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President's message

Greeting dear members of the SPIK family…..

A new team of office bearers have taken charge of SPIK. It is a pleasing blend of well experienced senior members and dynamic young members who are very enthusiastic about promoting the specialty of Periodontics in our state.

We have a task cut out in that the knowledge and application of various periodontal treatment modalities is very much less among our dental brethren and public at large. It is in this regard that we are planning to conduct more CDE and clinical club programs in various IDA branches in our state on the topic of diagnosis and treatment of periodontal diseases. The basic diagnosis of various periodontal diseases and the treatment options available must be discussed among general practitioners. The basic surgical treatments, use of regenerative materials, use of lasers and implant treatment can be presented. The inter-disciplinary treatment options also need to be presented. I request all our members to see that at least one program is conducted in their respective IDA branches this year. The message is loud and clear…. we as periodontists need to promote and project our specialty, nobody else will do it. The slogan is …Perio First….

Awareness among general public also needs to be enhanced, radio talk shows, awareness camps, newspaper articles and other public outreach programs are being planned. The importance of maintaining proper oral hygiene, the consequences of severe periodontal disease and its systemic inter relationship need to be stressed on.

We are also planning to conduct programs for undergraduate students and post graduate students as part of our organization's outreach program. Another pressing need is to revisit our organization's constitution, which is a beautifully drafted one but needs to be modified in tune with the growth in size of our organization.

I also humbly request all members to please send their suggestions on ways to improve the functioning and growth of our dear organization.

Regards,

Dr Arun Sadasivan
President -SPIK
Mob: 98472 46961
Email address: sadasivan_arun@hotmail.com

Secretary's Message

Dear SPIK members,

Another successful year has passed under Dr. Mathew Thomas' leadership. We're excited for the new team, led by Dr. Arun Sadasivan, a respected academician and clinician.

JSPIK has been instrumental in supporting our fraternity and postgraduates through high-quality publications. We're confident that Dr. Anjhana Narayanan, our new journal editor and the editorial team will bring innovative changes and elevate our journal's standards.

We look forward to the executive committee members' and life members' continued support in enhancing our fraternity's standards.

Thank you,

Dr. Deepak Thomas
Secretary, SPIK

Editorial

Greetings from the editor…

It is with immense gratitude and a sense of responsibility that I pen down my first editorial message for JSPIK following my instillation as Editor. At the outset, I would like to acknowledge the dynamic leadership of our President, Dr Arun Sadasivan, and our ever-supportive Secretary, Dr Deepak Thomas, whose vision will steer SPIK towards academic excellence.

JSPIK has always been a dedicated platform for periodontists in Kerala, nurturing the interests of academicians, clinicians, and postgraduates alike. As a speciality journal, our focus remains on showcasing clinical cases, research experiences, and highlighting the latest trends in understanding periodontal diseases and their management.

As we embark on this journey together, I encourage each member to actively contribute by sharing their clinical innovations, research findings, and unique case reports. Publishing scientific papers not only strengthens our speciality but also embraces a culture of evidence-based practice within our fraternity.

Looking forward to your enthusiastic participation and valuable contributions.

Warm regards,

Dr Anjhana Narayanan
Editor, JSPIK

Laser-Assisted Gingivectomy for Managing Inflammatory Gingival Enlargement in Orthodontic Patients: A Case Report

Jane Carolyn Maansingh[1], V.R. Balaji[2], D. Manikandan[3]

ABSTRACT

This case report presents the use of laser-assisted gingivectomy to manage inflammatory gingival enlargement associated with orthodontic appliances. A 22-year-old male undergoing orthodontic treatment experienced gingival enlargement and an unesthetic appearance of the gingiva despite scaling and oral hygiene maintenance. After mechanical debridement, a laser-assisted gingivectomy was performed under local anesthesia using a 2.5W diode laser. The procedure resulted in improved gingival contours with minimal postoperative discomfort, faster healing, and a highly satisfactory esthetic outcome. The patient reported no pain at both one-week and one-month follow-ups, with a Visual Analog Scale (VAS) score of zero. Laser-assisted gingivectomy was well-tolerated and demonstrated advantages over conventional techniques, including reduced swelling, enhanced healing, and better patient compliance. This case highlights the potential benefits of diode lasers in managing gingival health and esthetics in orthodontic patients. However, further evidence-based research is needed to support the widespread adoption of laser therapies in clinical practice.

Keywords: Laser-assisted gingivectomy, Orthodontic patients, Inflammatory gingival enlargement, Diode laser, Periodontal management

Introduction

Recent clinical and experimental studies have indicated that the most important etiological factor in periodontal disease is the bacterial plaque at the marginal gingiva. The introduction of orthodontic appliances into the mouth increases the number of retention areas, and thus the progression of gingival inflammation increases periodontal involvement and damage.[1] When gingival tissues are enlarged, varying from mild enlargement of isolated interdental papillae to segmental or uniform and marked enlargement affecting one or both jaws, the tooth surfaces become difficult to access, inhibiting good oral hygiene and resulting in more inflammation and bleeding because of the enlarged gingival tissues. This causes aesthetic and functional problems, and compromises orthodontic tooth movement. Therefore, it is necessary to provide additional treatment such as gingivectomy, in order to correct gingival margin contours.[2]

Gingivectomy is a relatively straightforward procedure that is typically well tolerated by patients. When performed with appropriate indications, it can yield highly satisfactory outcomes in terms of esthetics and dentogingival harmony. The procedure consists of removing the gingival deformities resulting in a better gingival contour, which can be performed by conventional scalpels, electrosurgery, chemosurgery, and laser.[2,3] The elimination of the pseudo pockets is the therapeutic endpoint of all these procedures.[2]

With the introduction of soft tissue diode lasers, which is economic and less painful than conventional

[1]Postgraduate Student, [2]Professor and Head, [3]Reader, Department of Periodontics and Implant Dentistry, CSI College of Dental Sciences and Research, Madurai. Corresponding Author: Dr. Jane Carolyn Maansingh, E-mail: janecsiperio@gmail.com Contact Number: 9843110466

methods, the gingivectomy treatment became a routine part of periodontal and also orthodontic treatment. Diode lasers provide proper hemostasis, reduce the infection risk, and prevent damage to the teeth and bone because of their effect range which is limited to soft tissue. They also improve esthetics while improving soft tissue healing. Edema, less swelling, and faster healing are the advantages of laser usage in soft tissue management.[5]

Hence, the aim of this case report is to present a case of inflammatory enlargement of gingiva associated with orthodontic appliances, managed using laser-assisted gingivectomy.

Case Report

A 22-year-old male patient presented to the outpatient section of Department of Periodontics, CSI College of Dental Sciences and Research, Madurai, Tamil Nadu, with the chief complaint of swollen and unesthetic appearance of the gums in the upper and lower anterior teeth for the past three months. The patient was undergoing orthodontic treatment at the time of reporting and the enlargement persisted despite undergoing scaling, according to the patient. Oral prophylaxis followed by laser-assisted gingivectomy was planned for the patient. The patient demonstrated better compliance with the treatment plan after being informed about the benefits of laser-assisted gingivectomy compared to the scalpel technique. Thorough mechanical debridement was performed and oral hygiene instructions were given. One week after oral prophylaxis, the patient was recalled to perform gingivectomy using laser. [Figure 1(a),1(b),2]

Under 2% Lignocaine Hydrochloride with Adrenaline 1:80,000, pocket markings was done by inducing bleeding points on the buccal aspect of 13-23 and 33-43 region. Since there was an adequate width of keratinized gingiva and pocket depth of 4-5 mm, gingivectomy of 2-3 mm was planned. The laser fiber tip (400µm in diameter) was used and the gingivectomy was performed with gentle, sweeping brush strokes with a power output of 2.5W in pulsed mode (pulse length of 0.5ms, pulse interval of 0.2ms), on buccal and palatal aspects of teeth 11,12,13,21,22,23 [Figure 3(a) and 3(b)] and buccal aspect of teeth 31, 32, 33, 41, 42, 43. [Figure 4]

During the entire procedure, the tip was constantly checked for any debris of the ablated tissues and was cleaned with sterile moist gauze. High volume suction was used to evacuate the laser plume and charred odor. 2 Hemostasis was checked and periodontal dressing was given. Post-operative instructions were given and medications (Paracetamol 650mg) were prescribed for pain control if necessary.

The patient was reviewed after one week and exhibited uneventful healing, expressing satisfaction with the esthetic outcome. Orthodontic treatment

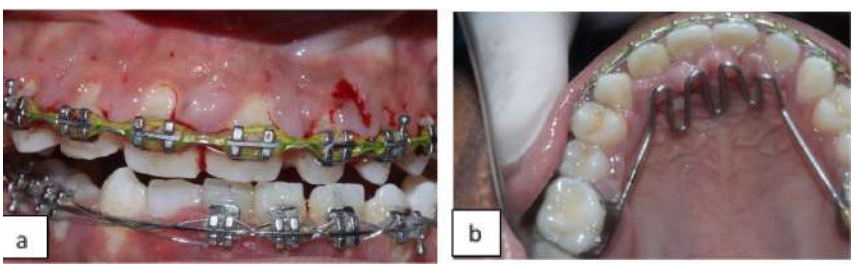

Figure 1(a),1(b): Preoperative views – upper arch

Figure 2: Preoperative view – lower arch

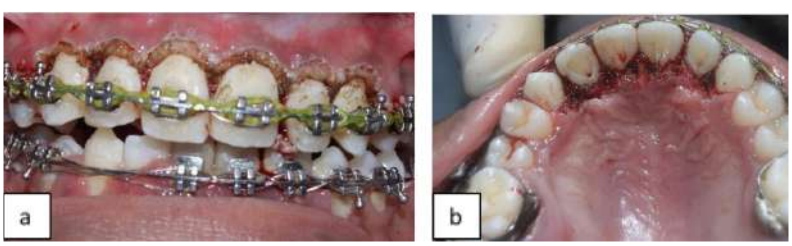

Figure 3(a),3(b): Intraoperative views – upper arch

Figure 4: Intraoperative view – lower arch

was completed prior to the three-month follow-up. The three-month follow-up also showed excellent results. (Figure 5)

Using Visual Analog Scale (VAS) scores, the patient was asked to rate their discomfort at both the one-week and three-month postoperative visits, reporting a score of zero on both occasions which indicates that the patient experienced no pain.

Discussion

Inflammatory gingival enlargement is a common finding in orthodontic patients due to increased plaque accumulation around brackets and wires, which creates additional retention areas for bacterial biofilm. The resultant gingival inflammation not only affects oral hygiene maintenance but also compromises esthetics and orthodontic tooth movement.

In this case report, these gingival alterations occurred in spite of the repeated motivation and instruction in toothbrushing given prior to and during the orthodontic treatment. Zachrisson et al., through a longitudinal study among 49 patients treated with fixed orthodontic appliances concluded that in spite of good brushing technique and low Plaque Index (PI) scores, most children developed general moderate hyperplastic gingivitis within one or two months after the placement of the appliances.[1] Hence, it can be said that it is essential for orthodontic patients to undergo regular periodontal maintenance checkups, and if necessary, receive periodontal treatments.

