymers, despite their comparatively low rigidity, offer a range of physical and biologic advantages over bioceramics, such as the possibility of controlling 3D cellular microenvironments for stem cell differentiation and tissue regeneration. Biomaterials are synthesized and/or manipulated to be used for growth factor, gene, and stem cell delivery applications with increasingly more successful outcomes. 3D printing and bioprinting have already revolutionized bone regeneration, and it is likely that the next generation of biomaterials for bone regeneration will take advantage of some method of 3D printing [3]; will more than likely become an increasingly essential tool for dentists and surgeons. Bio-ceramics, bioactive glasses, and resin composites are examples of biomaterials that are commonly used in dental applications. For instance, bio- ceramics are widely used today in endodontic treatmentsfor repairing and regenerating damaged pulp tissues, while bioactive glasses can help re-mineralize and repair dental caries. Resin composites, on the other hand, have unique properties such as durability and esthetics.

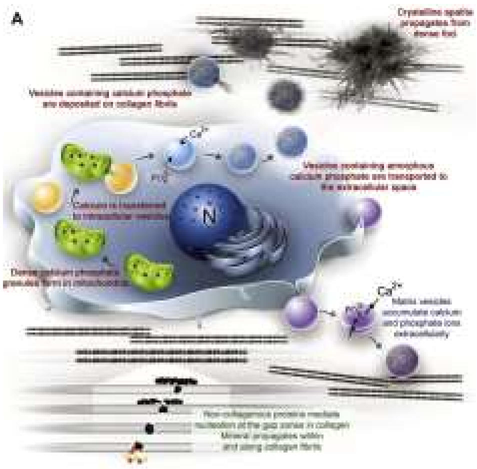


Fig. 9. (*A*) Diagram outlining current models proposed for bone mineral formation.

Bone apatite formation likely proceeds via several cooperative/redundant mechanisms. Calcium in-duces (*B*) cell proliferation and (*C*) bone morphogenetic protein-2 expression in human mesen-chymal stem cells (hMSCs) treated with Ca^{21}-enriched medium as compared with controlmedium. *p < 0.05; **p < 0.01; and ***p < 0.001. ([*A*] *From* Boonrungsiman S, Gentleman E, Car-zaniga R, et al. The role of intracellular calcium phosphate in osteoblast-mediated bone apatiteformation. Proc Natl Acad Sci U S A 2012;109(35):14174, with permission; and [*B*, *C*] *Adaptedfrom* Barradas AM, Fernandes HA, Groen N, etal. A calcium-induced signaling cascade leadingto osteogenic differentiation of human bone marrow-derived mesenchymal stromal cells. Bio-materials 2012;33(11):3206–8, with permission.)

Table 2
List of representative commercially available calcium orthophosphate cements

Commercial Name Formulations	Product Name	Applications
Biopex 75 wt% a-TCP, 18 wt% TTCP, 5 wt% DCPD and 2 wt% HA	Apatite Mitsubishi Materials (Tokyo, Japan)	Bone defect repair, reinforcement of orthopedic screws and implants, filling gaps between cement-less artificial joints and bone
Norian SRS MCPM 1 a-TCP 1 $CaCO_3$	Apatite DePuy Synthes (Welwyn Garden City, United Kingdom)	Skeletal distal radius fractures, craniofacial
BoneSource TTCP (73%), DCPD (27%)	Apatite Stryker-Leibinger (Kalamazoo, MI)	Craniofacial
ChronOS b-TCP (73%), MCPM (21%), $MgHPO_4\$3H_2O$ (5%)	Brushite DePuy Synthes (West Chester, PA)	Metaphyseal bone defects, cranioplasty, onlay augmentations in the craniomaxillofacial area
a-BSM ACP (50%), DCPD (50%)	Apatite ETEX (Cambridge, MA)	Filling of bone defects and voids, dental, craniofacial
Cementek a-TCP, TTCP	Apatite Teknimed (Vic-en-Bigorre, France)	Filling of bone defects
Biocement D 58% a-TCP, 24% DCPA, 8.5% $CaCO_3$, 8.5% calcium-deficient HA	Apatite Merck (GER) Biomet (Darmstadt, Germany)	Filling of bone defects in maxillary surgery
Mimix TTCP, a-TCP	Apatite Walter Lorenz Surgical (Jacksonville, FL)	Bony contouring of craniofacial skeleton, craniotomy cuts
Calcibon a-TCP, DCPA, CaCO3, HA	Carbonated Biomet Inc apatite (Warsaw, IN)	Filling of noninfected, metaphyseal, cancellous bone defects

