FUTURISTIC TRENDS IN PERIODONTOLOGY

Abstract

The digitalization of dentistry and its specializations has brought about a revolution in today's dental practice. The digital revolution has ushered in a transformative era in period ontology, which is driven by advancements in technology. Digital workflows, intraoral scanners, 3D printing, and computer-aided design/computer-aided manufacturing (CAD/CAM) systems have streamlined treatment planning and enabled the fabrication of customized materials and scaffolds which help in the regeneration of tissues and bone with the help of precision medicine and minimally invasive procedures. Furthermore, Teleperiodontology has improved patient access to care and the integration of AI and Machine Learning in diagnosis and treatment decision-making shows promising outcomes.

Keywords: Periodontology, Digital Dentistry, Artificial Intelligence, Machine Learning, Technology.

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I. INTRODUCTION

Periodontology is a branch of dentistry that deals with the treatment of diseases related to supporting structures of the teeth. The supporting structures include gingiva, bone, cementum, periodontal ligament, and alveolar bone. With the constant advent of technology along with research and development (R&D), the way dentistry is practiced nowadays is evolving regularly. The future of periodontology is not only intriguing but also exciting and inspiring to get the latest technologies in day-to-day use. This chapter briefs about some of the latest innovations that are already in use in certain countries. Also, others that are under development or proposed and still need further Research &Development so that,there can be a widespread usage and hencehave been briefly described in this chapter. The potential futuristic trends in periodontology are listed below.

- Newer Regenerative Therapies
- Precision Medicine
- Minimally Invasive Procedures
- Digital Dentistry
- Teleperiodontology
- Microbiome-based therapies.
- Artificial Intelligence (AI) and Machine Learning (ML)
- Nanotechnology in Periodontology

II. NEWER REGENERATIVE THERAPIES

Conventional clinical therapy for Periodontal Disease is primarily focused on eradicating infectious sources and reducing inflammation to halt disease progression. However, this approach alone cannot achieve the regeneration of lost periodontal tissues. To address this limitation, regenerative periodontal therapies have emerged over the last two decades. These therapies include guided tissue regeneration (GTR), the use of enamel matrix derivatives, bone grafts, delivery of growth factors, and the combination of cells and growth factors with matrix-based scaffolds. These innovative approaches target the restoration of lost tooth-supporting tissues, such as the periodontal ligament, alveolar bone, and cementum, offering new possibilities for more effective periodontal tissue regeneration.

A combination of natural and synthetic materials biomaterials have been developed recently with a focus on the improvement of optimization of mechanical and degradation properties and incorporation of new functions of the biomaterials used for GTR. Materials like PCL+ β-TCP + CaP (Polycaprolactone,β- Tri Calcium Phosphate, Calcium Phosphate), Chitosan(Derivedfrom chitin)+β-TCP, Collagen + HA(Hydroxy apatite),PCL + HA, drugs like atorvastatin and metforminand growth factors like Platelet-derived Growth factor (PDGF), Fibroblast Growth Factor (FGF) and Bone morphogenetic proteins(BMP) etcetera have been used with varied success. The ongoing research in this area seeks to further enhance the effectiveness and outcomes of GTR by exploring the potential of these biomaterial combinations and their functionalities. By continuously advancing and optimizing these biomaterials, researchers aim to achieve better regenerative results in periodontal tissue engineering and treatment modalities. However, further investigation and studies are still underway to fully understand and harness the potential of these materials and their applications in GTR.

III. PRECISION MEDICINE

The concept of precision medicine in periodontology relies on the integration of clinical parameters and biological markers to accurately predict periodontal disease susceptibility, facilitate early diagnosis, determine prognosis, and develop effective and personalized treatment plans. While traditional periodontal diagnostics mainly rely on clinical and radiological parameters, they may offer limited guidance due to the intricate nature of periodontal pathology. As a step forward, biomarkers have been introduced in the new classification of periodontal and peri-implant conditions, heralding the advent of precision periodontics and a more targeted approach to patient care. This shift promises to enhance therapeutic outcomes and better cater to the unique needs of individual patients.