The conventional scalpel 45° gingivectomy is considered as the gold standard approach. The alternative to scalpel excision is the laser gingivectomy, which offers several advantages as well as sterilization of the surgical field, reduced haemorrhage during excision, potential of prompt healing, and minimal postoperative discomfort.[7] Sobouti et al., in a controlled clinical trial concluded that experimental (laser-assisted surgery) patients had no postsurgical pain (VAS=0,1). In the control group (traditional surgery using scalpel), the average VAS pain was 5.2 out of 10.[10] Similarly, our patient reported no postoperative pain or discomfort, stated that they did not need to take the prescribed medications, and exhibited a VAS score of zero.

Mavrogiannis et al., concluded that laser surgery appears to have a lower rate of recurrence of gingival overgrowth when compared with conventional gingivectomy.[2] When compared to other techniques laser gingivectomy was the most preferred technique, as it demonstrates superior postoperative healing. In comparison, surgical gingivectomy is associated with more postoperative complications. Laser gingivectomy predominantly requires only topical local anesthesia.[8] Additionally, Kau et al., also concluded that photobiomodulation (low level laser therapy) accelerates orthodontic alignment and reduces the treatment time in the early phase of treatment.[4]

However, it is important to note that non-surgical periodontal treatment like laser therapy can be effective in controlling gingival health problems only in the presence of a meticulous oral hygiene in the long period, while this therapy should not be recommended when gingival enlargement is extensive and self-care is compromised.[2] Nonsurgical periodontal therapy, with or without adjunctive diode laser gingivectomy, can be effective in managing gingival health over time. However, incorporating diode laser gingivectomy as an adjunctive treatment may lead to faster and more pronounced improvements in gingival health, highlighting its potential advantages for orthodontic patients.[10]

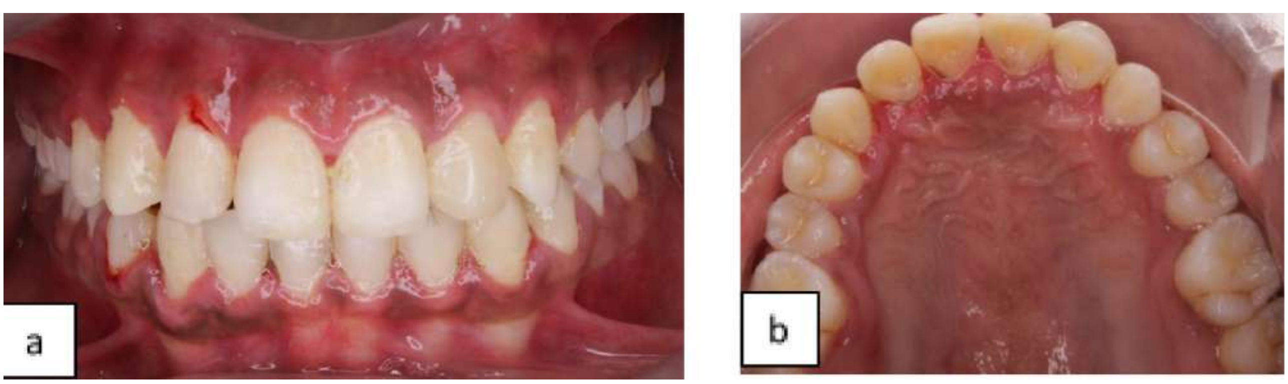

Figure 5(a), 5(b): Postoperative view (3 months)

It also remains challenging to draw definitive conclusions or make recommendations from the numerous published studies due to the variety of laser devices used, differing parameters, and the lack of long-term clinical research. Currently, there is no consensus on the optimal parameters for specific laser devices and their applications. As a result, parameters are often applied based on empirical knowledge and observation. However, most studies suggest that laser technology holds promise for periodontal and peri-implant treatments. More evidence-based research is needed to support the integration of this technology into clinical practice.[6]

Conclusion

In conclusion, laser-assisted gingivectomy proves to be an effective and minimally invasive treatment for inflammatory gingival enlargement in orthodontic patients. The technique offers benefits such as reduced postoperative pain, faster healing, and improved aesthetic outcomes. Despite the need for further evidence-based studies, laser therapy holds significant potential in periodontal and orthodontic treatments. Its ability to provide precise tissue removal with minimal discomfort makes it a promising alternative to conventional surgical methods.

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Hydrogel-Based Innovations in Oral Health: A Scoping Review of Current Applications and Cross-Disciplinary Developments

Bindu R Nayar [1], Anand Krishna VB[2]

ABSTRACT

Recent breakthroughs in hydrogel technology have revolutionized therapeutic approaches in oral health care. This scoping review synthesizes cutting-edge research from the past three years, highlighting how hydrogels—with their exceptional biocompatibility, customizable properties, and biomimetic characteristics—are transforming clinical practice. By analysing the latest evidence on composition strategies, delivery mechanisms, and therapeutic outcomes- four emerging trends: (1) smart responsive systems that activate in disease-specific microenvironments, (2) multifunctional platforms combining antimicrobial and regenerative capabilities, (3) precision-engineered scaffolds for complex tissue regeneration, and (4) minimally invasive delivery systems enhancing patient comfort and treatment accessibility. Hydrogels are water-absorbing polymer networks with broad engineering applications spanning biomedicine, environmental treatment and smart materials. While technical challenges persist in mechanical optimization and regulatory pathways, hydrogels increasingly bridge the gap between laboratory innovation and chair side application. This comprehensive analysis provides a roadmap for researchers and clinicians navigating this rapidly evolving field, with particular emphasis on translation to practical clinical solutions.

Keywords: Hydrogels, periodontal regeneration, dental biomaterials, tissue engineering, drug delivery, polymer networks

1. Introduction

Hydrogels are highly hydrated, biocompatible polymeric networks with tunable properties, making them promising materials for periodontal therapy1,6. Their ability to serve as scaffolds for tissue regeneration, controlled drug delivery systems, and injectable matrices for irregular defects enhances their utility in dentistry. Recent advancements (2022-2025) focus on composition strategies to mimic the extracellular matrix, innovative delivery mechanisms for therapeutic agents, and clinical applications aimed at reducing inflammation and promoting periodontal healing. Continued research is expected to refine hydrogel formulations for improved regeneration outcomes.

2. Methods

2.1 Search Strategy

A systematic literature search was conducted across electronic databases including PubMed, Scopus, Web of Science, and MEDLINE, covering the period from January 2022 to March 2025. The following search terms were used in various combinations: "hydrogel," "dental," "periodontal," "regeneration," "tissue engineering," "drug delivery," "biomaterial," and "polymer networks."

2.2 Inclusion and Exclusion Criteria

Inclusion criteria: Published original research and comprehensive review publications exploring

[1]Prof &Head, Dept of Periodontics, Govt. Dental College, Trivandrum, India, [2]Engineering Student, S8 CET, Trivandrum. Corresponding Author: Dr. Bindu R Nayar Email.

hydrogel implementations in dental practice and interdisciplinary contexts

Studies published between January 2022 and March 2025, in vitro, in vivo, and clinical studies

English language publications, Full-text availability

Exclusion criteria: Studies published before 2022, Conference abstracts, letters, editorials, and case reports, Studies focusing primarily on hydrogels for non-dental applications, Articles not available in English, Duplicate publications

2.3 Data Extraction and Analysis

The following data were extracted from eligible studies: author information, publication year, study design, hydrogel composition, fabrication methods, dental/periodontal application, key findings, and limitations. The collected information was categorized based on application type and synthesized narratively to identify trends, innovations, and knowledge gaps.

3. Composition and Design of Dental Hydrogels

3.1 Natural Polymer-Based Hydrogels

Recent studies have highlighted the potential of natural polymer-based hydrogels in periodontal therapy due to their biocompatibility and biodegradability. Chitosan-alginate hydrogel that enhanced periodontal ligament stem cell adhesion and proliferation by mimicking the extracellular matrix[2]. An injectable type I collagen hydrogel with platelet-rich fibrin (PRF), accelerating periodontal regeneration in a rat model through the combined effects of collagen scaffolding and PRF-derived growth factors[3]. A cross-linked hyaluronic acid (HA) hydrogel for delivering BMP-2, demonstrating significant bone formation in periodontal defects due to its optimal growth factor retention[20]. These findings underscore the therapeutic promise of hydrogels in periodontal tissue engineering.

3.2 Synthetic Polymer-Based Hydrogels

Synthetic polymer-based hydrogels offer reproducibility, tunability, and improved mechanical properties, making them valuable in periodontal applications. Photo cross linkable PEG-di acrylate hydrogel for sustained doxycycline release, showing antibacterial efficacy against periodontal pathogens[9]. A thermo sensitive PNIPAM-based hydrogel (Poly(N-isopropyl acrylamide) that transitions to a gel at body temperature, enabling prolonged metronidazole release and clinical improvement in periodontitis[33]. PVA hydrogel with nano hydroxyapatite, enhancing mechanical strength and bioactive potential for alveolar bone regeneration[28]. These advancements highlight the versatility of synthetic hydrogels in dental tissue engineering.

3.3 Hybrid and Composite Hydrogels

Hybrid hydrogels combining natural and synthetic polymers have shown great promise in periodontal applications. GelMA/PEG composite hydrogel with bioactive glass nanoparticles, enhancing mechanical strength and osteogenic potential for bone regeneration[23]. Chitosan/alginate hydrogel with silver nanoparticles, offering both antimicrobial and regenerative benefits for periodontal infections[14]. Self-healing alginate/hyaluronic acid hydrogel using dynamic imine bonds, ensuring excellent injectability and sustained growth factor release for tissue engineering[46]. These advancements highlight the growing potential of hybrid and nanocomposite hydrogels in dental therapy.

4. Hydrogels for Periodontal Regeneration

4.1 Cell-Free Approaches

Cell-free hydrogel systems have been extensively investigated for their practical advantages in clinical translation. Multifunctional chitosan/gelatin hydrogel incorporating bioactive glass nanoparticles and platelet-rich plasma, demonstrating synergistic effects on periodontal regeneration in a dog model[39]. The system provided a conducive environment for host cell migration and differentiation without the need for ex vivo cell culture. Biomimetic approaches aiming to recapitulate the natural periodontal microenvironment have shown promise. A gradient hydrogel system with spatially controlled delivery of cementum protein 1 (CEMP1) and bone morphogenetic protein-2 (BMP-2), successfully regenerating the complex periodontium with appropriate cementum-periodontal ligament-bone architecture in a rat model.[30]

4.2 Cell-Laden Hydrogels

Cell-laden hydrogels are a promising approach for periodontal regeneration, providing structural support while delivering cellular components. GelMA hydrogel modified with adhesive peptides, encapsulating dental pulp stem cells to enhance cell survival, proliferation, and odontogenic differentiation[47]. A compartmentalized hydrogel system supporting the co-culture of periodontal ligament and alveolar bone stem cells, enabling spatial growth factor delivery for improved periodontal complex regeneration in a mini-pig model[18]. An injectable hyaluronic acid hydrogel incorporating extracellular vesicles (EVs) from periodontal ligament stem cells, demonstrating immune modulatory and pro-regenerative effects in a rat periodontitis model[5]. These advancements underscore the growing potential of cell-based hydrogels in dental tissue engineering

4.3 Growth Factor Delivery

Controlled delivery of growth factors through hydrogel systems continues to be a major focus in periodontal regeneration. Heparin-functionalized hydrogel with affinity-based binding of fibroblast growth factor-2 (FGF-2), providing sustained release and enhanced periodontal regeneration in a rat fenestration defect mode[17].