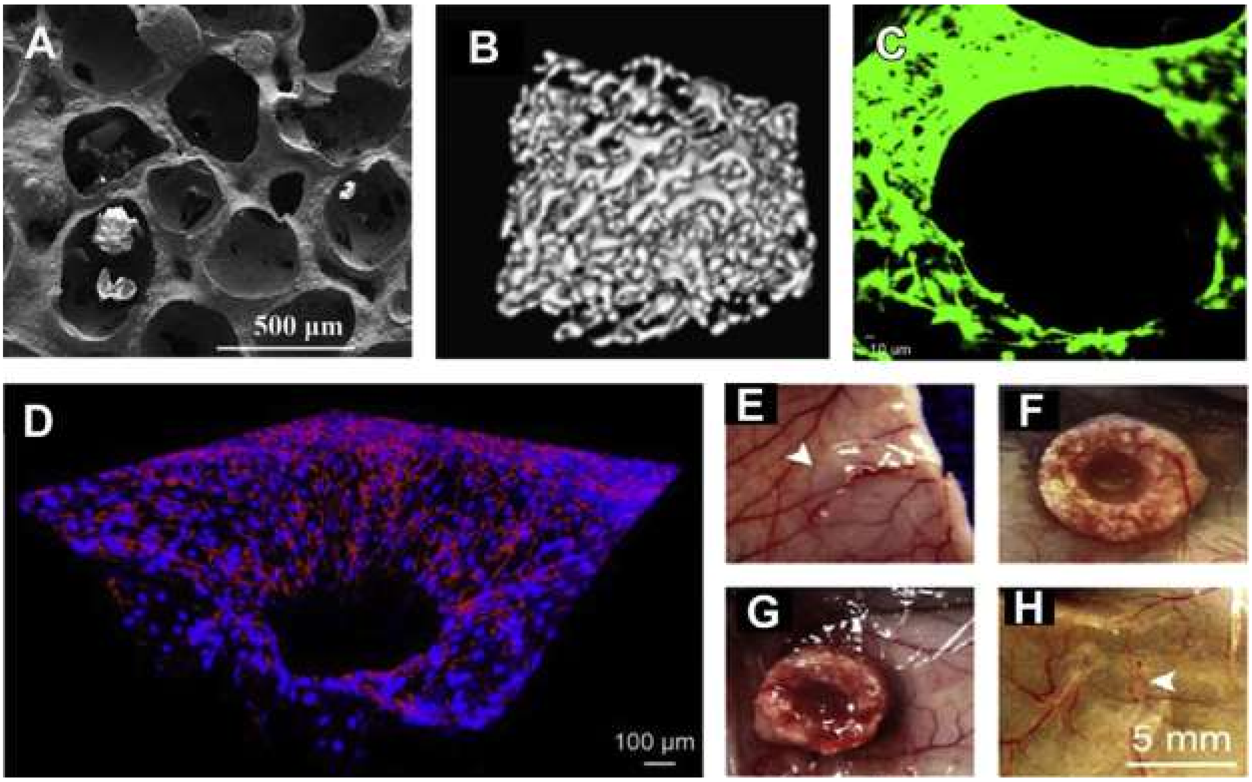


Fig. 10. Porous b-TCP scaffolds with angiogenic and osteogenic potentials. (*A*) Representative scanning electron microscopic image illustrating the 3D porous architecture of b-TCP scaffold. (*B*) Microcomputed tomography images showing interconnected pores of scaffold in 3D. (*C*)Fluorescent image showing the robust proliferation of human umbilical vein endothelial cells(HUVEC) after 7 days ofculture. (*D*) Immunofluorescentimage depicting the endothelium-lined microchannels of collagen-infiltrated, macroporous b-TCP scaffold. (*E–H*) Photographsshowing the subcutaneous implantation of four types of implants: collagen/HUVEC (*E*), collagen/HUVEC/b-TCP (*F*), collagen/channel/b-TCP (*G*), and collagen/channel b-TCP-based grafts in nude mice (*H*). *White arrows* depicts the collagen gels. (*From* [*A–C*] Kang Y, Kim S, Fah- renholtz M, et al. Osteogenic and angiogenic potentials of monocultured and co-cultured hBMSCs and HUVECs on 3D porous b-TCP scaffold. Acta Biomater 2013;9(1):4909, with permis- sion; and [*D–H*] Kang Y, Mochizuki N, Khademhosseini A, et al. Engineering a vascularizedcollagen-b-tricalcium phosphate graft using an electrochemical approach. Acta Biomater 2015;11:453–5, with permission.)

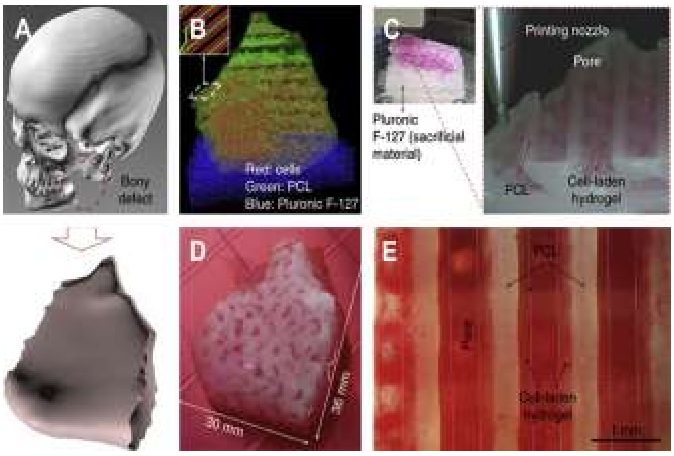


Fig. 11. 3D bioprinted human-scale mandible and calvarial bone constructs. (*A*) 3D computer- aided design model of mandible bony defect obtained by converting the medical computed tomography scan data

(*B*) Visualized motion program depicting the required dispensingpaths of cell-laden hydrogel (*red*); a mixture of PCL and tricalcium phosphate (*green*) as a scaffold; and Pluronic F127 (*blue*), which is used as a temporary support structure. (*C*) 3D patterning of cell-laden hydrogel on PCL platform. (*D*) Macroscopic image of the 3D-printedmandible bone defect construct, grown in osteogenic medium for 28 days. (*E*) Alizarin red Sstaining indicates terminal osteogenic induction and mineral deposition in human amniotic fluid–derived stem cell. (*From* Kang HW, Lee SJ, Ko IK, et al. A 3D bioprinting system to pro-duce human-scale tissue constructs with structural integrity. Nat Biotechnol 2016;34(3):314; with permission.) biocompatibility that make them ideal for restorative dental applications. Advancements in biomaterials research have led to the development of newer materials with enhanced properties and improved clinical outcomes [4-6].

IV. TISSUE ENGINEERING

Tissue Engineering has emerged as a promising approach for repairing, restoring, reconstructing, replacing, and/or regenerating missing and/or damaged tissues in the cranio- maxillo-facial complex, both intra- and extra-orally. This field combines biomaterials, cells, and growth factors to create scaffolds and promote the repair and regeneration of defective tissues [7,8].