The hallmark of precision medicine is the convergence of diverse biomedical disciplines, including genetics, microbiology, immunology, biochemistry, histology, and pathology, with clinical practice. This integration results in a highly effective management strategy that addresses the complex nature of diseases targeted by precision medicine. To achieve this, a comprehensive assessment of a wide range of anamnestic, clinical, and biological parameters is required. These parameters are fed into machine learning algorithms, which can analyze vast amounts of data and identify critical determinants within specific patterns. The outcome is an accurate and easily interpretable diagnostic information pool, allowing for more precise and personalized treatment approaches. [2]

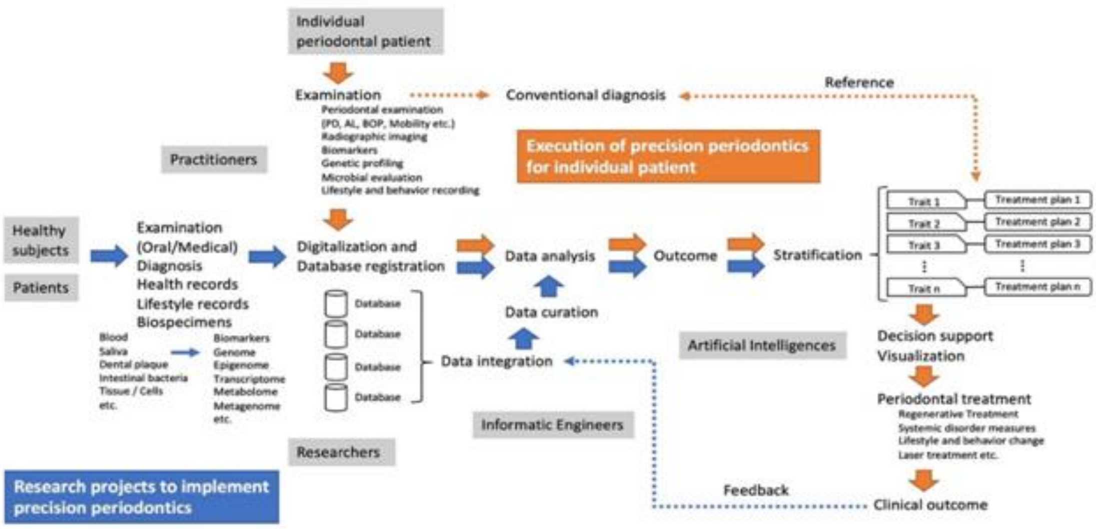

Figure 1: A flow diagram representing the steps to implement precision medicine, AI, ML [16].

IV. MINIMALLY INVASIVE PROCEDURES

The use of newer technologies in dentistry like the use of lasers, robotic surgeries, intra-oral scanning, and Cone Beam CT can help in better and more precise planning which helps in faster and better healing and improved patient outcomes.

The use of Soft tissue lasers for gingivectomy, gingivoplasty, and hard tissue lasers, sulcular debridement including removal of granulation tissue from bony defects, low-level laser therapy, and hard tissue lasers for sulcular debridement, osseous crown lengthening, osteoplasty, ostectomy, and osseous recontouring[3] can not only make the whole surgical procedure smoother, requires less time but also saves the hassles of conventional surgical technique and in most cases offers bloodless surgical field.

The use of intra-oral scanning and Cone Beam CT would help in accurate defect analysis and maybe this technology can be used to 3d scan, design, and print defect-specific scaffolds which can make the bone grafting and regeneration procedure much easier and predictable.

The use of robots for implant placement has already started in many countries with outstanding precision. However, robotics in periodontology and other fields still needs more research before its widespread usage. Having said that, several researches are ongoing at a good pace, and in a few years, robotics might be common just like the intra-oral scanners are routinely used nowadays.