Dual and sequential delivery strategies have gained attention for their potential to recapitulate the natural healing cascade. A layer-by-layer hydrogel system providing sequential release of anti-inflammatory cytokines followed by pro-regenerative growth factors, demonstrating enhanced periodontal healing in a peri-implantitis model through initial inflammation control followed by tissue regeneration[36-,38].

4.4 Gene Delivery

Gene therapy approaches utilizing hydrogels as delivery vehicles have shown promising results. A cationic hydrogel system for localized delivery of plasmid DNA encoding bone morphogenetic protein-7 (BMP-7), demonstrating sustained transfection efficiency and enhanced periodontal regeneration in a dog model of periodontitis[45]. RNA interference strategies have been explored for modulating inflammatory responses[16]. A chitosan-based hydrogel delivering siRNA targeting TNF-α, successfully suppressing inflammatory responses and promoting periodontal regeneration in a rat periodontitis model[17-,19].

5. Hydrogels for Drug Delivery in Periodontal Applications

5.1 Antimicrobial Delivery

Recent advancements in hydrogel-based antimicrobial delivery systems have demonstrated significant potential for periodontal infection management. A thermo sensitive Pluronic F127 hydrogel incorporating metronidazole and doxycycline, achieving sustained drug release and notable clinical improvement in chronic periodontitis[31]. A self-assembling peptide hydrogel loaded with LL-37, providing broad-spectrum antimicrobial activity against periodontal pathogens while promoting tissue regeneration[12]. A chitosan hydrogel with methylene blue as a photosensitizer, enhancing antimicrobial effects against biofilms upon light activation while supporting tissue healing. These studies highlight the evolving role of hydrogels in antimicrobial therapy and periodontal regeneration[22-25,34].

5.2 Anti-inflammatory Agents

Inflammation control is a key focus in periodontal therapy, with hydrogels emerging as effective delivery systems. A hyaluronic acid hydrogel delivering resveratrol, which significantly reduced alveolar bone loss in a periodontitis model by modulating inflammatory cytokines and inhibiting osteoclastogenesis[27-29]. An injectable pH-responsive hydrogel for dexamethasone delivery, achieving controlled drug release and notable reduction in gingival inflammation in patients with desquamative gingivitis[11]. These advancements highlight the potential of hydrogel-based approaches in managing periodontal inflammation.

5.3 Probiotics and Prebiotics

Probiotic and prebiotic hydrogel systems are emerging as innovative strategies for periodontal health. An alginate hydrogel incorporating Lactobacillus reuteri, demonstrating antimicrobial effects against periodontal pathogens while fostering beneficial microbial communities in an ex vivo biofilm model[3]. A fructo oligosaccharide-laden hydrogel that selectively promoted commensal oral bacteria while inhibiting pathogenic species linked to periodontitis, highlighting a promising approach to micro biome modulation for improved oral health[35].

6. Hydrogels in Dental Tissue Engineering

6.1 Pulp Regeneration

Dental pulp regeneration utilizing hydrogel scaffolds has shown considerable progress. GelMA hydrogel incorporating dental pulp stem cells and a controlled release system for basic fibroblast growth factor (bFGF), demonstrating successful pulp-like tissue formation with appropriate vascularization and innervation in a pulpectomy model[13,42]. Cell-free approaches utilizing bioactive molecules have been investigated for practical clinical translation. Self-assembling peptide hydrogel incorporating dentin matrix protein 1 (DMP1), demonstrating recruitment of endogenous stem cells and promotion of odontoblastic differentiation for pulp regeneration in a dog model[23,7].

6.2 Dentin-Pulp Complex Regeneration

Recapitulating the dentin-pulp complex requires advanced hydrogel designs that enable spatially controlled tissue regeneration. Gradient hydrogel system delivering specific growth factors to promote odontoblastic differentiation at the dentin interface and VEGF in the pulp region, facilitating organized tissue formation resembling native dentin-pulp architecture[21] Biomimetic mineralization by incorporating amorphous calcium phosphate nanoparticles and dentin phosphoprotein-derived peptides into a hydrogel matrix, achieving controlled mineralization and tubular dentin-like structure formation for integrated regeneration[32,37]. These findings highlight the potential of hydrogels in sophisticated dental tissue engineering.

6.3 Alveolar Bone Regeneration

Nanocomposite and growth factor-loaded hydrogels are advancing alveolar bone regeneration. Bioactive glass and graphene oxide hydrogel, enhancing mechanical strength and osteogenic differentiation of stem cells[40]. Heparin-functionalized hydrogel for sustained BMP-2 release, promoting efficient bone formation in extraction socket defects with a lower dose than conventional carriers. These innovations highlight hydrogels as promising tools in bone tissue engineering.[23]

7. Clinical Applications of Hydrogels in Dentistry

7.1 Periodontitis Treatment

Hydrogels have demonstrated promising applications across various dental treatments. In periodontitis treatment a chitosan hydrogel delivering doxycycline significantly improved clinical attachment levels and probing depth reduction in a randomized controlled trial[26]. An injectable hyaluronic acid hydrogel for periodontal regeneration in intrabony defects, achieving substantial bone fill through a minimally invasive, flapless approach[10]

7.2 Peri-implantitis Management

A thermosensitive hydrogel with minocycline, demonstrating reduced inflammatory markers and stabilized bone levels in a clinical pilot study4. A platelet-rich fibrin hydrogel for peri-implant defect regeneration, showing significant radiographic bone fill and clinical improvement[38].

7.3 Oral Wound Healing

Muco adhesive chitosan hydrogel incorporating epidermal growth factor, accelerating epithelialization and reducing pain in mucosal ulcerations[27]. Developed thermoresponsive hydrogel barrier membrane for guided tissue regeneration post-surgery, improving wound stability and reducing complications.[22]

7.4 Dental Pulp Therapy

Calcium silicate-incorporated hydrogel for direct pulp capping, demonstrating high success rates with dentin bridge formation[15]. Peptide hydrogel scaffolds were evaluated by Zhang et al. (2023) for regenerative endodontic applications in immature permanent teeth, resulting in stained root development and vital pulp preservation[43].

8. Emerging Approaches

While hydrogels have shown great promise in periodontal therapy, several challenges remain in their clinical translation. There is difficulty of balancing mechanical strength with injectability and biocompatibility in load-bearing applications for bone regeneration[36]. The complexity of matching hydrogel degradation rates to tissue regeneration, as premature breakdown or excessive longevity could hinder therapeutic outcomes[8]. As discussed the regulatory and manufacturing hurdles, including scalability and consistency, which must be addressed to meet clinical standards[44]. Overcoming these challenges will be crucial for advancing hydrogel-based periodontal treatments.

Hydrogels are versatile three-dimensional polymer networks that absorb large amounts of water while maintaining structural integrity, making them essential materials across multiple engineering disciplines. Their biocompatibility and ability to mimic natural tissues have made them indispensable in biomedical applications including drug delivery, tissue scaffolds, and wound healing, while their superabsorbent properties prove valuable in environmental engineering for water treatment and agricultural applications. The stimuli-responsive nature of hydrogels enables smart material design for sensors and actuators, and their tunable mechanical properties have revolutionized soft robotics and flexible electronics, establishing them as cornerstone materials in modern engineering solutions from healthcare to environmental remediation.[48,49,50]

8.1 Future Research Directions

Future research in hydrogel-based periodontal therapy focuses on enhancing precision and personalization. Real-time in vivo monitoring using imaging and biosensing technologies will improve understanding of degradation kinetics and tissue integration. Immunomodulatory hydrogels aimed at regulating inflammation while promoting regeneration hold promise for improving healing outcomes. Machine learning-driven optimization of hydrogel compositions based on patient-specific factors could enable personalized regenerative approaches. Long-term clinical studies will be essential to assess the durability and stability of hydrogel-assisted tissue regeneration, ensuring successful clinical translation..

9. Conclusion

This scoping review highlights the significant advancements in hydrogel applications for dentistry and periodontics over the past three years. The field has witnessed remarkable progress in hydrogel composition strategies, delivery methods, and therapeutic applications, with increasing translation to clinical practice. Despite remaining challenges in mechanical properties, degradation control, and regulatory considerations, emerging technologies such as smart responsive systems, bio printing approaches, and digital workflow integration hold promise for addressing these limitations. Future research focusing on immunomodulation, real-time monitoring, and personalized approaches may further enhance the clinical utility of hydrogels in dental and periodontal applications. The continued convergence of materials science, tissue engineering, and digital technologies is likely to drive further innovation in this rapidly evolving field.

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Innovations in Wound Dressings

Sandhra Surendran[1], Harish Kumar.V.V[2], Saumya Gopal[3], Anish Varkey[4]

ABSTRACT

Periodontal surgery involves the manipulation of the tissues. To overcome the post-surgical swelling, inflammation and bleeding a form of protection is to be provided. Aforesaid protection is provided by the periodontal dressings that cover the traumatized post-surgical tissue from post-operative irritation, trauma, and salivary contamination, alleviates pain, reduces haemorrhage and facilitate better recovery. Periodontal dressings are broadly classified into three categories based on the constituents. The compositions of the dressings have taken many modifications to enhance the effects of materials. Disagreements adjoining the validation of the application and shortcomings of the frequently engaged periodontal dressings and their up-to-date status in clinical run-through are labelled in this widespread review.

Keyword: Periodontitis, Periodontal dressing, Healing, Wound management

Introduction

For centuries, surgical dressings have been used to protect surgical sites, prevent postoperative infection and promote faster healing. Similar advantages were observed in periodontal surgeries with the use of periodontal dressings or packs. In 1923, Dr. A. W. Ward introduced and recommended the use of a periodontal pack following periodontal surgery. However, as early as 1918, Zentler had suggested using iodoform gauze as a periodontal dressing. Despite this, Ward is recognized as a pioneer in modern periodontal dressings, as he introduced Wondrpak and was the first to use the term "pack" in this context. Since then, dental professionals have utilized periodontal packs in various clinical applications[1].

Periodontal dressings are believed to protect the healing wound from mechanical trauma, help stabilize the surgical site, shield it from fibrinolytically active saliva, and aid in hemorrhage control. Despite their numerous benefits and applications, their impact and effectiveness in periodontal wound healing have been questioned. Some reports indicate complications such as erythema, edema, and allergic reactions, potentially caused by certain agents incorporated into periodontal dressings.

Periodontal dressings are conventionally grouped as eugenol based or non-eugenol based periodontal packs. Another group, recognized as non- zinc oxide, non-eugenol are also in use. The original product comprised of zinc-oxide eugenol-based with alcohol, pine oil, and asbestos fibres as additives. To achieve desired physical and chemical properties several additives to zinc oxide eugenol has been tried by manufacturers. For instance, tannic acid to control bleeding and corticosteroids to reduce inflammation are a few modifications. Chemical constituents of the periodontal pack should not lead to tissue damage. Studies have shown inhibition of human fibroblast by eugenol dressings. However, literature shows conflicting reports on the same. Hence, newer materials to overcome the shortcomings of conventional periodontal dressings have been introduced.