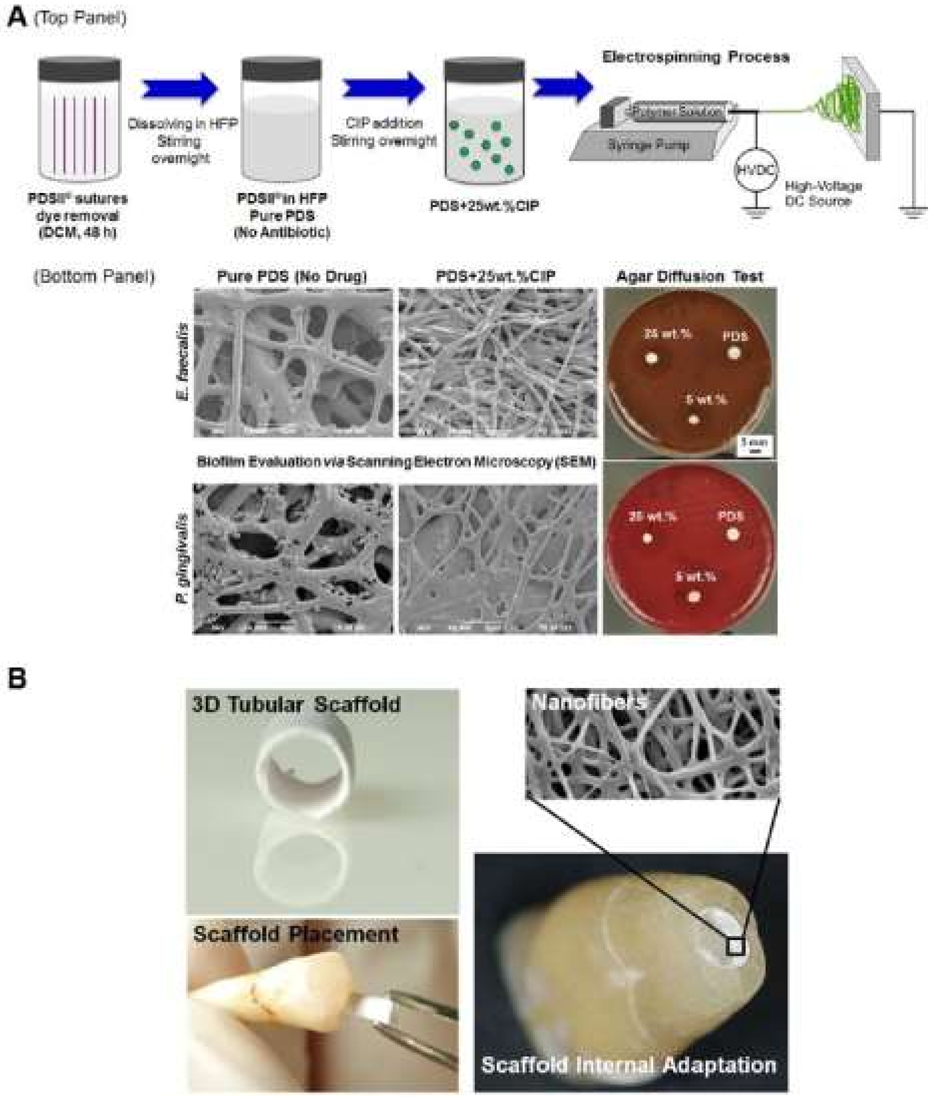


Figure 12. Summarized schematic of nanofibrous antibiotic-containing scaffolds (*e.g.*, ciprofloxacin [CIP]) processed *via* electrospinning and antimicrobial effects. (A) (top panel)FDA-approved polydioxanone suture filaments were used (PDS II®, Ethicon, Somerville, NJ, USA). First, the violet color of filament sutures is removed by immersion in dichloromethane. Then, the cleared PDS filaments are dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol (HFP, Sigma-Aldrich, St. Louis, MO, USA) at optimized concentration under stirring conditions. CIP- containing PDS solution is prepared by the addition of CIP at a known concentration, beingmixed together under vigorous stirring. (bottom panel) Representative

scanning electron microscopy (SEM) micrographs showing the antimicrobial effects of antibiotic-containing PDS- based electrospun scaffolds on bacterial growth. Representative macrophotographs of the agar diffusion test show growth inhibition of *E. faecalis* and *P. gingivalis*) (adapted with permission from Bottino *et al.*, 2013). (B) Potential clinical application of a three-dimensional (3D) tubular scaffold produced via electrospinning. Electrospun scaffolds can be fabricated in a cylindrical shape simulating the tubular and parallel format of immature root canals, making it easy to place and adapt into the root canal. Inset shows the nanofibrous structure of the 3D scaffold.

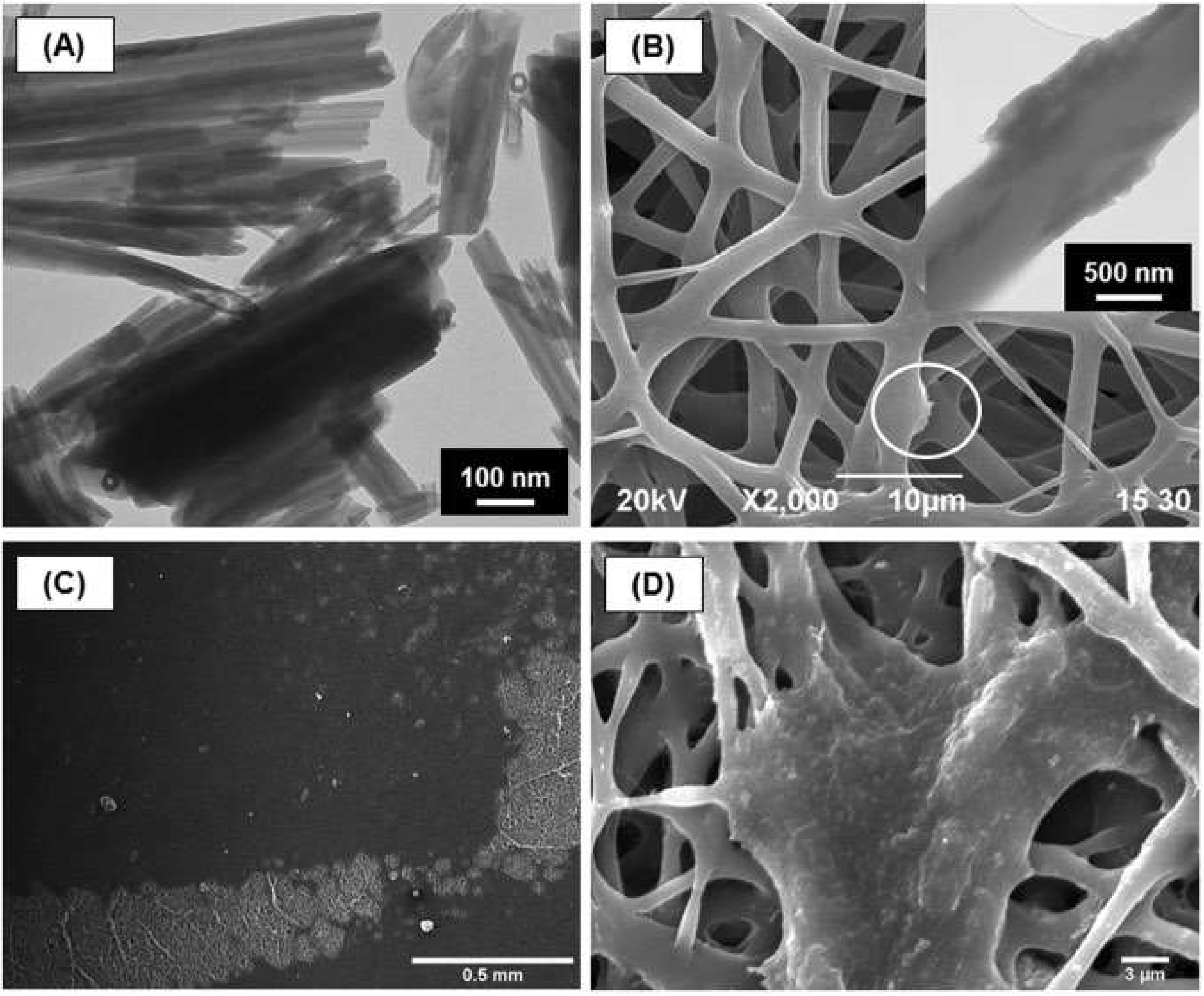


Figure 13. Polymer nanocomposite electrospun scaffolds synthesized with aluminosilicate clay nanotubes. (A) Representative transmission electron microscopy (TEM) micrograph of aluminosilicate clay Halloysite nanotubes (HNTs). (B) Representative scanning electron microscopy (SEM) micrograph of electrospun HNT-incorporated nanofibrous scaffolds. (inset) Representative TEM micrograph of HNTs protruding from the fiber structure. (C-D) Representative SEM micrographs showing the interaction between human-derived dental pulp fibroblast cells and PDS-HNT fibrous scaffolds (adapted with permission from Bottino *et al.*, 2014b).