V. DIGITAL DENTISTRY

Technology has become the backbone of modern dentistry with many procedures becoming easier and more comfortable. In periodontology, newer generation digital probes which provide automated measurements, controlled force, and digitized data are being used[4].Digital method to check occlusal forces with the use of the ‘T-scan’ method (T-scan III version 7.0) analyses the series of occlusal contacts while at the same time calculating changes in the percentage of a force of the same contacts from the moment the teeth begin contact in maximum intercuspation. This is helpful in trauma from occlusion cases[4].

3D imaging system like Cone beam CT has been used to correctly identify the type of defect and to plan its treatment with the help of 3D scanning and printing scaffolds for bone grafting as described in the minimally invasive procedures. Periodontal procedures require local anesthesia and nowadays computerized local anesthesia delivering systems are available which can help in giving the perfect amount and painless anesthesia, improving patient comfort.

VI. TELEPERIODONTOLOGY

"Tele-periodontics" is a novel branch of telehealth that falls under the umbrella of telemedicine and teledentistry. It centers on utilizing telecommunication and internet-based technologies to provide oral health care services (diagnosis, consultation, treatment, public health, education, etc.) without the need for physical presence or direct involvement of specialists. This innovative approach enables the delivery of oral health care across geographic distances, expanding access to quality care and improving overall health outcomes for patients in remote or underserved areas.[5]

Periodontitis is a silent disease that leads to tooth loss and is one of the most common causes of tooth loss in adult populations. Teleperiodontology can offer quick detection and diagnosis in these cases by consultation with a periodontist. The most used methods of

Teleperiodontology are the store and forward method and video conferencing[5]. The earlier method involves taking all the necessary clinical pictures and parameters and then forwarding them to the periodontist. The other method involves real-time video conferencing with either the periodontist or general dental practitioner and the patient, this allows more in-depth discussion, and the general dental practitioner can get more clarity on the treatment while the patient can better understand the disease. In addition to that considering the promising future of tele periodontology certain peripheral devices can be developed and attached to video conferencing like tele probes, which can give real-time parameters to the periodontist for better evaluation.Tele periodontology can be a boon for remote rural areas where easy access to quality healthcare is not possible, provided high-speed internet and other required equipment are available.

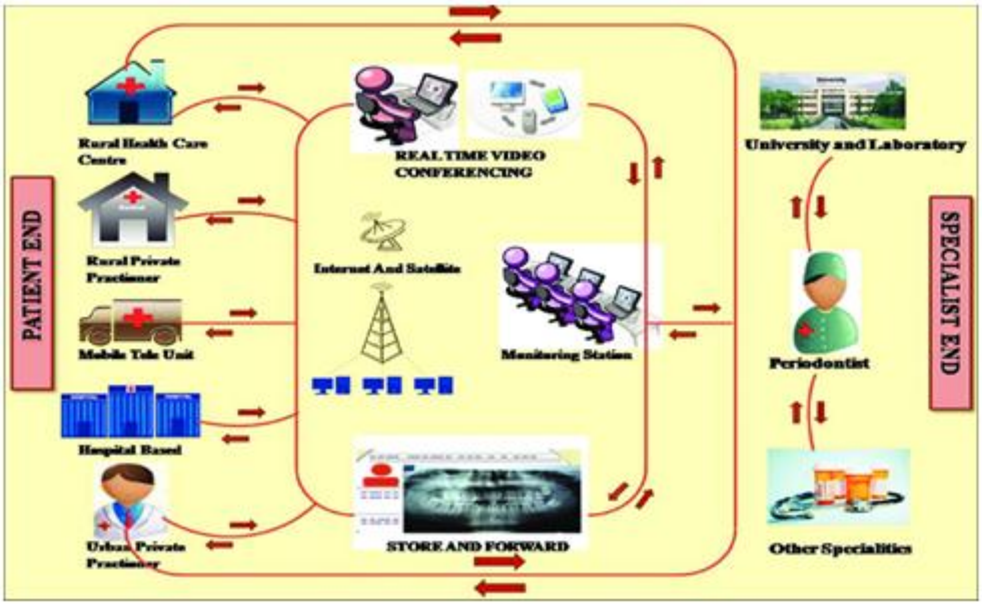

Figure 2: A conceptual model of Teleperiodontology as described above.[5]

