CURRENT MULTIDISCIPLINARY APPROACHES IN DENTISTRY

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PREFACE

Scientific and technological developments in the field of dentistry have significantly transformed diagnostic and treatment approaches and have increased the importance of an interdisciplinary perspective in achieving clinical success. The adoption of current, evidence-based practices enables more predictable outcomes in both functional and aesthetic terms. This book aims to address contemporary approaches across various dental specialties from a holistic perspective.

Within this work, the effects of orthodontic forces on root resorption, the role of bulk-fill resin composites in restorative dentistry, the importance of the periodontal–prosthetic approach in anterior region aesthetics, nanotechnological applications in oral hygiene products, and personalized medical applications in the diagnosis and treatment of periodontal diseases are presented in light of the current literature.

This book is intended to serve as a valuable reference for academics, residents in dental specialties, and clinicians seeking to make scientifically grounded decisions in their clinical practice. I would like to express my sincere gratitude to all chapter authors who contributed to the preparation of this work and to the staff of UBAK Publishing for their meticulous management of the publication process.

Sincerely,

16.12.2025

Assist. Prof. Dr. Fatma ALTIPARMAK

EDITOR

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CHAPTER 1

EFFECT OF ORTHODONTIC FORCES ON ROOT RESORPTION

Res. Assist. Kazım Kaan YILDIZ
Res. Assist. Fatma Selenay UÇAŞ YILDIZ

INTRODUCTION

Orthodontic treatment is a biomechanical process that involves the application of certain forces to the teeth in order to correct malocclusions and provide aesthetic and functional improvement. However, this process may also cause some undesirable biological side effects on teeth and surrounding tissues. One of these side effects is root resorption occurring on the tooth root surface (Yassir et al., 2021).

Root resorption is a pathological process with a multifactorial etiology that is frequently observed, especially during orthodontic treatment. Resorption is characterised by the destruction of cement and dentin tissues and is usually irreversible. Clinically, it is often asymptomatic, but in advanced cases it may adversely affect the prognosis of the tooth (Heboyan et al., 2022).

The magnitude, duration, and type of force applied, anatomical features of the tooth, individual biological response, and genetic factors play an important role in the development of root resorption due to orthodontic treatment. In recent years, numerous histological, radiographic and molecular studies have been conducted to better understand these mechanisms (Dawood et al., 2023).

In this chapter, the mechanisms of root resorption during orthodontic treatment, factors affecting it and prevention strategies will be discussed in the light of current literature.

1. Definition and Classification of Root Resorption

Root resorption is a process characterised by the destruction of cementum and dentine tissues on the tooth root surface due to physiological or pathological causes. Under normal conditions, the cementum layer and periodontal ligament present on the root surface act as a protective barrier against resorptive cells. However, when this barrier is compromised, the resorption process may begin.

The mechanical forces applied during orthodontic treatment can cause cellular and biochemical changes in the periodontal tissues, paving the way for root resorption. In this process, cells similar to odontoclasts and osteoclasts become particularly active (Nakai et al., 2023).

Root resorption can be classified clinically and histologically in different ways:

- Superficial Resorption:
  - Occurs in small, limited areas.
  - It usually heals spontaneously and is clinically asymptomatic.

- Substitutional Resorption:
    - The resorbed root surface is replaced by bone tissue.
    - It is mostly observed after trauma.
- Inflammatory Resorption:
    - Develops as a result of pulpal or periodontal inflammation.
    - It is the most common type in root resorption due to orthodontic forces.
- Cervical Resorption:
    - It starts from the cervical region of the root surface.
    - It may be difficult to detect clinically and may be progressive.

The most common type of resorption encountered during orthodontic treatment is inflammatory root resorption. This type of resorption begins with damage to the cementum layer on the root surface, followed by the migration of resorptive cells (particularly cells similar to odontoclasts and osteoclasts) to the area. The pressure and hypoxia that develop in the periodontal ligament in the area where orthodontic forces are applied trigger a cellular inflammatory response. Various biochemical mediators, such as cytokines, prostaglandins, and enzymes, are released during this process. These mediators increase the activation of resorptive cells, leading to tissue loss on the root surface (Iglesias-Linares & Hartsfield, 2017).