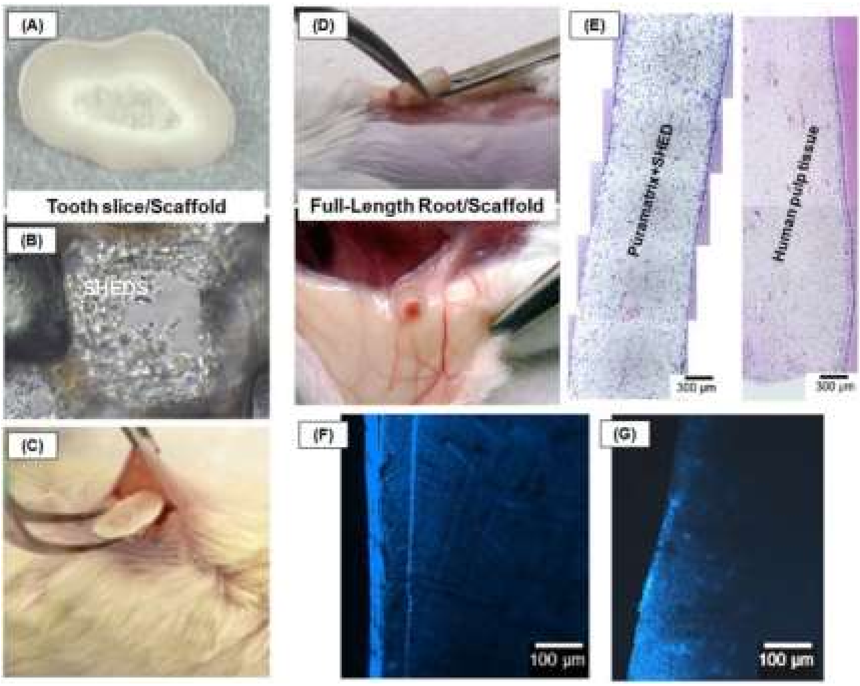


Figure 14. Summarized schematic of the (A-C) tooth slice and (D-G) full-length root/scaffold models. (A) Tooth slice provided from the cervical third of a human third molar with a highly porous PLLA scaffold placed within the pulp chamber. (B) SHED proliferation intothe tooth slice/scaffold. (C) Insertion of a tooth slice and scaffold containing SHED into the subcutaneous space of the dorsum of an immunodeficient mouse. (D) Subcutaneous transplant of a human full-length root injected with hydrogel-based nanofibrous scaffoldscontaining SHEDs. (E) Photomicrographs of the engineered pulp-like tissue and human pulp tissue (control) in the root canal. (F) Layer of dentin formation after pulp tissue induction in PuraMatrix+SHEDs.(G) Dentin slice with no SHEDs (adapted with permission from Sakai*et al.*, 2011; Casagrande *et al.*, 2011; Rosa *et al.*, 2013).

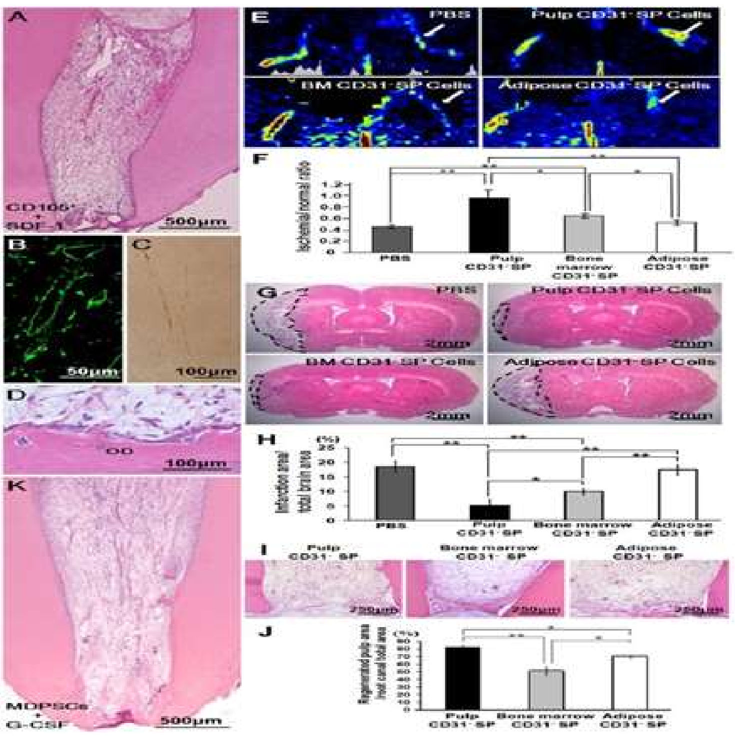


Figure 15. Clinical evidence of dentin-pulp complex regeneration. (A-D) Complete regeneration of pulp tissue after autologous transplantation ofCD105^{+} cells with SDF-1 in the pulpectomized root canal in dogs.

(B) Immunostaining with BS-1 lectin. (C) Immunostaining with PGP 9.5. (D) Odontoblastic cell lining to newly formed osteodentin/tubular dentin(OD), along with the dentinal wall. (E, F) Neovascularization in the ischemic hindlimb model 14 days after transplantation of pulp, bone marrow, and adipose-derived $CD31^-$ side-population (SP) cells. (E) Laser Doppler imaging. (F) Quantification of blood flow in mouse ischemic hindlimbs ($n = 4$ in each group). (G, H) Infarct area on day 21 afterinjection of PBS, pulp, bone marrow, and adipose $CD31^-$ SP cells. (H) Reduction of the infarct volume 21 days after injection ($*p < .05$, $**p < .01$). (I, J) Ectopic pulp regeneration 28 days after transplantation of pulp, bone marrow, and adipose-derived $CD31^-$ SP cells into porcinetooth root. (J) Ratio of regenerated pulp area to root canal area. Data areexpressed as means ± SD of 5 determinations. $*p < .05$, $**p < .01$.(K) Complete regeneration of pulp tissue after autologous transplantation of mobilized dental pulp stem cells (MDPSCs) with G-CSF in the pulpectomized root canal in dogs (adapted with permission from Iohara*et al*., 2011; Ishizaka *et al*., 2013; Iohara *et al*., 2013).