VII. MICROBIOME BASED THERAPIES

Periodontal disease is characterized by a multifaceted interplay between the host's inflammatory response and the dysbiosis of the oral-dental biofilm, which is formed by a diverse microbial community. This intricate relationship triggers chronic inflammation in the periodontal tissues, culminating in the progressive destruction of the bone supporting the teeth and, in severe cases, leading to tooth loss. The complex nature of this disease underscores the importance of comprehensive management strategies that address both the microbial imbalance and the host's inflammatory response to effectively prevent and treat periodontal disease.

Conventional periodontal treatment traditionally involves mechanical and chemical methods to remove dental plaque, with the option of flap surgery when necessary. However, a recently emerging approach known as microbiome-targeted therapy has gained attention. This therapy utilizes probiotics, prebiotics, and targeted antibiotic treatments. Probiotics are live microorganisms that, when consumed, offer health benefits by positively impacting the gut microbiota. Prebiotics, on the other hand, are compounds found in food that foster the growth and activity of beneficial microorganisms in the gut. Antibiotics are also employed in this context, exerting beneficial effects by non-specifically suppressing the microbiome at the treated site. These innovative treatments show promise in promoting a balanced and healthy oral microbiome, potentially leading to improved periodontal health outcomes. [6]

In a 2015 study, Pozhitkov et al put forward a concept of microbial transplant as a potential therapy for the treatment of periodontitis which consisted of three steps :(i) harvesting sub- and supra-gingival microbiota from a healthy donor, e.g., spouse or a partner; (ii), performing deep cleaning, root planning and applying a broad-spectrum antimicrobial agent to the periodontitis patient; and (iii) neutralizing the antimicrobial agent immediately following by rinsing with a microbial suspension harvested from the healthy donor in the periodontitis patient.[7]

VIII. ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING(ML)

AI's integration into dentistry has witnessed significant growth in recent years, mirroring its impact across various industries. Within the dental field, AI applications can be categorized into diagnosis, decision-making, treatment planning, and predicting treatment outcomes. Among these applications, AI's most prominent and widely adopted use is in the domain of diagnosis. AI algorithms and machine learning models aid dental professionals in accurately and efficiently diagnosing various oral conditions and diseases, thus enhancing the overall diagnostic process. As AI continues to evolve, its potential to transform dental practice and improve patient care remains highly promising.[8]In periodontology, the use of AI is still in its infancy and needs more research. Several studies are ongoing where they are using the existing and different types of data, various complex algorithms like Neural Networks(NN)-Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Support Vector Machine (SVM), Random Forest(RF) and Regularized Logistic Regression (RLR) to identify the usability of these latest technologies in periodontics and dentistry (refer figure 1). CNN is specifically designed for handling image-based dataand its architecture has multiple layers where early layers pick up gross content and later layers more specific.[9] Hence, they are more commonly used for periodontal applications like periodontal bone loss detection, and detection of a periodontally compromised tooth, and other algorithms are mostly used to identify the severity of chronic periodontitis prediction.[8]

Additionally, AI is also used in intra-oral scanner software to complete smaller parts of the scanned 3d image, not scanned properly due to less mouth opening, heavy undercut, etc.

Machine Learning (ML) complements AI in dental research and applications. As a subset of AI, ML plays a pivotal role in creating intelligent systems that can aid in prediction and other use cases within dentistry. ML algorithms work in conjunction with AI to learn from data and extract meaningful patterns and insights that can be utilized for various tasks in dentistry.