The severity and extent of inflammatory resorption are influenced by numerous factors, including the magnitude of the applied orthodontic force, the duration of the force, the type of force (continuous or intermittent), and the individual biological response. Particularly in cases of high-intensity and long-term force application, the ischaemic areas formed in the periodontal tissues become larger and the resorption process becomes more pronounced.

Additionally, individual anatomical and genetic characteristics can also influence this process. For example, a thin and conical root morphology, a history of trauma, or systemic factors can increase susceptibility to root resorption (Dindaroğlu & Doğan, 2016).

Consequently, inflammatory root resorption, prolonged orthodontic treatment duration, the use of inappropriate force levels, and patient-specific biological sensitivities can become a more pronounced and clinically significant problem.

2. The Biological Mechanism of Root Resorption During Orthodontic Treatment

The forces applied to the teeth during orthodontic treatment trigger a series of biomechanical and biological events in the alveolar bone and periodontal ligament. As a result of the applied force, areas of pressure and tension are created in the periodontal tissues. This differentiated microenvironment causes cellular responses to begin within the tissue and leads to the release of biochemical mediators (Cornelis et al., 2008).

The fundamental step in the initiation of resorption is the reduction in blood flow in the pressure zone of the periodontal ligament and the resulting hypoxic environment. Hypoxia initiates an inflammatory response in local cells and creates an environment that facilitates the activation of osteoclast-like resorptive cells. Macrophages, lymphocytes, fibroblasts, and osteoclasts are involved in this process. IL-1β, TNF-α, RANKL, prostaglandin E2 (PGE2), and matrix metalloproteinases (MMPs) released by cells play a key role in the progression of the resorption process (Krishnan & Davidovitch, 2006)

Under normal conditions, the cement surface is resistant to resorption because the protective layer of cementoblasts and presementum prevents resorptive cells from attaching. However, when this protective layer is damaged as a result of force application, odontoclasts attach to the cement surface, forming Howship lacunae. These lacunae are microscopic resorption areas where cementum and dentine tissue are destroyed (Brezniak & Wasserstein, 1993).

As resorption progresses, the dentine beneath the cementum layer also begins to resorb. If this process continues clinically for a long time, root shortening may occur. When the body's natural healing mechanisms are activated, the resorption area can be recoated by cementoblasts and reparative cementum can form. However, this is not always complete; particularly when prolonged and high-intensity forces are applied, irreversible resorption areas may remain (Weltman et al., 2010).

The biological mechanism of resorption is largely similar to osteoclastic bone resorption. Therefore, in orthodontic treatment planning, the risk of root resorption can be reduced by considering the magnitude of force, duration of application, and individual differences in biological response.

3. Factors Affecting Root Resorption

The development and severity of root resorption during orthodontic treatment is determined by a combination of mechanical factors, biological factors, and patient-specific individual characteristics. Therefore, commencing treatment without risk assessment may pave the way for irreversible root shortening (Levander & Malmgren, 1988).

3.1. Magnitude and Duration of Orthodontic Force

The intensity of the applied orthodontic force is one of the most important determining factors in the development of root resorption. High forces create larger ischaemic areas in the periodontal ligament and increase resorptive cell activity. This situation can lead to significant root shortening, particularly with long-term force application. The literature reports that light forces optimise the biological response, whereas high forces significantly increase the risk of resorption (Owman-Moll et al., 1996).

3.2. Force Type (Continuous vs. Intermittent Forces)

The type of force is also an important factor affecting the resorption process. In cases of continuous force application, there is insufficient time for periodontal tissues to heal, and resorptive activity increases. In contrast, intermittent forces have been shown to allow tissues time to remodel and reduce the risk of resorption. Therefore, maintaining force within physiological limits is of great clinical importance (Arias & Marquez-Orozco, 2006).

3.3. Treatment Duration

The prolongation of orthodontic treatment is another important factor that increases the risk of root resorption. Prolonged force application causes a continuous inflammatory response in the periodontal ligament, and resorption areas may merge over time, leading to clinically significant root shortening.

3.4. Morphological Characteristics of Teeth

Root morphology (conical or short roots), tooth position and periodontal ligament thickness are also factors affecting the risk of resorption. In conical-rooted teeth, pressure concentrates in certain areas, increasing the risk of resorption. Furthermore, this risk is higher in teeth with a history of trauma or in devitalised teeth.