Despite nine decades of inception, there appears to be no proper consensus on the universal applica-

[1]Post graduate student, [2]Professor and Head, [3]Associate Professor, [4]Associate Professor, Dept of Periodontics, KMCT Dental College, Mukkam, Kozhikode - 673 602

tion of periodontal dressing following periodontal surgeries. Meanwhile the search for materials with better properties and optimum results continue. This review aims to explore the current trends and advances in periodontal dressing .

Current Trends in Wound Dressing

1. Enamel Matrix Derivative

In 1997, enamel matrix derivative (EMD) was introduced, derived from the enamel of developing porcine teeth. It primarily consists of enamel matrix proteins (EMPs), with amelogenin being the most significant component, along with propylene glycol alginate (PGA), which has antibacterial properties. EMD preferentially supports periodontal ligament cells over epithelial and gingival cells, exhibiting cytostatic rather than cytotoxic effects, with minimal impact on epithelial cells. Additionally, no adverse effects, such as allergic reactions or incompatibility, have been reported.

EMPs are secreted by Hertwig's epithelial root sheath and play a crucial role in promoting periodontal regeneration. For successful regeneration, space provision and clot stabilization in infrabony defects are essential. However, due to its gel-like consistency, EMD has limited space-maintaining properties and does not provide adequate soft tissue support. Therefore, root instrumentation should be performed following flap elevation using a simplified papilla preservation flap (SPPT) or modified papilla preservation flap (MPPT) to achieve primary closure and clot stabilization, ultimately leading to improved clinical outcomes[2].

2. Curcumin Gels

Curcumin is applied topically for its wound-healing properties, including anti-inflammatory, antimicrobial, antiviral, antifungal, antioxidant effects, and as a chemo-sensitizing agent. The impact of curcumin gel and non-eugenol periodontal dressing (Coe-Pak) on wound healing and post-operative pain following periodontal flap surgery was assessed. The findings indicated that curcumin slightly outperformed the periodontal dressing in terms of anti-inflammatory effects and was particularly effective in reducing post-operative pain[3]. When used locally in combination with scaling and root planing (SRP), curcumin has shown improvement in periodontal parameters4. Additionally, curcumin has been found to yield more favourable results in periodontal outcomes compared to ornidazole gel[5].

Furthermore, a study by Dave et al. demonstrated that applying topical curcumin gel along with SRP led to greater reductions in plaque accumulation, sulcular bleeding, and pocket probing depth compared to SRP alone, highlighting its effectiveness as an adjunct to periodontal therapy[6].

3. Mucoadhesive Patches

Topical drugs like mucoadhesive oral patches (MOPs) are non-irritating to the mucosa and enhance drug permeability to oral tissues.

Buccal flexible films, which are solid, thin, and mucoadhesive, can serve as dressings that protect mucosal lesions from the oral cavity environment. Their benefits include flexibility, comfort during application, improved patient compliance, and better adhesion to the oral mucosa. Additionally, buccal films help protect the wound surface, reducing pain and enhancing the effectiveness of treatment for oral conditions[7].

TBM Ora-Aid is an intra-oral patch designed to protect affected or treated areas, typically used after periodontal procedures such as flap surgery, connective tissue grafts, dental implants, crown lengthening, and for conditions like traumatic ulcers. A clinical study by Han-Seul et al explored the impact of attachable periodontal wound dressings on post-operative pain and healing. The results showed reduced bleeding, less post-operative pain and discomfort, and less difficulty eating among patients using the attachable dressing. Advantages include easy application and good adhesion to tissue surfaces, while the main disadvantage is its limited duration of 6-12 hours[1].

TBM Curatick is a transparent, mouth-adhesive wound dressing. A clinical trial conducted by Chungnam National University in Korea using an oral wound model found that the Curatick group had a higher amount of collagen fibres on the 3rd, 7th, and 14th days compared to the control group. Its advantages include ease of application and strong adhesion to tissue surfaces. However, a disadvantage is that its adhesion weakens over time[1].

4. PRF

Platelet-Rich Fibrin (PRF) is a natural biomaterial obtained from a patient's own blood and used as a wound dressing to accelerate soft tissue healing and regeneration in periodontal surgical sites. It promotes blood vessel formation and gradually releases growth factors concentrated within the fibrin matrix, serving as a natural scaffold for tissue repair. PRF is a dense fibrin network containing leukocytes and platelets, which continuously release growth factors and cytokines over approximately seven days[8].

Research has shown that during wound healing, platelets and cytokines accumulate within the fibrin clot, releasing various growth factors into the surrounding tissues. These growth factors and cytokines play a crucial role in the healing process. Additionally, platelets secrete fibrin, vitronectin, and fibronectin, which serve as a structural matrix for connective tissue formation. This highlights the significant potential of platelet concentrates in promoting periodontal tissue regeneration.

A comparative study evaluating PRF and gelatin sponge in managing palatal wounds following epithelialized free gingival grafts found that the PRF bandage group achieved significantly faster complete re-epithelialization. Participants in this group also reported less discomfort, minimal changes in feeding habits, and required lower doses of analgesics[9].

5. Hyaluronic Acid

In periodontics, hyaluronic acid (HA) is regarded as a promising wound dressing material due to its natural presence in periodontal tissues, its role in promoting tissue repair and regeneration, and its anti-inflammatory properties. These characteristics contribute to faster and more effective healing following periodontal surgeries or treatments for gum disease.

Hyaluronic acid (HA) is highly biocompatible and non-immunogenic, with bacteriostatic, fungistatic, anti-inflammatory, anti-edematous, osteoinductive, and proangiogenic properties, making it a valuable agent for wound healing. Its hygroscopic nature helps retain water while maintaining structural stiffness, and its viscoelastic properties provide tissue stability and elasticity while delaying bacterial and viral penetration[1].

A randomized controlled clinical trial evaluated the effects of topically applied HA on pain and palatal epithelial wound healing. Two test groups received 0.2% and 0.8% HA gels, while a control group was treated with periodontal dressing alone. The results demonstrated improved wound healing, evidenced by enhanced epithelialization and better tissue color match[10]. Additionally, patients experienced reduced post-operative pain and burning sensations, highlighting HA's effectiveness in promoting healing and patient comfort.

6. Amniotic Membrane Dressing

An amniotic membrane dressing is a wound dressing made from the innermost layer of a fetal membrane. An amniotic membrane dressing in periodontics refers to the use of a thin membrane as a biological dressing to promote healing and regeneration of periodontal tissues, often used in procedures like gingival recession treatment or periodontal surgery due to its anti-inflammatory, anti-scarring properties, and ability to stimulate cell growth and blood vessel formation; essentially acting as a protective barrier over the wound site while facilitating tissue repair[1].

Fresh Human Amniotic Membrane (HAM) is processed in the laboratory for clinical use in various forms, including fresh, dried, frozen, or cryopreserved. However, fresh HAM must be used within 24 hours and may pose a slight risk of antigenicity. Glycerol is commonly used as a cryoprotective agent for drying the membrane, allowing for its long-term preservation and making it more convenient for clinical applications.

Despite its advantages, glycerol-preserved HAM lacks certain growth factors, leading to the development of hyper-dry HAM to address this limitation. Additionally, methods for the procurement and decellularization of HAM before seeding specific cells have been reported, further enhancing its potential for therapeutic applications[11].

7. Laser Bandage

In periodontics, a "laser bandage" refers to a wound dressing formed by using a laser to denature proteins on the surface of a surgical site, creating a protective layer from the patient's own tissue. This natural barrier helps reduce post-operative pain and supports faster healing. As a minimally invasive technique, the laser bandage is commonly applied after periodontal procedures such as gingivectomy to enhance patient comfort and improve wound management.

LASERs are considered an effective option for wound coverage at surgical sites due to their hemostatic properties. The "hot-tip" effect, caused by heat accumulation at the fiber's end, creates a thick coagulation layer known as a laser bandage (LB). When applied post-surgically, the laser bandage minimizes wound contraction and scarring by inducing fewer myofibroblasts than conventional scalpel techniques.

The use of a laser bandage also reduces the need for local anesthesia, shortens intervention time, and eliminates the need for sutures. Additionally, it helps reduce post-operative edema, bleeding, infection, pain, and medication use[12].

Advantages: Faster healing, Minimal to no pain, Enhanced revascularization, Facilitates surface keratinization.

This minimally invasive technique significantly improves post-operative outcomes and patient comfort in periodontal procedures[12].

8. Propolis Extract

Propolis extract serves as an effective wound dressing in periodontics due to its natural antibacterial, anti-inflammatory, and healing properties. It is considered a potential adjuvant therapy for periodontal disease treatment, commonly applied as a topical gel or irrigation solution. By promoting tissue regeneration and reducing inflammation in periodontal pockets, propolis contributes to improved healing outcomes and overall periodontal health.

Propolis is a non-toxic resinous substance, known for its antimicrobial, antifungal, anti-inflammatory, antioxidant, and antitumor properties. These beneficial effects have gained significant attention from researchers in both the medical and dental fields.

Propolis is a natural mixture of plant extracts combined with bees' saliva, with its composition varying based on geographic origin, botanical sources, and bee species. Despite its complex composition, its main bioactive components include flavonoids and phenolic esters such as caffeic acid phenethyl ester, which exhibit antimicrobial, anti-inflammatory, and immunomodulatory properties. These properties make propolis particularly useful in treating conditions like aphthous ulcers, candidiasis, gingivitis, and periodontitis[13].

The antimicrobial effects of propolis against periodontal pathogens have been studied both in vivo and in vitro. Nakao et al. reported significant improvements in clinical attachment level (CAL) and probing pocket depth (PPD), along with a reduction in Porphyromonas gingivalis a key pathogen in periodontal disease when using propolis solutions[14]. Similarly, Yoshimasu et al. demonstrated the antimicrobial efficacy of isolated propolis compounds such as artepillin C, baccharin, and ursolic acid against P. gingivalis, with artepillin C and baccharin acting as bacteriostatics and ursolic acid disrupting bacterial membranes due to its highly lipophilic nature[15].

These findings highlight propolis as a promising adjunct in periodontal therapy due to its potent antimicrobial and healing properties.

9. Blue®M Oral

Blue®M Oral Gel serves as an effective wound dressing in periodontics by promoting faster healing through the delivery of a high concentration of active oxygen to the surgical site. This makes it particularly beneficial for treating periodontal pockets, bleeding gums, and wounds resulting from dental extractions or implant placement. By accelerating tissue regeneration and reducing post-operative discomfort, Blue®M Oral Gel acts as a supportive agent in periodontal wound management.

Blue®M was developed by Peter Blijdorp and colleagues for the treatment of periodontal and peri-implant diseases. These oxygen-based therapy products, available as an oral gel, mouthwash, and toothpaste, have demonstrated significantly improved treatment outcomes[16].