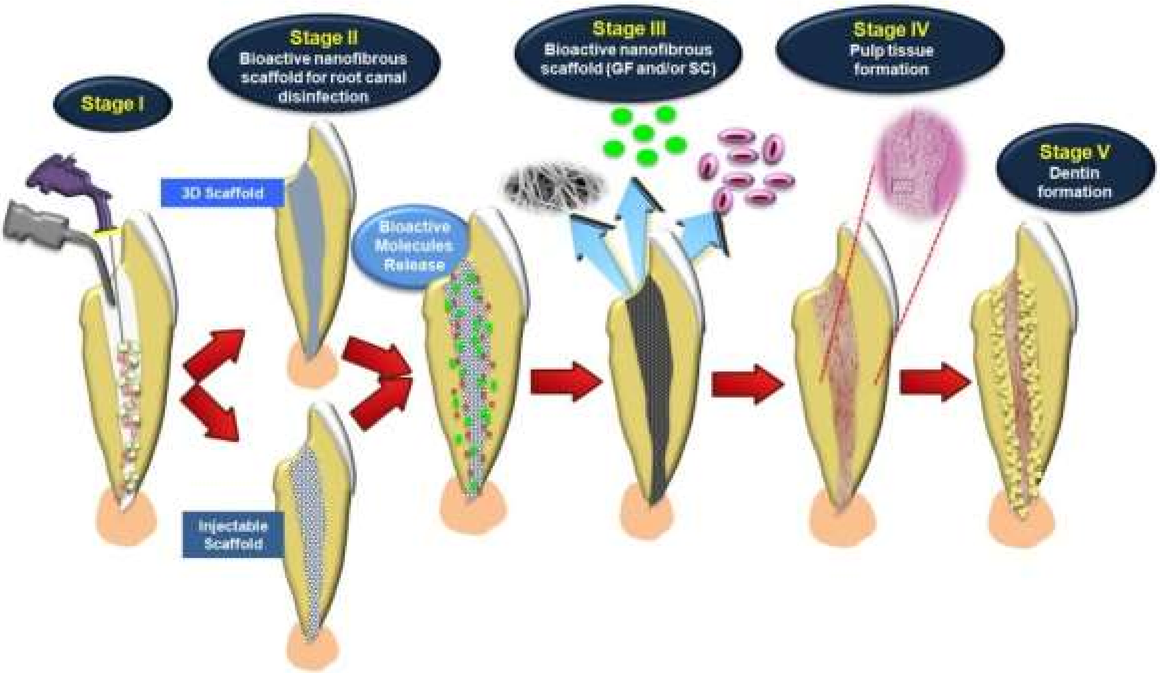


Figure 16. Tissue-engineering-based strategies for regenerative endodontics in immature teeth. Strategies have included the incorporation of (i) therapeutic agents, such as antimicrobial drugs to be released and promote root canal disinfection, as well as (ii) bioactive molecules that can trigger stem cell differentiation to aid in regeneration of the pulp-dentin complex. Stage I: Disinfection of the root canal using irrigant solutions. Stage II: Bioactive nanofibrous scaffold with antibiotics as intracanal medication. Stage III: Nanofibrous scaffold with growth factors and/or stem cells. Stage IV: Pulp tissue formation. Stage V: Dentin formation. (Histology of pulp-like tissue formation, adapted with permission from Rosa et al., 2013.

Dental tissue engineering is one sub-area where significant progress has been made, withpromising results in bone and cartilage regeneration, as well as salivary gland regeneration [7-9]. One recent study published in the journal Biomaterials Science has shown that a combination of hydroxyapatite and graphene oxide can enhance the osteogenic differentiation of stem cells for bone regeneration [10]. Another study published in the Journal of Dental Research has shown that a collagen scaffoldloaded with bone morphogenetic protein-2 can promote periodontal regeneration by enhancing the attachment and proliferation of periodontal ligament cells [11]. In addition todental tissue engineering, recent studies have also explored tissue engineering for soft tissues in the cranio-maxillo-facialcomplex. One study published in the Journal of Craniofacial Surgery has shown that a combination of adipose-derived stem cells and platelet-rich plasma can be used to promote the regeneration of soft tissues in the face [12]. Anotherstudy published in the Journal of Tissue Engineering and Regenerative Medicine has demonstrated the potential ofa de-cellularized extra-cellular matrix scaffold to promote the regeneration of oral mucosa [13]. Furthermore, tissue engineering has shown promise in the regeneration of hard tissues beyond the teeth and bone. For example, one recent study published in the Journal of Tissue Engineering and Regenerative Medicine has shown that a combination of a bonesubstitute material and dental pulp stem cells can be used toregenerate mandibular condylar defects [14].

V. BIOFILM

Biofilm formation on dental implants is a major cause of implant failure and peri-implantitis [16]. To overcome this issue, new strategies have been and are being developed to prevent biofilm formation on titanium (Ti) implant surfaces,such as the use of anti-microbial coatings (including silver- and copper-based nanoparticles) [16,17]. Indeed, the useof anti-microbial coatings has shown promising results in inhibiting bacterial adhesion and growth. For instance, a recent study investigated the use of a silver nanoparticle coating on Ti implant surfaces to prevent biofilm formation and found that the coating was effective in inhibiting bacterial attachment and biofilm formation [18]. Anotherstudy evaluated the use of a polymer coating containing chlorhexidine, a broad-spectrum antimicrobial agent, on Ti implant surfaces and demonstrated a significant reductionin bacterial adhesion and biofilm formation [19]. In additionto anti-microbial coatings, other strategies such as the useof probiotics and prebiotics have also been investigated to prevent biofilm formation. A recent study explored the use ofa probiotic bacterial strain, Streptococcus salivarius K12, to inhibit the growth of pathogenic bacteria on implant surfacesand found that it significantly reduced biofilm formation [20]. Another study investigated the use of prebiotics, specifically oligosaccharides, to promote the growth of beneficial bacteria on implant surfaces, which in turn reduced the growth of pathogenic bacteria and biofilm formation [21]. Henceforth, these current and emerging strategies do show promise in preventing biofilm formation and reducing the risk of peri- implantitis and Ti implant failure. Ongoing research and innovation efforts aim to further optimize these approaches and develop new strategies to improve implant success rates.

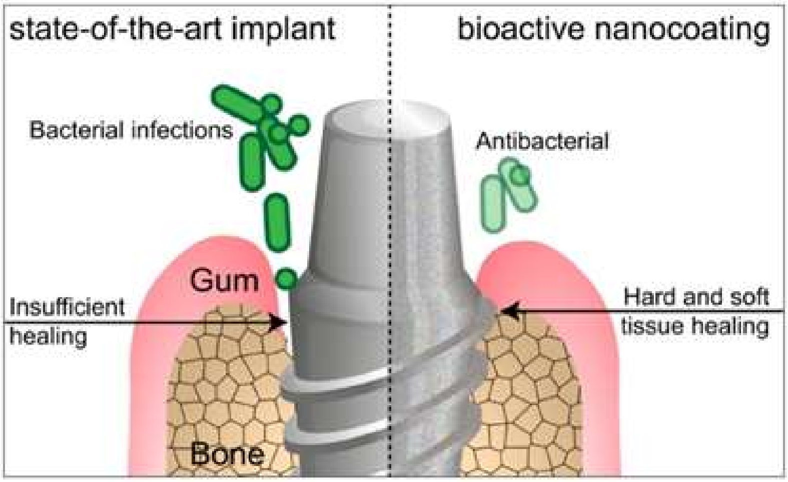


Figure 17: Bioactive nanocoating to reduce incident of periimplantitis

VI. BIOSENSING

Bioimaging technologies have advanced significantly in recent years, offering new opportunities to improve oral anddental health care. Biosensors are one such technology that canbe used to detect and monitor specific biomolecules in salivaor oral fluids, enabling the early diagnosis and management of oral and dental diseases [22]. For instance, researchers have developed biosensors to detect periodontitis-associatedbacteria such as Porphyromonas gingivalis, Aggregatibacter actinomycetemcomitans and Tannerella forsythia in saliva and plaque samples [22-25]. These biosensors utilize specific recognition elements such as antibodies, aptamers, or enzymes to capture the target bacteria and generate a measurable signal. Similarly, biosensors have also been developed to detect oral cancer biomarkers in saliva, such as matrix metalloproteinase-8 and -9, and carcinoembryonicantigen [26,27]. These biosensors can provide a non-invasiveand cost-effective alternative to traditional methods of oral cancer diagnosis, which often require invasive biopsies. In addition to biosensors, bioimaging techniques such as opticalcoherence tomography (OCT) and confocal microscopy can provide high-resolution images of oral and dental tissues, aiding in the diagnosis of various oral pathologies. For example, OCT has been used to visualize the enamel and dentin structures of teeth, as well as to identify the depth and extent of caries lesions [28,29]. On the other hand, confocal microscopy has been used to study the structure and function of biofilms formed on dental surfaces, revealingnew insights into the complex interactions between bacteriaand host tissues [30]. Taken together, such current and emerging bioimaging technologies will considerably improve diagnosing and managing diseases in the oral, dental, and cranio-maxillo-facial tissues, for better patient outcomes

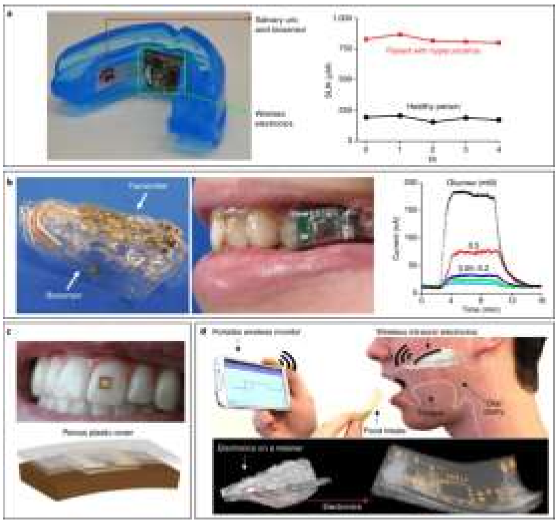


Figure18: Biosensor in dentistry.