3.5. Genetic and Systemic Factors

Recent studies have shown that genetic factors play an important role in the development of root resorption. In particular, polymorphisms in the IL-1β, TNF-α and RANKL genes can cause different levels of sensitivity among individuals by determining the severity of the inflammatory response. Additionally, systemic conditions such as asthma, hypothyroidism, or autoimmune diseases may also increase the risk of resorption (Dawood et al., 2023).

4. Clinical Findings and Diagnosis of Root Resorption

Root resorption developing during orthodontic treatment is a silent process that often progresses without clinical symptoms. Therefore, early detection of resorption is possible through routine clinical check-ups and radiological follow-up. Early diagnosis is crucial in preventing progressive resorption (Brezniak & Wasserstein, 1993).

4.1. Clinical Findings

Although root resorption is usually asymptomatic, the following findings may be observed in some cases:

- Mild tooth mobility (especially in advanced stages),
- Percussion sensitivity,
- Long treatment duration or history of high force application,
- Radiographic root shortening without increase in periodontal pocket depth.

These findings are more suspicious than diagnostic. Radiological examinations are necessary for definitive diagnosis.

4.2. Radiological Diagnostic Methods

The most commonly used method for diagnosing root resorption is radiographic examination. The main techniques used are as follows:

- **Periapical Radiography:** This is the most commonly used method in clinical practice. A series of periapical radiographs taken before, during, and after treatment are particularly important for monitoring resorption. However, as it is a two-dimensional imaging technique, it may not show the full extent of the resorption areas.
- **Panoramic Radiography:** Can be used for general assessment, but has low sensitivity in detecting early stages of resorption.
- **Cone Beam Computed Tomography (CBCT):** CBCT allows for three-dimensional assessment of resorption areas. It has high sensitivity, particularly in detecting small areas of resorption in the early stages. However, due to the higher radiation dose, it is preferred in suspected cases rather than for routine use (Durack & Patel, 2012).

4.3. Classification of Resorption and Assessment Scales

The Levander and Malmgren Classification is one of the most commonly used systems for the clinical assessment of root resorption. This classification is based on radiographic findings:

- Grade 0: No resorption

- Grade 1: Minor cement resorption

- Grade 2: Cement and mild dentin resorption

- Grade 3: Moderate root resorption

- Grade 4: Severe root shortening

This classification helps clinicians monitor the progression of resorption and modify the treatment plan as necessary (Levander & Malmgren, 1988).

5. Prevention and Management of Root Resorption

It may not always be possible to completely prevent root resorption during orthodontic treatment; however, the severity of this condition can be significantly reduced by controlling risk factors and applying appropriate biomechanical principles. Preventing resorption is a combination of accurate diagnosis, careful treatment planning and regular follow-up (Sameshima & Sinclair, 2001)

5.1. Pre-Treatment Risk Assessment

One of the most important steps in preventing resorption is identifying high-risk patients prior to treatment. Individuals with a history of dental trauma or those with short or conical roots are at higher risk of resorption. Therefore, prior to orthodontic treatment:

- Detailed dental anamnesis,
- Clinical examination,
- Periapical radiographs or CBCT examination should be performed.

Thanks to these assessments, the clinician can formulate the treatment plan in a more controlled manner (Mirabella & Artun, 1995).

5.2. Arrangement of the Force Application Protocol

One of the most effective ways to reduce the risk of resorption is the use of light and controlled orthodontic forces.

- Excessive force applications should be avoided.

- Forces should be within physiological limits as much as possible.

- Intermittent force applications may be preferred because they allow periodontal tissues to heal.

In addition, as the risk of resorption increases with prolonged treatment, it is of great importance not to prolong the treatment unnecessarily. (Owman-Moll et al., 1996).

5.3. Radiological Monitoring During Treatment

Since resorption is mostly asymptomatic, routine radiological control is indispensable for early diagnosis.

- In the mild risk group: Periapical radiography every 6-12 months after the start of treatment,

- High risk group: More frequent radiographic evaluation is recommended.

In the case of resorption detected at an early stage, it is possible to stop the progression by reducing the force or temporarily interrupting the treatment (Brezniak & Wasserstein, 1993; Keller et al., 2017).

5.4. Biological and Pharmacological Approaches (Current Research)

Recent studies have focused on controlling root resorption at the biological level.