Blue®M formulations primarily consist of sodium peroxoborate, glycerol, lactoferrin, and cellulose, allowing for a slow and sustained release of oxygen when applied topically. This controlled oxygen release aids in wound bio-modulation, reduces inflammation, enhances healing, and promotes neovascularization. Additionally, the formulation releases hydrogen peroxide in combination with lactoferrin, providing bactericidal benefits, further supporting its effectiveness in periodontal therapy[16].

10. Smart Dressing

Smart dressings represent a significant leap forward in wound management, as they enable continuous monitoring of the wound healing process. They incorporate sensors and drug delivery systems. Smart dressings, for instance, can monitor wound conditions in real-time, providing valuable data that can assist care providers in making informed decisions about treatment strategies. These advanced wound care products not only enhance the healing process but also aim to reduce the length of hospital stays and improve patient outcomes. These dressings can track parameters such as temperature, moisture levels, and pH, notifying care providers when interventions are necessary. By providing timely information, smart dressings can help prevent complications, such as infections, and facilitate the rapid assessment of wound status. This real-time feedback can be especially beneficial for patients with chronic wounds who require stringent monitoring to promote effective healing.

These products are designed to create optimal conditions for skin wound healing by maintaining moisture and temperature, which are critical for cellular repair processes. Advanced wound care technologies can also help to reduce pain and discomfort associated with wound treatment and minimize the frequency of dressing changes. Furthermore, these innovations have the potential to accelerate wound healing and reduce the overall healthcare costs associated with prolonged treatment and care for patients with chronic wounds.

Conclusion

Innovations in periodontal dressings have led to the development of advanced materials and formulations aimed at enhancing wound protection, promoting healing and improving patient comfort. Modern periodontal dressings incorporate antimicrobial agents, biodegradable components, and improved adhesive properties to optimize clinical outcomes. While traditional dressings have proven beneficial, ongoing research and technological advancements continue to refine their efficacy, biocompatibility, and ease of application. Future innovations may further enhance periodontal wound healing by integrating bioactive compounds, personalized treatment approaches, and smart biomaterials, ultimately improving post-surgical care in periodontology.

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Laser-Enhanced Esthetics: Frenectomy and Gingivectomy for a Confident Smile-A case report

Aswathi S[1], Anish Varkey[2], Sruthi VG[3], Surya S[4]

ABSTRACT

Lasers in dentistry offer a precise, minimally invasive approach to soft tissue procedures, promoting faster healing and reduced discomfort compared to conventional techniques. Their bactericidal and hemostatic properties make them ideal for enhancing both clinical outcomes and patient experience in esthetic treatments.

A 13-year-old female patient was presented with a chief complaint of gummy smile. On examination there was compromised smile aesthetics because of excessive gingival display on smiling and there is no vertical maxillary excess.

Conclusion: This case report highlights the use of diode laser technology in performing frenectomy and gingivectomy procedures to enhance smile esthetics and patient comfort. The minimally invasive approach resulted in optimal soft tissue contouring, reduced postoperative discomfort, and improved overall smile confidence.

Keywords: laser gingivectomy, smile correction using laser, laser frenectomy

Introduction

Lasers have emerged as a groundbreaking tool in modern dentistry, redefining the approach to smile designing. LASER is an acronym for "Light Amplification by Stimulated Emission of Radiation". Laser is a monochromatic, unidirectional and coherent beam of radiation that is produced by stimulated emission, a state where there are more excited atoms (i.e., more atoms in upper of two energy levels than in lower level), a condition called population inversion to obtain a radiation output greater than the incident radiation[1].

Orthodontic treatment is often the first step toward achieving a harmonious smile, aligning teeth and correcting malocclusion. However, post-orthodontic refinements are frequently necessary to perfect the smile's overall appearance. An aesthetically pleasing smile often requires additional procedures such as gingivectomy and aberrant frenum correction.

Traditionally performed with scalpel-based surgery, these procedures have been significantly transformed with the advent of laser technology

This case report presents a surgical procedure using diode laser (Indilase) at 980 nm.

Case Report

A 13-year-old female patient was presented with a chief complaint of gummy smile (Figure 1A). On examination there was compromised smile aesthetics because of excessive gingival display on smiling and there is no vertical maxillary excess. The patient

[1,3]Senior Lecturer, [2]Reader, [4]Post graduate, Dept of Periodontology, KMCT Dental college, Manassery, Mukkam,Calicut, Kerala, India. Corresponding author: Dr Aswathi S. e-mail: aswathisujil@gmail.com

reported a history of orthodontic treatment to correct dental malalignment, which improved tooth positioning but did not resolve the gummy smile. Clinical Examination of the patient revealed excessive gingiva covering the anatomical crowns of the maxillary anterior teeth with uneven gingival margins, suggesting altered passive eruption. A thick, aberrant labial frenum was observed, (figure 1B) contributing to aesthetic concerns. A diagnosis of altered passive eruption type I Subgroup A was made after periodontal examination according to Coslet et al[2].

Due to the patient's age and high level of anxiety, this case was managed with frenectomy and gingivectomy utilizing a diode laser (Indilase 980nm) in an effort to minimize bleeding and increase patient comfort throughout the procedure. Frenectomy was performed under LA at a power of 1 Watt in continuous wave and in contact mode, with a 400 µm optical fibre and laser was fired in an elliptical direction starting from the bottom most portion of the frenal attachment. This allowed ease of access in performing a deeper cut of the frenum in a horizontal dimension. The design of frenectomy was rhomboidal. (Figure 2)

The excessive gingival display was addressed using a diode laser, allowing precise ablation of gingival tissue to achieve a more proportionate and harmonious smile. The LASER at a power of 1 Watt in continuous wave and in contact mode, with a 400 µm optical fibre was used to contour the gingival margins under LA, ensuring minimal trauma to the surrounding tissues and effective hemostasis during the procedure. (figure 3 & 4)

Figure 1: A) gummy smile, B) Thick Gingival type of frenal attachment

Figure 2: Immediate Post-Op (Rhomboidal shape)

Figure 3: post-op laser gingivectomy

Figure 4: immediate post op

Figure 5: post op after 10 days

Figure 6: before and after the procedure

Throughout the procedure, wavelength specific goggles were worn and high-volume evacuation was employed to reduce the slight charred odour and to remove the laser plume.

Post operatively, the patient experienced minimal discomfort and rapid healing. The patient was provided with instructions to maintain good oral hygiene and use an antiseptic mouthwash to support recovery.

The procedure successfully reduced the gingival display and aberrant frenum, significantly enhancing the patient's smile aesthetics. (figure 5 & 6)

This case highlights the benefits of laser-assisted gingivectomy and frenectomy in managing a gummy smile and aberrant frenum, offering precision, reduced postoperative discomfort and faster healing compared to conventional methods.

Discussion

Frenectomy and gingivectomy surgical procedures can be performed using two main methods: the traditional scalpel-based technique or a minimally invasive laser approach utilizing various wavelengths. In recent years, the application of lasers in soft tissue surgeries has become increasingly common. Numerous studies have indicated that lasers may offer advantages over the traditional scalpel technique[3,4]. These benefits include easier execution of the procedure, effective hemostasis, improved visibility of the surgical area, shorter operation time, reduced requirement for local anesthesia, sterilization of the surgical site, elimination of the need for sutures, and decreased post-operative swelling, pain, and scarring[5].

When we evaluate dental laser for its use in patient, we must consider its safety before its use along with its effectiveness and efficacy. Safety of laser involves assessing the final result in terms of pre-operative stage and evaluating it for any permanent, undesired damage to tissue, body along with clinical benefit. Use of correct eyewear is very important as different wavelength of laser can damage various parts of unprotected eyes[6].

The current case reports highlight the benefits of diode laser surgery, intentionally bypassing conventional procedures. Diode lasers deliver energy to the tissues, leading to effects such as warming, tissue welding, coagulation, protein denaturation, drying, vaporization, and carbonization. These lasers are specifically designed for soft tissue procedures and pose no risk of damaging or etching the enamel, as their wavelength does not interact with tooth structures[7].

Conclusion

Clinical and aesthetic benefits are substantial when laser technology is used in periodontal operations like gingivectomy and frenectomy. Diode laser-assisted therapies can provide accurate soft tissue alteration with little discomfort, less bleeding, quicker healing, and increased patient satisfaction, as demonstrated in this case study. The favorable result highlights the importance of laser-enhanced periodontal therapy in attaining both functional and aesthetic rehabilitation, which increases self-esteem and improves quality of life.

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Delving Deeper into the Realm of Artificial Intelligence in Periodontics

Resma Jessy James[1], Anu Mathew[2], Majo Ambooken[3], Jayan Jabob Mathew[4], Lekshmi A.J.[5]

ABSTRACT

Artificial Intelligence (AI) is modernizing healthcare by simulating human cognitive functions through advanced computational systems. In the field of Periodontology and Implantology, AI offers prospects for improving diagnostic accuracy, treatment planning, and patient management. This review explores the current applications and future potential of AI technologies within these specialties. AI tools, including machine learning algorithms and natural language processing, have shown efficacy in maintaining patient records, assessing periodontal risk, enhancing diagnostic precision, and facilitating early disease detection. Furthermore, AI contributes to personalized treatment planning and real-time monitoring of periodontal conditions, thereby optimizing clinical outcomes. In Implantology, AI aids in CBCT interpretation, implant type recognition, and treatment outcome prediction. Despite these advancements, AI in periodontics and implant dentistry remains in its infancy, facing limitations such as data quality issues, lack of adaptability to evolving practices, and inability to incorporate patient-specific nuances and emotional intelligence. Nevertheless, AI holds significant potential to transform periodontal care through improved efficiency, precision, and personalization. Future progress depends on high-quality research, interdisciplinary collaboration, and the ethical integration of AI systems into routine practice. This review aims to summarize current evidence, identify limitations, and encourage further exploration to harness AI's full potential in dental specialties.

Keywords: Artificial Intelligence (AI), AI in periodontics, Machine learning

Introduction

Artificial intelligence (AI) seeks to create computer systems capable of replicating human behaviours through machine capabilities, ideally in a shorter time and with higher accuracy.[1] With the advent of AI, there has been a notable increase in interest among periodontist's in harnessing AI technologies to enhance the accuracy of diagnosis, optimize treatment planning, and streamline the management of various periodontal conditions, ultimately aiming to improve patient outcomes and advance the field of dentistry as a whole. AI technology can likewise be employed to enhance the effectiveness and precision of implant placement, treatment strategy, and diagnostic processes. Additionally, AI shows potential in improving patients' dental health and general wellness by facilitating the early identification of periodontal disease. Having said that in the realms of Periodontology and Implantology, AI remains relatively nascent and has not been fully leveraged. Considering its benefits in diagnostic support, data evaluation, and comprehensive regression analysis, it seems that significant advancements could be achieved by utilizing this technology.[2] Due to the limited literature available on this topic, this review sought to evaluate the existing evidence regarding the application of artificial intelligence in Periodontics and Implant dentistry. This review aims to outline current

[1,2]Post Graduate Student, [3]Professor and HOD, [4]Professor, [5]Senior Lecturer, Department of Periodontics, Mar Baselios Dental College, Kothamangalam - 686 691 | Corresponding author: Dr Resma Jessy James

practices and encourage future research in the field.