VII. TELE-DENTISTRY

The COVID-19 pandemic has accelerated the adoption of teledentistry, allowing dental providers to provide virtual consultations and care. Tele-dentistry, nonetheless, is an emerging trend that is changing the way dental care is delivered. With teledentistry, patients can access dental care remotely, allowing for greater convenience and improved access to care [31]. Tele-dentistry can also improve patient outcomes by providing faster access to care, reducing the need for travel, and allowing for more frequent monitoring of oral health; while minimizing the risk of infection.Indeed, several studies have noted that teledentistry could be particularly useful for patients with complex conditions who require frequent monitoring and follow-up. Moreover, teledentistry can improve the efficiency of dental practices, allowing dentists to see more patients and improve their bottom line [32].

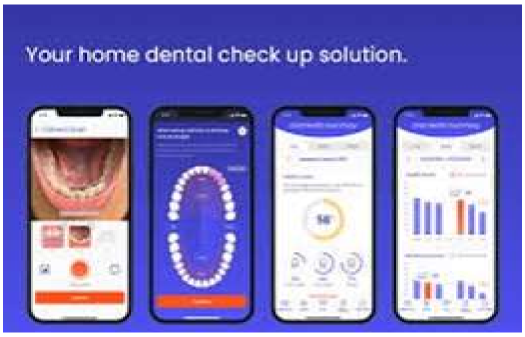
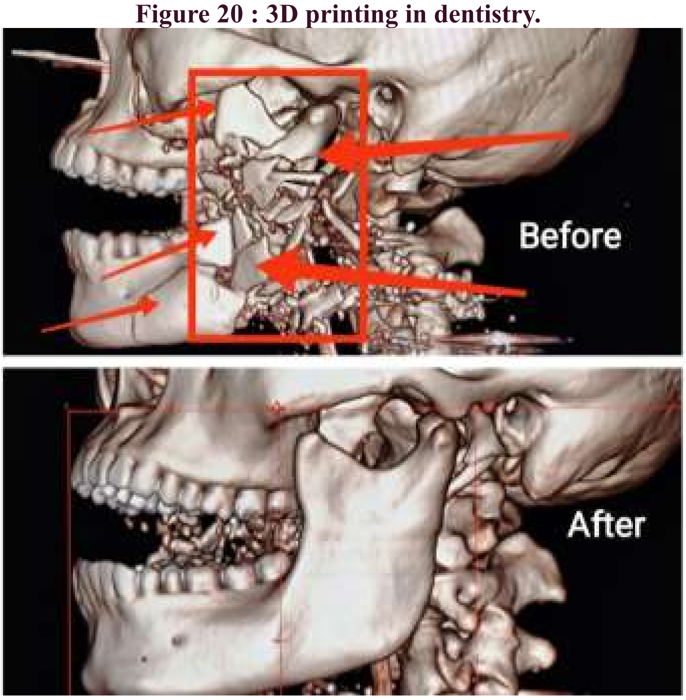


Figure19: Tele dentistry

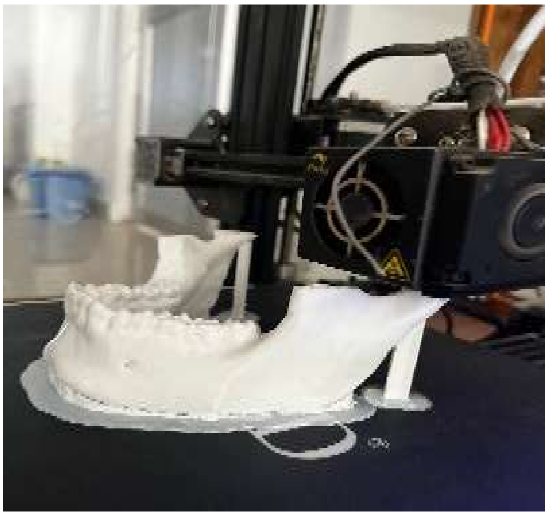
VIII. 3D PRINTING

3D printing technology has revolutionized the field ofdentistry, allowing for the rapid production of custom dentalimplants, crowns, and other devices [33]. 3D printing is transforming how we practice dentistry by allowing for the rapid production of custom dental implants and crowns. With 3D printing technology, dentists can create precise, customized dental restorations that fit the unique needs of each patient [34]. Additionally, 3D printing technology allows for faster turn-around times, reducing the time patient’s chair side time. Recent studies have demonstrated the potential of 3D printing technology in various oral, dental, and cranio- maxillo-facial applications. For instance, one study reported the successful use of 3D printing technology in the fabrication of implant-supported fixed dental prostheses with improved accuracy and efficiency compared to traditional methods [35] .Another study reported the successful use of 3D printing technology in the fabrication of custom surgical guides for dental implant placement [36]. Furthermore, researchers evaluated the accuracy and efficiency of 3D printing technology in the fabrication of customized mandibular reconstruction plates for patients with mandibular defects. Herein, the study found that 3D printing technology provided an accurate and efficient method for producing customized plates that fit the needs of individual patients [37]. Last but not least, others reported on the successful use of 3D printing technology in the fabrication of custom-made implants for patients with complex craniofacial defects [38]. Altogether, such accruing studies and recent scoping literature reviews tend to further highlight the potential capabilities of 3D printing technology in various oral, dental, and cranio- maxillo-facial applications, including dental prostheses, surgical guides, and custom-made implants. 3D printing technology is expected to continue to advance, allowing for greater precision, efficiency, and customization in/for dental and cranio-maxillo-facial treatments.

Figure 20 : 3D printing in dentistry.



21 Figure A. 3D reconstruction CT Scan by AI.



21 Figure B. 3D printing of the mandible,using additive layer printing .

21 Figure C. 3D printed mandibular model for surgical planning.

IX. LASERS

Lasers have become an increasingly popular tool in dentistry due to their precision and minimally invasive nature.There are several types of lasers used in dentistry, includingdiode, carbon dioxide, and erbium: yttrium-aluminum- garnet (Er: YAG) lasers [39]. Laser technology can be used ina variety of dental procedures, including cavity removal, gumdisease treatment, teeth whitening, and oral surgery. Laser therapy offers several advantages over traditional techniques,including reduced bleeding, swelling, and discomfort, as wellas faster healing times. Additionally, lasers can be used for more precise and conservative treatment, preserving more ofthe healthy tooth structure or gum tissue [40]. As technologycontinues to advance, more dental procedures will be using lasers, providing our patients with even better treatment outcomes.