The accuracy of ML models improves as they are trained on larger and more diverse datasets. This process allows the algorithms to recognize inherent structures in the data and apply the acquired knowledge to make predictions on new and previously unseen data. By leveraging mathematical algorithms, ML empowers computers to become adept at understanding and processing complex dental information, opening up exciting opportunities for advanced diagnosis, treatment planning, and patient care. As the field of ML in dentistry continues to evolve, it holds the potential to revolutionize dental practices and enhance patient outcomes.[10]

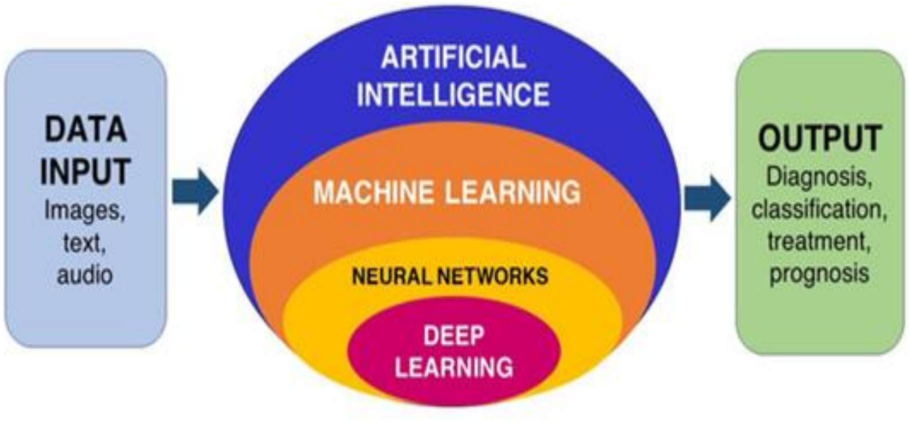

Figure 3: A simple understanding of how AI and ML work. [18]

Example: A 2022 study by Tsoromokos et al uses Machine learning to estimate the alveolar bone loss. In this study, Manual values are compared with the machine learning model developed by training a CNN algorithm to automatically assess Alveolar bone loss in periapical radiographs. Their findings were very promising with a moderate to good reliability on ML to detect periodontal disease by estimating alveolar bone loss.[11]

IX. NANOTECHNOLOGY IN PERIODONTOLOGY

Nanotechnology is a field of science that focuses on manipulating materials and technology at the atomic or molecular level, where at least one dimension is less than 100 nm. Nanomaterials, owing to their tiny size, exhibit significantly increased surface area per unit mass when compared to larger particles. This unique characteristic results in the alteration of various properties, such as electrical, optical, and magnetic properties. As a result of these alterations, nanotechnology holds tremendous promise for a wide range of applications, including in medicine, electronics, energy, and materials science.[13]

The integration of nanotechnology into the treatment of periodontal diseases represents a significant breakthrough in the field of periodontics. It can help address the major challenge of accessing certain areas of inflammation, nanomaterials can be combined with existing modalities to enhance treatment predictability and site-specificity. Nanotechnology has a pervasive presence across various treatment modalities in periodontics, ranging from nonsurgical therapies to dental implants. By leveraging nanomaterials, periodontal treatments can be made more effective, efficient, and tailored to individual patient needs.

Widely used methods in periodontics include local drug delivery, where controlled drug release using nanomaterials has been tested using nanospheres, core-shell structures, nanotubes, and nanocomposites. The use of triclosan, tetracycline, and doxycycline at localized inflamed sites has produced satisfactory results.