History

Alan Turing, the British mathematician, established the groundwork of AI in the 1950s by introducing the notion of the Turing test, initially referred to as the Imitation Game, which assessed a machine's ability to demonstrate intelligent behaviour closely resembling that of humans. The 1956 Dartmouth Conference is considered the inception of AI, where John McCarthy first coined the term Artificial Intelligence. In 1955, Allen Newell and Herbert Simon developed the very first AI program. In 1959, Arthur Samuel introduced the term "Machine Learning"(ML).[3]

Scope of AI in periodontics

Figure 1 shows the scope of AI in periodontics that can be comprised under patient record maintenance, periodontal risk assessment, periodontal diagnostics, early detection and screening, and patient education.

Patient record maintenance

The integration of AI tools, especially Natural Language Processing (NLP)—a sophisticated branch of artificial intelligence that equips machines with the ability to comprehend, interpret, and convey information in a format that is easily accessible to humans—

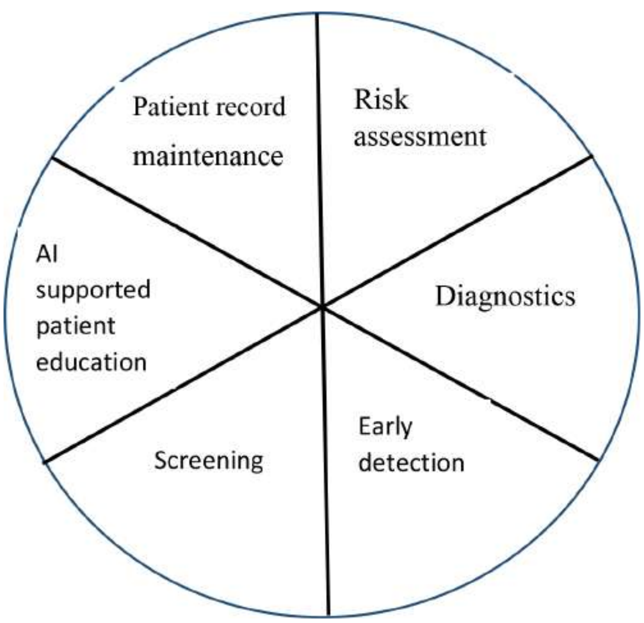

Fig.1: Scope of AI-based personalized diagnostics

into record-keeping processes markedly optimizes the documentation workflow, thereby improving overall operational efficiency and accuracy. In addition to facilitating record maintenance and diagnostic processes, NLP algorithms possess the capability to analyse patient feedback and reviews, thereby yielding valuable insights into the patient experience; such analyses can inform and refine treatment approaches, ultimately enhancing the quality of care and ensuring greater patient satisfaction.[4]

AI for periodontal risk assessment

Evaluating the risk of periodontal disease progression is essential for the formulation of effective treatment plans and preventive strategies, as AI tools are capable of analysing a myriad of risk factors—such as demographic data, medical history, and clinical parameters—to accurately predict the likelihood of future periodontal complications.[5]

AI's role in Periodontal Diagnostics

AI-powered imaging analysis systems have the capability to rapidly process radiographs and intraoral scans, enabling the detection of subtle variations in bone density and gingival tissue, while simultaneously identifying potential areas of concern that could easily be overlooked by the human eye.[6] Machine learning algorithms, which represent a sophisticated subset of artificial intelligence, are meticulously trained to recognize intricate patterns within these images, thereby enabling them to differentiate between healthy and diseased tissues, assess the progression of periodontal diseases, and facilitate early detection. This capability not only empowers healthcare professionals to implement timely interventions but also plays a crucial role in preventing further deterioration of the patient's condition.[7]

Early detection and screening

Using AI we can detect a wide range of biomarkers in metabolome, microbiome, proteome, etc., by which we can understand the pathophysiology of periodontal diseases. Nonetheless, this methodology has not been extensively embraced within the realm of Periodontology, despite its potential implications for advancing the understanding and treatment of periodontal conditions. Recently a study used ML to detect biomarkers from metabolome or microbiome.[8]

A comparative study employed machine learning techniques to analyse the oral microbiome composition in patients with periodontal disease, delineating differences between those with and without concurrent rheumatoid arthritis.[9] A recent investigation assessed the efficacy of AI-assisted self-monitoring by patients who captured images of their oral cavities following periodontal treatment; this approach involved the delivery of digital reminders via smartphones, which significantly enhanced patient compliance, fostered improved oral self-care behaviors, diminished plaque accumulation, and led to favorable periodontal outcomes observed during both one and three month follow-up evaluations[10].

AI driven treatment planning

AI algorithms are capable of synthesizing patient-specific data, including periodontal measurements, genetic markers, and treatment preferences, to formulate personalized treatment plans that are meticulously tailored to address the unique needs and circumstances of each individual.[1] In their 2019 study, Allahverdi and Akcan introduced a sophisticated decision support system that leverages fuzzy logic and genetic algorithms to optimize treatment planning within periodontal therapy. By integrating patient preferences alongside established clinical guidelines, these AI-driven tools for treatment planning not only enhance adherence to prescribed interventions but also contribute to the improvement of long-term oral health outcomes.[11]

AI in patient management and followup

The longitudinal monitoring of patients' oral health status and their responses to treatment is essential for effective disease management and the prevention of recurrence; in this context, AI technologies, including natural language processing (NLP) and predictive analytics, can proficiently analyze electronic health records (EHRs) and patient-reported outcomes to meticulously track disease progression and assess the efficacy of therapeutic interventions.[5] For instance, Krois et al. pioneered an AI-based platform designed for the real-time monitoring of periodontal parameters and patient-reported symptoms. By embedding these AI-driven monitoring systems into standard clinical practice, healthcare professionals are empowered to detect early indicators of disease recurrence and initiate timely interventions, thereby mitigating the risk of complications.[12]

AI in Implantology

a) Treatment planning

AI technology offers significant assistance to clinicians encountering challenges in the comprehensive evaluation of cone-beam computed tomography (CBCT) scans, which are crucial for meticulous implant planning and the identification of anatomical structures. In the context of modern prosthetically driven Implantology, three-dimensional (3D) dental implant placement has become indispensable, and AI facilitates the decision-making process for dental practitioners, serving as a valuable asset in the planning of dental implants.[13]

b) Detection of implant type

In the event of complications arising with the implants or their associated components, it may become necessary to undertake additional surgical, periodontal, or prosthetic interventions. During these instances, comprehensive information—including but not limited to the specific implant length, diameter, platform design, manufacturer details, and type of abutment—will be essential for effective management and resolution of the issues encountered. If the implant treatment have been administered at an alternate clinic and the treating provider is unreachable, the process of acquiring the necessary information can become quite cumbersome, complicating any subsequent care or interventions. The use of AI for the detection of the implant brand can be a solution in such cases.[13] In their systematic review and meta-analysis, Chaurasia et al. documented a remarkable range of accuracy, from 70.75% to 98.19%, in the identification and classification of various dental implant systems (DISs) based on periapical and panoramic radiographs, as derived from an analysis of nine distinct studies utilizing deep learning models.[14] A systematic review conducted by Revilla-León et al. revealed that artificial intelligence models developed for the purpose of identifying implant types from radiographic images demonstrated an impressive accuracy range of 93.8% to 98%, representing a significant advancement in the application of AI technologies within the field of implantology.[15]

c) Prediction of treatment outcomes

The precise prediction of therapeutic outcomes in implant dentistry is essential for optimizing patient care, and it is anticipated that AI will assume a pivotal role in enhancing this predictive capability through advanced analytical methodologies and data-driven insights. Previous research has employed neural networks to effectively model and predict the risk associated with implant loss, leveraging sophisticated algorithms to analyze complex datasets and identify potential contributing factors. In a systematic review conducted by Revilla-León et al., it was found that the accuracy of AI algorithms in predicting the success of dental implants or the process of osseointegration varied significantly, ranging from 62.4% to 80.5%, thereby highlighting the variability in predictive performance across different models and methodologies.[15]

Advantages of AI[16]

- Gives accurate and updated information
- Facilitates the automation of tasks including appointment scheduling, patient monitoring, acquisition of clinical data, and provision of personalized treatment guidance, thereby enhancing efficiency and support in patient care management.
- Conserves time and resources through the automation of critical procedures, thereby enabling clinicians to dedicate more attention to patient examinations and diagnostic assessments, ultimately improving the accuracy and timeliness of disease identification.
- Supports research efforts by aggregating extensive data from a diverse array of sources, facilitating comprehensive analysis and insights.

Disadvantages of AI[16]

- Requires human oversight, as AI functions based on logical reasoning rather than emotional understanding or empathy.
- Could contribute to unemployment and raise equity concerns, particularly if healthcare professionals face job displacement after investing significant time and resources in their education and training.
- Privacy concerns

AI's Limitations in Periodontology & Implantology

Suboptimal or inaccurate treatment recommendations and predictive outcomes may result from training data that is insufficient, biased, or of poor quality, potentially compromising patient care and decision-making accuracy.[17] Moreover, the rapidly evolving landscape of Implantology and periodontal disease management may challenge AI systems, as they may struggle to continuously adapt to the frequent updates and advancements required to remain clinically relevant and effective. Additionally, AI algorithms are often unable to account for nuanced patient preferences, emotional considerations, and complex clinical judgments, all of which are essential factors in providing tailored care within specialized dental treatments.[18]

Conclusion

This comprehensive review provides a detailed exploration of how machine learning techniques are being increasingly integrated into the field of Periodontology, highlighting their potential to transform diagnostic, prognostic, and therapeutic approaches within dental care. Despite existing challenges and inherent limitations, the rapid evolution of artificial intelligence technologies presents remarkable opportunities to enhance precision, streamline workflows, and elevate personalized treatment approaches in periodontal practice, paving the way for transformative advancements in patient care and clinical outcomes. To fully unlock the potential of AI in dentistry, especially in periodontology and implantology, more research is essential. The advancement and seamless integration of these technologies into clinical practice will rely heavily on coordinated efforts among researchers, dental practitioners, and technology developers, fostering a multidisciplinary approach to drive innovation and implementation.

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An Overview of GF-MoR Complexes in Periodontal and Peri-Implant Diseases and Conditions

Ummu Salma[1], Anjoom CT[2], Safwana PP[3], Deepak Thomas[4], Sreekanth Puthalath[5], Deepu Mathews Panickal[6]

ABSTRACT

Periodontal and peri-implant diseases remain major challenges in oral health. These conditions are driven by complex microbial communities that upset the delicate equilibrium between health and illness. For decades, Socransky's bacterial complexes introduced in 1998 have been the gold standard for identifying and classifying oral pathogens. However, with advances in DNA sequencing and microbiome research, we now recognize many additional bacteria that play a crucial role in oral health and disease. They aren't included in the original framework, and there was no peri-implant focus in earlier classifications. This gap has led researchers to propose an updated classification system, GF-MoR complexes, which better reflects today's understanding of oral microbiology and aids clinicians and researchers by offering a more relevant and updated bacterial grouping system for diagnostic and therapeutic applications, including peri-implant diseases.