X. ORAL SURGERY AND CRANIO-MAXILLO-FACIAL APPLICATIONS

Computer-aided design and manufacturing (CAD/ CAM) has also been applied in oral surgery, particularly in cranio-maxillo-facial procedures [41,42]. Using CAD/CAM technology, surgeons can create precise 3D models of surgeries, reduce the risk of complications, and lead to betterfunctional and aesthetic outcomes for patients. Additionally,3D printing technology can be used to create patient-specificimplants for cranio-maxillo-facial reconstruction, which can improve the fit and stability of the implant and reduce the risk of complications. The use of digital technologies in oral and cranio-maxillo-facial surgery is expected to continue to expand in the coming years, with the potential to revolutionizethe field and improve patient outcomes [42,43].

XI. NANO DENTISTRY AND CONTROLLED DRUG DELIVERY

Nanotechnology has been utilized in various fields of medicine, including dentistry, to develop new materials and drug delivery systems with enhanced properties. Nanotechnology involves the use of particles that are smallerthan 100 nanometers in size [44]. In dentistry, nanotechnology can be used to create materials with enhanced properties, such as improved strength, durability, and anti-microbial activity. Nanoparticles can also be used to deliver drugs or other therapeutic agents directly to the affected area, providing targeted and more effective treatment [44,45]. Likewise, controlled drug delivery systems are designed to deliver drugs to specific target sites in a controlled and sustained manner. In dentistry, controlled drug delivery can be used (gels, films, etc...) for a range of applications, including pain management, anti-microbial treatment, and tissue regeneration. These systems can be designed to releasedrugs locally at a specific rate and duration, reducing the riskof adverse effects and improving treatment outcomes [45].

XII. CONCLUSION

New technologies has had major impact on dentistry, from artificial intelligence, virtual reality, advance biomimetics restorative materials. Tissue engineering, 3D printing, laser, nanodentistry and drug delivery system has lots of potential to clinically benits the patient's treatment outcome for treatment of intra-osseous periodontal defects, enhanced maxillary and mandibular grafting procedures, promote more rapid wound healing of oral wounds and ulcers, Advancement in these technologies have the great potential to improve patient's treatment outcome, reduce treatment cost and increase access to dental and oral health care, it will be really interesting to witness the great evolving trend of dental surgery in the future.

REFERENCES

1. Schwendicke F, Krois J, Gomez J. Artificial intelligence in dentistry: chances and challenges. J Dent Res 2021;100(1):9-14.
2. Zecha JAEM, Raber-Durlacher JE, Nair RG. Detection and diagnosis of oral cancer: artificial intelligence and new technologies. J Oral Pathol Med. 2019; 48(10):771-777.
3. Liu Y, de Groot JF, Klar RM. Biomaterials for craniofacial boneregeneration. J Dent Res. 2018; 97(5):506-515.
4. Poggio C, Lombardini M, Dagna A. Ceramics and composite resins indentistry: a review of types and clinical applications. Materials (Basel). 2021; 14(2):382. doi:10.3390/ma14020382
5. Aggarwal H, Jain V, Shivakumar S, Singh RD, Sharma V. Bioactive glass in dentistry: a review. J Clin Diagn Res. 2017; 11(9):ZE06-ZE09. doi:10.7860/JCDR/2017/29448.10559
6. Heintze SD. Clinical relevance of testing bonding performance of adhesive systems. Dent Mater. 2013; 29(4):e100-e124. doi:10.1016/j.dental.2013.01.004.
7. Hutmacher DW. Scaffolds in tissue engineering bone and cartilage. Biomaterials. 2000 Dec;21(24):2529-43. doi: 10.1016/s0142-9612(00)00121-6. PMID: 11071603.
8. Albuquerque MT, Valera MC, Nakashima M, Nör JE, Bottino MC. Tissue-engineering-based strategies for regenerative endodontics. J Dent Res. 2014 Dec;93(12):1222-31. doi: 10.1177/0022034514549809. Epub 2014 Sep 8. PMID: 25201917; PMCID: PMC4237634.
9. Chien CH, Ho HO, Chen YJ. Biomaterials for salivary gland tissue engineering. J Dent Res. 2020; 99(7):714-722. doi:10.1177/0022034520924758.
10. Gao C, Liu Y, Yuan Z, Li L, Zhang Y, Chen X, Zhang X. Hydroxyapatite/graphene oxide composite scaffolds for enhanced osteogenic differentiation of stem cells for bone regeneration. Biomaterials Science. 2021; 9(3): 1053-1063.
11. Kim JY, Lee J, Lee SH, Choi SH. Collagen scaffolds loaded with bone morphogenetic protein-2 promote periodontal regeneration by enhancing attachment and proliferation of periodontal ligament cells.Journal of Dental Research. 2021; 100(1): 79-87.
12. Lee SH, Kim YJ, Lee JW, Kim KT, Park JC, Cho DW. Adipose-derivedstem cells and platelet-rich plasma for soft tissue regeneration inthe craniofacial region. Journal of Craniofacial Surgery. 2020; 31(4): e3Lee H, Lee JY, Jeong YJ, Kim BS, Kim SW. Regeneration of oral mucosa with a decellularized extracellular matrix scaffold. Journal of Tissue Engineering and Regenerative Medicine. 2020; 14(6): 889-897.
13. Chen Y, Zhang Z, Wang X, Jiang Y, Zhang X, Liu H, Xu B. Bone substitute material loaded with dental pulp stem cells for regenerationof mandibular condylar defects. Journal of Tissue Engineering and Regenerative Medicine. 2021; 15(5): 483-492.
14. Albrektsson T, Johansson C, Johansson LA, Sennerby L. Bioactive glass implants in the temporomandibular joint: An experimental studyin rabbits. Journal of Oral Rehabilitation. 2020; 47(7): 857-865.
15. Schwarz F, Herten M, Sager M, Wieland M, Dard M, Becker J.Risk factors of plaque formation at the implant-abutment interface:a prospective study. J Periodontol. 2010; 81(10):1517-1523. doi:10.1902/jop.2010.100226.
16. Kulkarni M, Mazare A, Schmuki P, Iglič A. Antibacterial and bioactive implant coatings. Mater Sci Eng R Rep. 2017; 119:1-27. doi:10.1016/j.mser.2017.
17. Chen C, Chen X, Zhang Y, Lu X, Zhang L, Cheng Y. Silver nanoparticlecoating on titanium implant surfaces inhibits bacterial adhesion and biofilm formation. Journal of Materials Science and Technology. 2021;69: 1-10.