Tissue engineering using nanofibers has been experimented with, for the regeneration of lost periodontal tissues due to periodontitis. Potential applications of tissue engineering include use in dental implants by creating nano grooves and nanopillars and chemical coatings with nanoparticles to reduce osseointegration time.The nanoscale surface morphology of dental implants increases their surface area, allowing for a more substantial interaction with the biological environment. This enlarged surface area facilitates improved cell adhesion, protein adsorption, and mineral deposition, which are essential for promoting osseointegration and ensuring the long-term success of dental implants.[15]

Nanocarriers and nanocomposites with calcium phosphate interdigitate with bone supporting its growth. Nanoscale bone rafts have been successfully used in the treatment of intrabony defects, socket preservation, and sinus augmentation procedures.[14]

Nano titanium particles coated surfaces on laser irradiation have been shown to increase collagen production. Based on this, gingival depigmentation and other periodontal procedures can be performed. Diode laser along with nanoparticles can be used to decontaminate the dentin surface. [14]

The concept of using Nanorobots (also known as ‘dentifrobots’) left by mouthwash or toothpaste on the occlusal surfaces of teeth can clean organic residues by moving throughout the supragingival and subgingival surfaces, continuously preventing the build-up of calculus. These nanorobots show impressive mobility, as they can move as fast as 1 to 10 microns/second thus helping in thorough cleaning and they are safely deactivated when they are swallowed ensuring no health risk to the individual using it.[15] This would be very helpful in the periodontal maintenance phase post-surgery.Although this technology remains in the realm of speculation and research at present, its potential impact on oral care should not be underestimated.

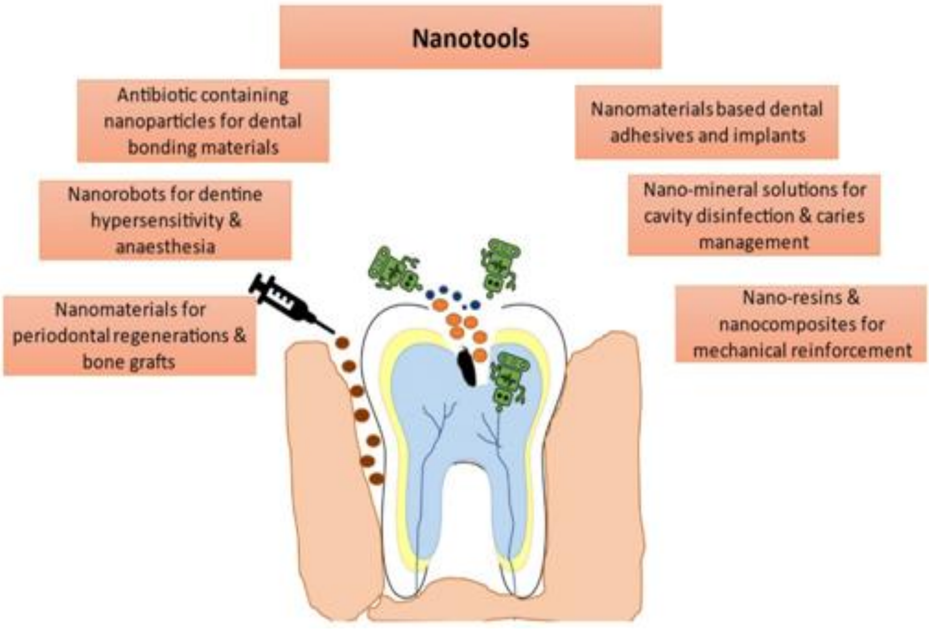

Figure 4: A sample diagram showing the applications of nanotechnology in periodontology.

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X. CONCLUSION

The future of periodontology with these trends holds tremendous promise driven by cutting-edge technologies and innovative approaches. Newer regenerative therapies, precision medicine, and digital dentistry will likely reshape the landscape of periodontal care, providing more personalized and minimally invasive treatments. Furthermore, with the integration of AI, ML, nanotechnology, and tele-periodontology, diagnostics and maintenance would be revolutionized, leading to an enhanced and favorable outcome and overall improved patient experience. Embracing these futuristic trends can provide an exciting glimpse into the potential advancements and undoubtedly propel the field of periodontology into a new era of advanced and effective dental care. However, not all these trends are currently in practice, and a lot more research is to be done before these trends can become widespread or fully realized.

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