Keywords: GF-MoR's complexes, Socransky's complexes, microorganisms, dysbiosis

Introduction

The human body functions as a superorganism, home to trillions of microorganisms that play essential roles in maintaining health and, at times, contribute to disease. Pathobionts form as a result of complex interactions between genetic, microbial, host, and environmental variables that disturb the healthy microbiota.[1]

The oral microbiome alone includes more than 800 bacterial species that have been identified in oral samples by DNA-based analysis. In various micro niches within the oral cavity, they form multiple species complexes. Several factors contribute to the growth of microorganisms in the oral cavity. The temperature range in the oral cavity is 35- 37 °C, which provides stable conditions suitable for the growth of a wide range of microorganisms.[2]

Periodontal disease is prevalent worldwide. One of its earliest stages, gingivitis, is a mild form of inflammation limited to the gingival tissue, affecting nearly 90% of the population.

Fortunately, gingivitis can be reversed if microbial deposits are thoroughly removed. However, if left untreated, gingivitis may progress to periodontitis, a more severe condition characterized by irreversible loss of clinical attachment and destruction of alveolar bone. This progression typically occurs in susceptible individuals with certain risk factors that compromise the immune response. The chronic inflammation seen in periodontitis arises from the destructive host immune response to dysbiotic microbial changes triggered by ecological disturbances.[3]

Understanding how the composition of the oral microbiome changes from healthy to gingivitis and periodontitis has been a persistent area of research. Even if the host response is modified by a number of factors, early diagnosis and prevention of periodontal disease depend on the identification of certain microbial challenges linked to its onset and progression. Earlier research employing low-throughput measurement methods such as microarrays, PCR analysis, and

[1,2,3]Post Graduate Student, [4]Professor, [5]Professor and HOD, [6]Reader, Department of Periodontics, Educare Institute of Dental Sciences, Malappuram. Corresponding Author: Dr Ummu Salma, Email: salma.mts@gmail.com

checkerboard hybridization has not fully characterized the composition of the oral microbiome.[4]

History

1. It was Willoughby D.miller (1890), the first to apply germ theory to dentistry, who proposed that microorganisms cause oral disease, including periodontal inflammation.
2. Non-specific plaque hypothesis, Harold Loe et al (1965).
3. Specific plaque hypothesis, Walter Loesche (1976).
4. Ecological plaque hypothesis Philip D. Marsh (1994)
5. Landmark study: Socransky et al (1998), used DNA-DNA hybridization to classify subgingival bacteria, grouping periodontal pathogens into 5 color-coded complexes based on their association with disease severity. It was the first systematic classification of periodontal pathogens, which laid the foundation for understanding oral pathogens.[5]
6. Key stone pathogen hypothesis and polymicrobial synergy and dysbiosis (PSD) model, Hajishengallis et al, 2012, which gravitates around the potential role of P. gingivalis and its virulence factors in orchestrating inflammatory conditions in the periodontium that convert a symbiotic microbiota into a dysbiotic one.[6]
7. Inflammation-Mediated-Polymicrobial-Emergence and Dysbiotic-Exacerbation (IMPEDE) Model (2020): Inflammation is the hallmark of the dysbiotic events.[7]

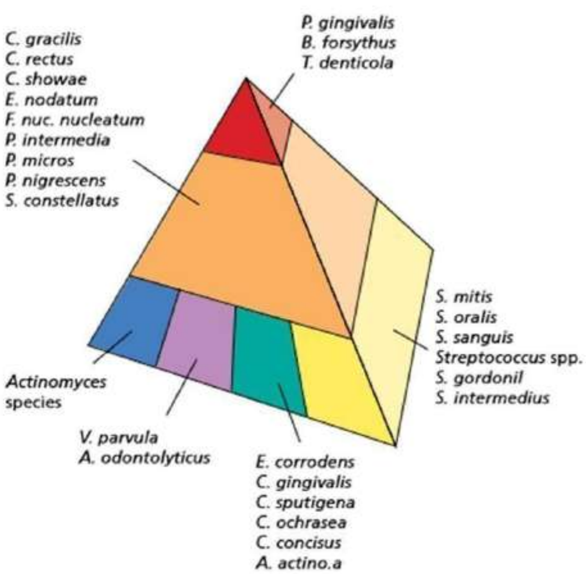

Fig. 1. Socransky's complexes

Advances in technology (16SrRNA sequencing, metagenomics, and next generation sequencing), which allow precise bacterial identification, lead to the discovery of many novel pathogens and the recognition of dysbiosis rather than single pathogens. Despite these developments, the original framework has remained largely unchanged, prompting the need for an updated model that accommodates this broader microbial spectrum.[8]

Socransky's complexes

In the landmark study, Socransky et al. (1998) examined 13,261 samples of subgingival plaque from 185 adult participants. They demonstrated the existence of particular microbial communities in the tooth plaque by employing community ordination and DNA hybridization techniques. In the plaque sample, 40 subgingival taxa were identified by checkerboard DNADNA hybridization and whole genomic DNA probes. Five complexes were formed from these organisms based on the presence of microorganisms and related periodontal status[5].

Blue complex was adapted later.

- **1st complex (Red complex):** *Tannerella forsythia, Porphyromonas gingivalis, and Treponema denticola.*
- **2nd complex (Orange complex):** *Eubacterium nodatum, Campylobacter rectus, Campylobacter showae, Streptococcus constellatus, and Campylobacter gracilis.*
- **3rd complex (Yellow complex):** *Streptococcus sanguis. S. oralis, S. mitis, S. gordonii, and S. intermedius.*
- **4th complex (Green complex):** *Campylobacter concisus, Eikenella corrodens, and Actinobacillus actinomycetemcomitans serotype a.*
- **5th complex (purple complex):** *Veillonella parvula and Actinomyces odontolyticus.*

The clinical parameters most significant in periodontal diagnosis, such as probing depth and bleeding on probing, had the strongest correlation with the red complex and its component species.[5]

GF-MoR complexes: [General Framework for Microorganism organization and Relationships]

A new framework for understanding bacterial associations in periodontal and periimplant diseases. It was introduced in 2024 by Fernandes et al., which focuses on the latest understanding of microbial communities involved in periodontal and peri-implant diseases and conditions. It expands upon Socransky's classification, incorporating bacteria identified in the most recent research. This includes bacteria found not only in periodontitis and healthy tissue, but also in gingivitis, peri-implant mucositis, peri-implantitis, necrotizing periodontitis, and molar-incisor pattern periodontitis. The authors created GF-MoR complexes using a structured search of research from 1998 to 2024. A total of 153 human studies were included, and bacteria were ranked based on their frequency of occurrence in each condition.[8]

The seven most significant bacteria in all 6 groups are gram-negative, which include:

1. HEALTH: 58 species(blue)

36 gram-negative bacteria and 22 gram-positive bacteria

1. *Campylobacter rectus (5.56%)*
2. *Porphyromonas gingivalis (5.56%)*
3. *Prevotella intermedia (5.56%)*
4. *Tannarela forsythia (5.56%)*
5. *Bacteroidales spp. (3.33%)*
6. *Leptotrichia spp. (3.33%)*
7. *Porphyromonas spp. (3.33%)*

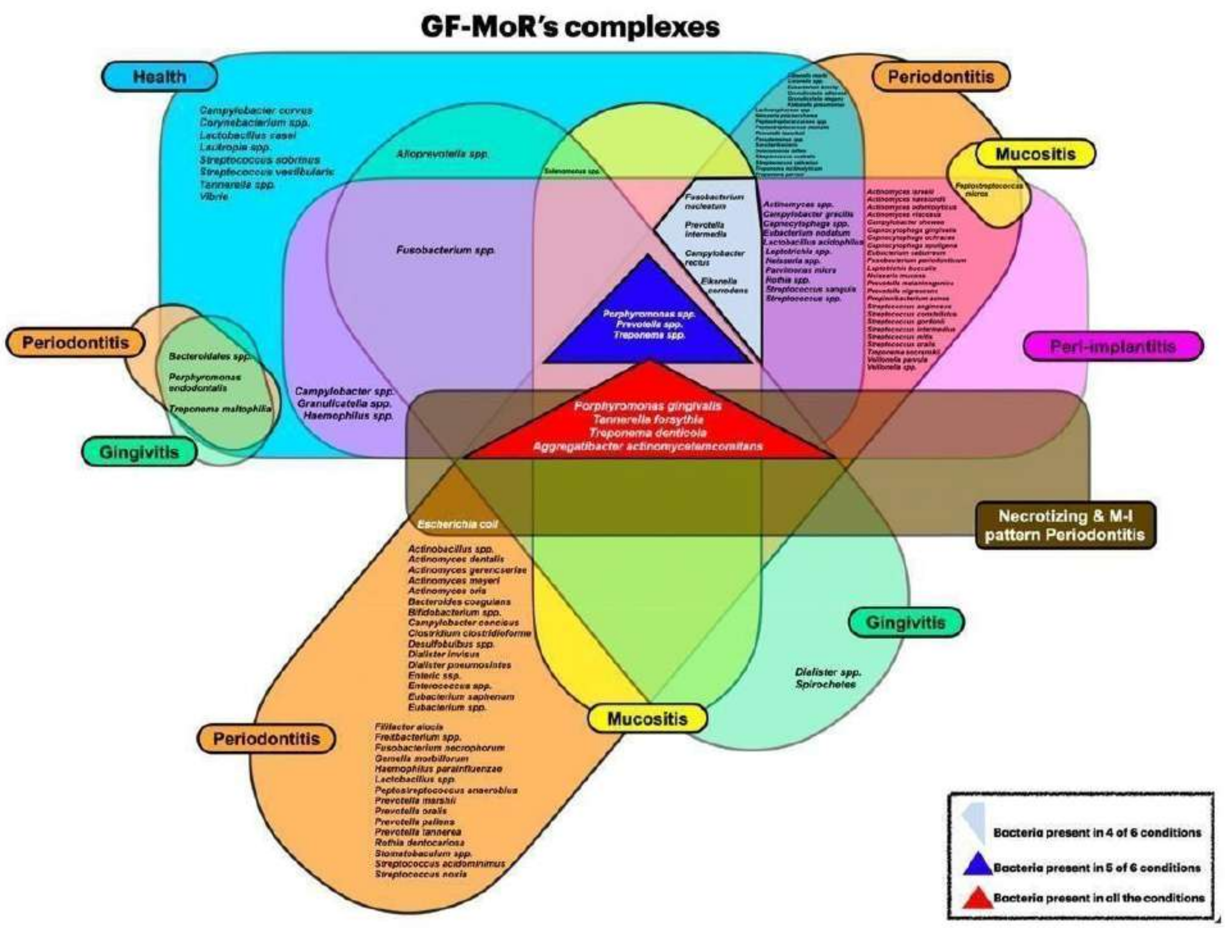

Fig. 2. GF -MoR complexes organized according to bacteria in different clusters.