18. Posa F, Di Stefano DA, Abdallah MN, Bortolini S, Martini D, Nocini PF.Chlorhexidine-containing polymer coating on titanium implant surfaces reduces biofilm formation in vitro. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 2021; 109(5): 538- 546.
19. Ricci S, Terrer E, Peralbo-Molina Á, Manzanares-Céspedes MC, Viñas M, Álvarez M. The use of probiotic bacteria to inhibit the growth of pathogenic bacteria and biofilm formation on dental implantsurfaces. Journal of Applied Microbiology. 2021; 131(6): 2824-2834.
20. Agarwal A, Weisgerber DW, Chen X, Tannenbaum R. Oligosaccharide-based prebiotic treatment of dental implants reduces pathogenicbacteria and biofilm formation. ACS Applied Materials & Interfaces. 2021; 13(7): 8993-9003.
21. 21.Xu H. Biosensors for Estai M, Bunt S. Best practices and recommendations for teledentistryduring COVID-19: a systematic review.
22. JDR Clin Trans Res. 2021; 6(3):256-268.
23. Vandenbulcke J, Van Bael MJ, Kruth JP. Additive manufacturing of dental materials: A review. Materials Science and Engineering C. 2021; 121:111821.
24. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. Int J Dent. 2014;2014:783948. doi: 10.1155/2014/783948. Epub 2014 Apr 8. PMID: 24817888; PMCID: PMC4000974.
25. Duraccio D, Mussano F, Faga MG. Biomaterials for dental implants: current and future trends. J Mater Sci. 2015; 50(14):4779-4812. doi:10.1007/s10853-015-9059-0.
26. Ahuja B, Mathur VB, Kaur G, Sandhu M, Kaur H. A review of 3D printing techniques and its applications in dental implants. J Oral Biol Craniofac Res. 2021; 11(1):1-7. doi:10.1016/j.jobcr.2020.07.003.
27. Alharbi N, Wismeijer D, Osman RB. Additive Manufacturing Techniquesin Prosthodontics: Where Do We Currently Stand? A Critical Review.Int J Prosthodont. 2017 September/October;30(5):474–484. doi: 10.11607/ijp.5079. Epub 2017 Jul 27. PMID: 28750105.
28. Zandinejad A, Atai M, Pahlavanpour M. Applications of 3D printing inDentistry: A review of literature. Rapid Prototyping J. 2016; 22(5):611-623. doi:10.1108/RPJ-07-2014-0086.
29. Fortin T, Isidori M, Bouchet H. Digital technologies in implant dentistry.Journal of prosthodontic research. 2015; 59(1): 34-46.
30. Li W, Sun YC, Li Q, Chen J. Application of computer-aided design andmanufacturing (CAD/CAM) in oral and maxillofacial surgery. Journal of International Medical Research. 2019; 47(5): 1855-1866.
31. Liu Y, de Groot JF, Klar RM. Biomaterials for craniofacial boneregeneration. J Dent Res. 2018; 97(5):506-515.
32. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. Int J Dent. 2014;2014:783948. doi: 10.1155/2014/783948. Epub 2014 Apr 8. PMID: 24817888; PMCID: PMC4000974.
33. Lee H, Lee SW. Controlled drug delivery systems for oral cancer treatment: current status and future perspectives. Pharmaceutics. 2020; 12(6):532.
34. Gupta AK, Gupta M. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. Biomaterials. 2005 Jun;26(18):3995-4021. doi: 10.1016/j.biomaterials.2004.10.012. PMID: 15626447.
35. Ahmed TA, Aljaeid BM. Preparation, characterization, and potential application of chitosan, chitosan derivatives, and chitosan metal nanoparticles in pharmaceutical drug delivery. Drug Des Devel Ther. 2016 Jan 28;10:483-507. doi: 10.2147/DDDT.S99651. PMID: 26869768; PMCID: PMC4734734.
36. Pilloni A, Pompa G, Cattabriga M, Palma SD, Campus G. Chitosan nanoparticles for periodontal pathogens. A systematic review. European Journal of Clinical Investigation. 2019; 49(10):e13142.
37. Gaharwar AK, Peppas NA, Khademhosseini A. Nanocomposite hydrogels for biomedical applications. Biotechnol Bioeng. 2014 Mar;111(3):441-53. doi: 10.1002/bit.25160. Epub 2013 Dec 6. PMID:24264728; PMCID: PMC3924876.
38. Lu M, Xia L, Zhou L, Zheng X, Jiang X, Kong L. Enhanced bone regeneration with BMP-2 loaded functionalized nanoparticle-hydrogel complex. Journal of Materials Chemistry B. 2017; 5(16):3034-44.
39. Gaharwar AK, Peppas NA, Khademhosseini A. Nanocomposite hydrogels for biomedical applications. Biotechnol Bioeng. 2014 Mar;111(3):441-53. doi: 10.1002/bit.25160. Epub 2013 Dec 6. PMID:24264728; PMCID: PMC3924876.
40. Lu M, Xia L, Zhou L, Zheng X, Jiang X, Kong L. Enhanced bone regeneration with BMP-2 loaded functionalized nanoparticle-hydrogel complex. Journal of Materials Chemistry B. 2017; 5(16):3077
41. Li W, Sun YC, Li Q, Chen J. Application of computer-aided design andmanufacturing (CAD/CAM) in oral and maxillofacial surgery. Journal of International Medical Research. 2019; 47(5): 1855-1866.
42. Liu Y, de Groot JF, Klar RM. Biomaterials for craniofacial boneregeneration. J Dent Res. 2018; 97(5):506-515.
43. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. Int J Dent. 2014;2014:783948. doi: 10.1155/2014/783948. Epub 2014 Apr 8. PMID: 24817888; PMCID: PMC4000974.
44. Lee H, Lee SW. Controlled drug delivery systems for oral cancer treatment: current status and future perspectives. Pharmaceutics. 2020; 12(6):532.
45. Gupta AK, Gupta M. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications. Biomaterials. 2005 Jun;26(18):3995-4021. doi: 10.1016/j.biomaterials.2004.10.012. PMID: 15626447.
46. Ahmed TA, Aljaeid BM. Preparation, characterization, and potential application of chitosan, chitosan derivatives, and chitosan metal nanoparticles in pharmaceutical drug delivery. Drug Des Devel Ther. 2016 Jan 28;10:483-507. doi: 10.2147/DDDT.S99651. PMID: 26869768; PMCID: PMC4734734.
47. Pilloni A, Pompa G, Cattabriga M, Palma SD, Campus G. Chitosan nanoparticles for periodontal pathogens. A systematic review. European Journal of Clinical Investigation. 2019; 49(10):e13142.
48. Gaharwar AK, Peppas NA, Khademhosseini A. Nanocomposite hydrogels for biomedical applications. Biotechnol Bioeng. 2014 Mar;111(3):441-53. doi: 10.1002/bit.25160. Epub 2013 Dec 6. PMID:24264728; PMCID: PMC3924876.
49. Lu M, Xia L, Zhou L, Zheng X, Jiang X, Kong L. Enhanced bone regeneration with BMP-2 loaded functionalized nanoparticle-hydrogel complex. Journal of Materials Chemistry B. 2017; 5(16):3034-44.
50. Gaharwar AK, Peppas NA, Khademhosseini A. Nanocomposite hydrogels for biomedical applications. Biotechnol Bioeng. 2014 Mar;111(3):441-53. doi: 10.1002/bit.25160. Epub 2013 Dec 6. PMID:24264728; PMCID: PMC3924876.
51. Lu M, Xia L, Zhou L, Zheng X, Jiang X, Kong L. Enhanced bone regeneration with BMP-2 loaded functionalized nanoparticle-hydrogel complex. Journal of Materials Chemistry B. 2017; 5(16):3077