- Anti-inflammatory agents,

- RANKL inhibitors,

- Regulation of vitamin D level,

- Methods such as genetic susceptibility testing are being investigated, especially in high-risk individuals.

Although most of these methods have not yet entered routine clinical practice, they are expected to play an important role in individualised orthodontic treatment in the future. (Keller et al., 2017; Krishnan & Davidovitch, 2006).

5.5. Management Strategies When Resorption Develops

If clinically or radiologically significant resorption is detected during treatment:

- The force should be reduced or treatment should be temporarily suspended.

- The treatment plan should be reviewed.

- If necessary, treatment should be terminated and periodontal tissues should be allowed to heal.

- In advanced cases, a multidisciplinary approach (endodontics and periodontology consultation) may be required (Weltman et al., 2010; Yassir et al., 2021).

6. Treatment of Root Resorption

Root resorption developing during orthodontic treatment is often mild and may remain stable without requiring additional treatment or may partially heal with reparative cement formation. However, in cases of advanced resorption, establishing an appropriate treatment plan is critical for the long-term prognosis of the tooth (Pandis et al., 2008).

6.1. Reduction of Orthodontic Force or Suspension of Treatment

When root resorption is detected, the first and most important approach is to reduce the applied force or to temporarily interrupt the treatment.

- In mild resorption (Grade 1-2), the progression of resorption may stop with force reduction.

- In moderate or advanced resorption (Grade 3-4), treatment may be interrupted for 3-6 months. During this period, periodontal tissues are allowed to heal and cementoblast activity is allowed to resume. (Brudvik & Rygh, 1993).

6.2. Modification or Termination of Orthodontic Treatment

If resorption is significant and threatens the prognosis of the tooth, the treatment plan should be reviewed.

- In mild cases, it may be sufficient to reduce the force or change the direction of movement.

- In severe cases, early termination of treatment may be considered. This decision is especially important for short-rooted incisors in the anterior region.

- After termination of treatment, the tooth should be stabilised as functionally as possible and monitored (Brezniak & Wasserstein, 1993).

6.3. Endodontic Approaches (Advanced Cases)

In cases where root resorption progresses to the pulp or pulpal necrosis develops, endodontic treatment may be required as well as interruption of orthodontic treatment.Pulpa vitalitesi kaybolmuşsa kanal tedavisi uygulanır.

- If the resorption area is limited, restorative treatment with MTA or bioceramic materials can be performed.

- Surgical approach may be required in advanced cervical or external inflammatory resorption (Weltman et al., 2010).

6.4. Pharmacological and Biological Supportive Therapies

Considering the biological processes of resorption, some support approaches are being investigated in addition to treatment:

- Anti-inflammatory agents (e.g. NSAIDs) may reduce the inflammatory response.

- RANKL inhibitors may suppress osteoclast activity.

- Vitamin D and calcium balance may favour bone and cement metabolism.

- In the future, genetically targeted therapies may play an important role in individualised orthodontic planning (Arias & Marquez-Orozco, 2006).

6.5. Long-Term Monitoring

After the treatment of root resorption is completed:

- The vitality, mobility and radiographic status of the tooth should be monitored regularly.

- It is recommended to check every 6 months for the first 1 year and annually in the following periods.

- The prognosis is generally good in stable cases. However, careful retention plan should be made in advanced cases (Cornelis et al., 2008).

7. Conclusion

Orthodontic treatment is an effective method for correcting malocclusions, but it can cause undesirable biological side effects in the teeth and surrounding tissues. The most significant of these side effects is inflammatory root resorption, which often progresses silently but can adversely affect tooth prognosis in advanced stages. Root resorption is a direct result of the effect of orthodontic forces on biological tissues and has a multifactorial aetiology.

Development of resorption;

- Magnitude and type of force,

- Duration of treatment,

- Morphological features of the tooth,

- Individual biological response and

- Genetic factors play a decisive role.

Therefore, individualised protocols should be applied in treatment planning rather than a one-size-fits-all approach. The use of light and controlled forces, avoiding unnecessary prolongation of treatment duration, regular radiological follow-up, and identification of risk factors prior to treatment are fundamental strategies in preventing root resorption.