2. GINGIVITIS: 16 species(green)

All 16 spp are gram-negative

1. *Prevotella spp. (25%)*
2. *Treponema spp. (9.38%)*
3. *Aggregatibacter actinomycetemcomitans (6.25%)*
4. *Fusobacterium spp. (6.25%)*
5. *Porphyromonas gingivalis (6.25%)*
6. *Porphyromonas spp. (6.25%)*
7. *Selenomas spp. (6.25%)*

3. PERI-IMPLANT MUCOSITIS: 17 species (yellow)

14 gram-negative and 3 gram-positive

1. *Prevotella spp. (12%)*
2. *Treponema denticola (12%)*
3. *Tannarela forsythia (12%),*
4. *Aggregatibacter actinomycetemcomitans (8%)*
5. *Fusobacterium nucleatum (8%)*
6. *Porphyromonas gingivalis (8%)*
7. *Prevotella intermedia (8%)*

4. PERIODONTITIS: 101 species(orange)

54 gram-negative and 47 gram-positive

1. *Porphyromonas gingivalis (11.12%)*
2. *Aggregatibacter actinomycetemcomitans (10.3%)*
3. *Tannarela forsythia (8.43%)*
4. *Prevotella intermedia (7.61%)*
5. *Fusobacterium nucleatum (7.14%)*
6. *Treponema denticola (6.44%)*
7. *Campylobacter rectus (3.4%)*

5. PERI-IMPLANTITIS: 61 species(purple)

34 gram-negative and 27 gram-positive

1. *Fusobacterium nucleatum (9.38%)*
2. *Tannarela forsythia (7.81%),*

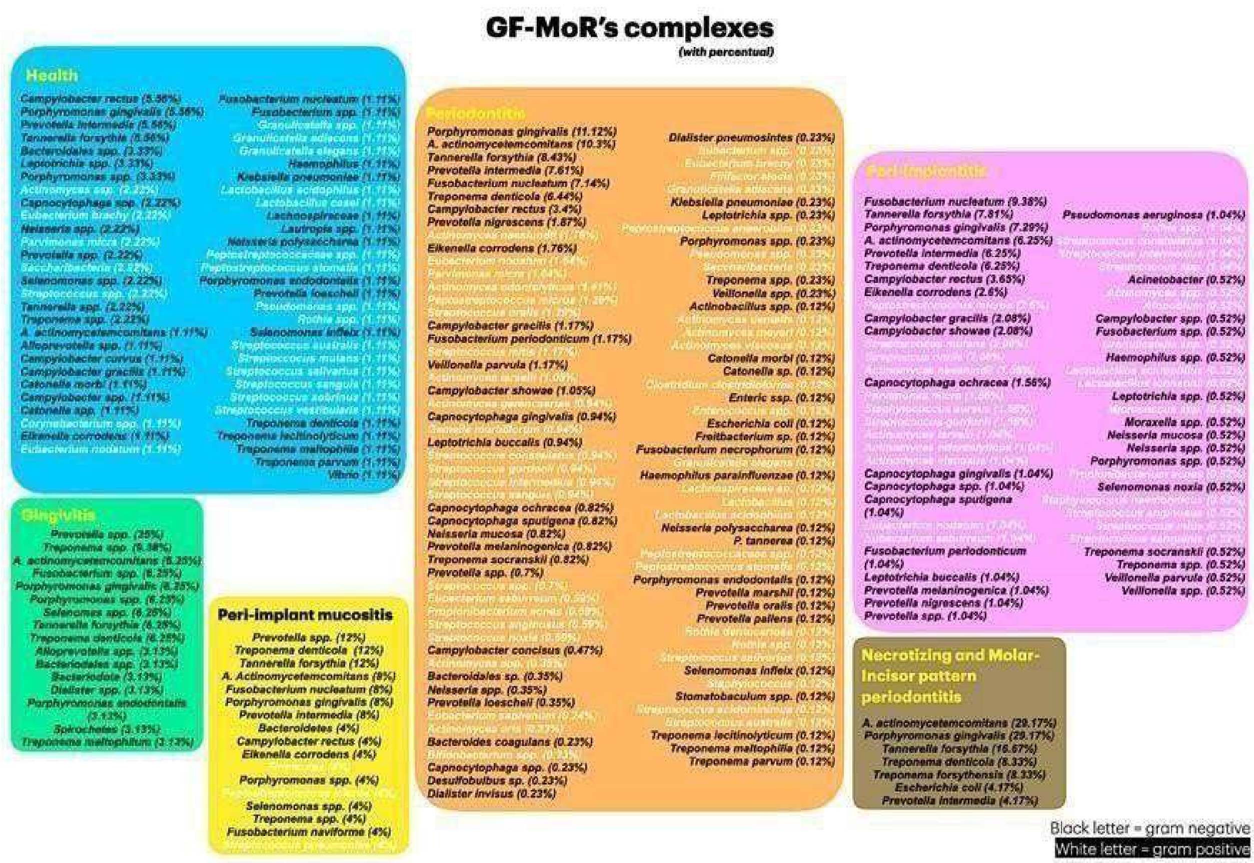

Fig. 3. Bacteria organized by citation frequency across different periodontal and peri-implant conditions.

3. *Porphyromonas gingivalis (7.29%)*
4. *Aggregatibacter actinomycetemcomitans (6.25%)*
5. *Prevotella intermedia (6.25%)*
6. *Treponema denticola (6.25%)*
7. *Campylobacter rectus (3.65%)*

6. NECROTIZING AND MOLAR–INCISOR (M-I) PATTERN PERIODONTITIS: 7 species (brown)

All 7 spp are gram-negative

1. *Aggregatibacter actinomycetemcomitans (29.17%)*
2. *Porphyromonas gingivalis (29.17%)*
3. *Tannarela forsythia (16.67%)*
4. *Treponema denticola (8.33%)*
5. *Treponema forsythensis (8.33%)*
6. *Escherichia coli (4.17%)*
7. *Prevotella intermedia (4.17%)*

THE 3 GEOMETRIC CLUSTERS

1. RED TRIANGLE (universal pathogens) present in all conditions

- *Porphyromonas gingivalis*
- *Tannerella forsythia*
- *Treponema denticola*
- *Aggregatibacter actinomycetemcomitans*

BLUE TRIANGLE (2nd most observed)5 out of 6 conditions

- *Porphyromonas spp*
- *Prevotella spp*
- *Treponema spp*

GREY POLYGON (3rd most observed)4 out of 6 conditions

- *Fusobacterium nucleatum*
- *Prevotella intermedia*
- *Campylobacter rectus*
- *Eikenella corrodens*

The red triangle of the GF-MoR complex reflects the microbial composition of Socransky's red complex, along with the addition of *Aggregatibacter actinomycetemcomitans.*

These are associated with GF-MoR's grey polygon (Socransky's orange complex bacteria). It is possible to confirm that the red triangle of GF-MoR and Socransky's red complex are closely associated with the progression of periodontal and peri-implant diseases. This underscores the importance of considering the entire microbial ecosystem, rather than focusing solely on specific pathogens, when studying periodontal and peri-implant diseases.[8]

Aggregatibacter actinomycetemcomitans is given more importance in GF-MoR complexes than in Socransky complexes since it is present in every group, particularly in necrotizing and M-I pattern periodontitis (29.17%). Finding these bacteria in periodontal or peri-implant areas emphasizes the necessity of keeping an eye on microbial profiles in patients who have periodontitis or dental implants. A non-linear and accelerated pattern of illness evolution is made possible by the lack of treatment for any of the diseases under study.[8]

Drivers of dysbiosis

The oral microbiota is in dynamic equilibrium with the host; a change in any key parameter that influences microbial growth can perturb this equilibrium and determine whether the oral microbiota will have a symbiotic or dysbiotic relationship with the host. Synergistic interactions between several bacterial species emphasize the polymicrobial nature of the organism, intensifying the inflammatory response and accelerating the course of disease. A framework for comprehending the interactions between various bacterial species in periodontal disorders is provided by the idea of polymicrobial synergy and dysbiosis (PSD). According to this model, the presence of some bacteria might increase the pathogenic potential of others[9].

The dynamic interaction between the host immune response and microbial community is crucial in the progression of disease. Eg. The inflammatory response is intensified when *P. gingivalis* coexists with other microorganisms. It has been shown to elicit a profound effect on the quantitative and qualitative composition. *P. gingivalis* drives dysbiosis of the normally benign oral microbiota into a community structure responsible for the tissue and bone destruction. The fact that these changes may occur when low numbers of *P. gingivalis* were present led to the proposal that this bacterium may be considered a keystone pathogen with elevated disease potential above that anticipated for a low-abundance species.[9] It should be noted that the existence of these "keystone pathogens" alone might not be enough to start a disease because the host's reaction to the microbiome is altered by genetic and environmental factors that are still poorly understood.[10]

As the pioneer species in the formation of biofilms, Streptococcus first adheres to the surfaces of teeth, allowing other bacteria to attach.[11] *Streptococcus* and *Actinomyces* collaborate to form a mature biofilm structure. Haemophilus works with Streptococcus and Actinomyces to maintain the stability of the oral ecosystem, [12] which together form the backbone of early dental plaque. As a secondary colonizer, *Veillonella* engages in a mutualistic interaction with Streptococcus. *Veillonella* sustains other bacterial species in the biofilm by using lactic acid produced by Streptococcus as a carbon source. *Fusobacterium* can co-adhere to most of the oral bacteria and act as a "bridging" species between early colonizers and late-stage pathogenic bacteria by facilitating interspecies connections. It plays a role in modulating host immune responses, thereby promoting the dynamic equilibrium of the biofilm, and also contributes to the degradation of complex organic compounds, supporting the coexistence of various microbial communities. *Rothia spp,* recognized as a marker of oral health, is strongly linked to a balanced and healthy oral environment through its special nitrate reduction effect. It may also interact with the host immune system to suppress overactive inflammatory responses.[13]

Conclusion

Maintaining good oral health and preventing oral diseases are significantly influenced by the microbiota. One crucial first step in reducing the disease progression is the elimination of dental plaque. The likelihood of periodontal inflammation is considerably decreased with early treatment, which also helps maintain a healthy dental environment. Current treatment approaches include antibiotic therapy in conjunction with scaling, root planing, deep pocket debridement, and laser therapy to reduce the quantity of harmful bacteria present.[14]

Novel therapies using stem cells, gene therapy, photodynamic therapy, 3D printing and layered biostructures, and Oral microbiome transplantation, which may be able to alter oral microbiota and bring about a healthier state of ecological balance, are still in the laboratory research phase.[15] Probiotics may help to maintain a healthy oral microbiome, and integrating nitrate-based strategies into periodontal treatment represents an innovative approach.[16] Despite the promising results observed using probiotics, it has been attributed to heterogeneity in the mode of administration, frequency, dosage, and different treatment protocols across studies. Therefore, the use of probiotics in the treatment of periodontitis is still not recommended by the latest S3 treatment guideline.[17,18]

It is important to acknowledge that most of the studies are focused on health, periodontitis, and peri-implantitis, limiting the number of bacteria detected in other clusters, highlighting the need for further research in these areas. The increasing understanding of host/bacterial and interbacterial interactions may be used in future treatment plans to avoid periodontal dysbiosis and treat periodontitis.

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