When root resorption is detected, the initial approach should be to reduce the force or suspend treatment. In advanced cases, endodontic or surgical treatments may be necessary. Therefore, early diagnosis is of great importance. Advanced imaging methods such as CBCT enable the detection of resorption in its early stages, helping to preserve the prognosis of the tooth.

Current research has revealed that root resorption is closely related not only to mechanical but also to biological and genetic processes. In the future, genetic predisposition testing, targeted biological treatments, and new biomaterials may make it more feasible to control resorption.

In conclusion, root resorption is a preventable or controllable complication. For this, it is crucial that clinicians master biomechanical principles, properly assess risk factors, perform regular follow-ups, and apply multidisciplinary approaches when necessary.

REFERENCES

Arias, O. R., & Marquez-Orozco, M. C. (2006). Aspirin, acetaminophen, and ibuprofen: their effects on orthodontic tooth movement. Am J Orthod Dentofacial Orthop, 130(3), 364-370. https://doi.org/10.1016/j.ajodo.2004.12.027

Brezniak, N., & Wasserstein, A. (1993). Root resorption after orthodontic treatment: Part 1. Literature review. Am J Orthod Dentofacial Orthop, 103(1), 62-66. https://doi.org/10.1016/0889-5406(93)70106-x

Brudvik, P., & Rygh, P. (1993). Non-clast cells start orthodontic root resorption in the periphery of hyalinized zones. Eur J Orthod, 15(6), 467-480. https://doi.org/10.1093/ejo/15.6.467

Cornelis, M. A., Scheffler, N. R., Nyssen-Behets, C., De Clerck, H. J., & Tulloch, J. F. (2008). Patients' and orthodontists' perceptions of miniplates used for temporary skeletal anchorage: a prospective study. Am J Orthod Dentofacial Orthop, 133(1), 18-24. https://doi.org/10.1016/j.ajodo.2006.09.049

Dawood, H. M., Kroeger, A., Chavda, V., Chapple, I. L. C., & Kebschull, M. (2023). Under pressure—mechanisms and risk factors for orthodontically induced inflammatory root resorption: a systematic review. European Journal of Orthodontics, 45(5), 612-626. https://doi.org/10.1093/ejo/cjad011

Dindaroğlu, F., & Doğan, S. (2016). Root Resorption in Orthodontics. Turk J Orthod, 29(4), 103-108.

https://doi.org/10.5152/TurkJOrthod.2016.16021
Durack, C., & Patel, S. (2012). Cone beam computed tomography in endodontics. Braz Dent J, 23(3), 179-191. https://doi.org/10.1590/s0103-64402012000300001
Heboyan, A., Avetisyan, A., Karobari, M. I., Marya, A., Khurshid, Z., Rokaya, D., Zafar, M. S., & Fernandes, G. V. O. (2022). Tooth root resorption: A review. Sci Prog, 105(3), 368504221109217. https://doi.org/10.1177/00368504221109217
Iglesias-Linares, A., & Hartsfield, J. K., Jr. (2017). Cellular and Molecular Pathways Leading to External Root Resorption. J Dent Res, 96(2), 145-152. https://doi.org/10.1177/0022034516677539
Keller, B., La Harpe, R., & García-Sevilla, J. A. (2017). Upregulation of IRAS/nischarin (I(1)-imidazoline receptor), a regulatory protein of μ-opioid receptor trafficking, in postmortem prefrontal cortex of long-term opiate and mixed opiate/cocaine abusers. Neurochem Int, 108, 282-286. https://doi.org/10.1016/j.neuint.2017.04.017
Krishnan, V., & Davidovitch, Z. (2006). Cellular, molecular, and tissue-level reactions to orthodontic force. Am J Orthod Dentofacial Orthop, 129(4), 469.e461-432. https://doi.org/10.1016/j.ajodo.2005.10.007
Levander, E., & Malmgren, O. (1988). Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. Eur J Orthod, 10(1), 30-38. https://doi.org/10.1093/ejo/10.1.30

Mirabella, A. D., & Artun, J. (1995). Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients. Am J Orthod Dentofacial Orthop, 108(1), 48-55. https://doi.org/10.1016/s0889-5406(95)70065-x

Nakai, Y., Praneetpong, N., Ono, W., & Ono, N. (2023). Mechanisms of Osteoclastogenesis in Orthodontic Tooth Movement and Orthodontically Induced Tooth Root Resorption. J Bone Metab, 30(4), 297-310. https://doi.org/10.11005/jbm.2023.30.4.297

Owman-Moll, P., Kurol, J., & Lundgren, D. (1996). The effects of a four-fold increased orthodontic force magnitude on tooth movement and root resorptions. An intra-individual study in adolescents. Eur J Orthod, 18(3), 287-294. https://doi.org/10.1093/ejo/18.3.287

Pandis, N., Nasika, M., Polychronopoulou, A., & Eliades, T. (2008). External apical root resorption in patients treated with conventional and self-ligating brackets. Am J Orthod Dentofacial Orthop, 134(5), 646-651. https://doi.org/10.1016/j.ajodo.2007.01.032

Sameshima, G. T., & Sinclair, P. M. (2001). Predicting and preventing root resorption: Part I. Diagnostic factors. Am J Orthod Dentofacial Orthop, 119(5), 505-510. https://doi.org/10.1067/mod.2001.113409

Weltman, B., Vig, K. W., Fields, H. W., Shanker, S., & Kaizar, E. E. (2010). Root resorption associated with orthodontic tooth movement: a systematic review. Am J Orthod Dentofacial

Orthop, 137(4), 462-476; discussion 412A. https://doi.org/10.1016/j.ajodo.2009.06.021

Yassir, Y. A., McIntyre, G. T., & Bearn, D. R. (2021). Orthodontic treatment and root resorption: an overview of systematic reviews. Eur J Orthod, 43(4), 442-456. https://doi.org/10.1093/ejo/cjaa058

CHAPTER 2

THE ROLE of BULK-FILL RESIN COMPOSITES in RESTORATIVE APPROACHES

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INTRODUCTION

Nowadays, polymer-based compounds are frequently preferred as dental restorative materials due to their favorable physical, mechanical, and thermal properties (Yadav & Kumar, 2019). The increasing aesthetic demands in restorative dentistry have led to a significant rise in the use of resin-based composite restorative materials (Chesterman et al., 2017). However, polymerization shrinkage stress in these materials remains a major disadvantage, as it affects the integrity of the tooth–restoration interface (Gonçalves et al., 2011; Han et al., 2016). Polymerization shrinkage of resin composites occurs as monomers convert into a polymer network (Al Sunbul et al., 2016), and this process is accompanied by shrinkage stress, a multifactorial phenomenon influenced by factors such as volumetric contraction, viscoelastic behavior, and reaction kinetics (Braga et al., 2005). Shrinkage during polymerization can lead to issues such as marginal gaps, secondary caries, and postoperative sensitivity (Yenier Yurdagüven, 2025).

The layering (incremental) technique used for application of resin composite restorative materials into cavities was developed to reduce polymerization shrinkage of conventional light-cured resin composite, achieve a more uniform degree of conversion, prevent marginal deterioration, and ensure adequate aesthetics (Arbildo-Vega et al., 2020). When a split horizontal incremental technique is applied to the gingival margin of a cavity, lower levels of microleakage have been reported (Roopa & Anupriya, 2011). In Class II restorations, applying an oblique placement technique following the split horizontal incremental method at the occlusal margin has shown the lowest microleakage levels (Chandrasekhar et al., 2017). In the incremental technique, resin composite is placed and cured in 2 mm-thick layers within the cavity. This method is time-consuming and can lead to air entrapment between the composite layers (Arbildo-Vega et al., 2020), which may result in interlayer adhesive failures (Guney & Yazici, 2020). Additionally, it can pose challenges when restoring more conservative cavities and is associated with an increased risk of contamination (Guney & Yazici, 2020). The literature has also reported that increasing the number of layers can lead to higher elastic modulus and greater post-polymerization shrinkage (Almeida Junior et al., 2017; Versluis et al., 1996).

Bulk-fill resin composite have been developed to address the limitations of conventional light-cured resin composites. Manufacturers have introduced various strategies to minimize polymerization shrinkage while achieving greater depth of cure. To this end, bulk-fill composites utilize increased translucency and alternative photoinitiator systems to ensure adequate monomer conversion, while adjustments in monomer structure and enhanced interactions with fillers aim to reduce polymerization shrinkage stress at the cavity margins (Van Ende et al., 2017; Ilie et al., 2014; Fronza et al., 2015). These materials are designed to allow restorations to be applied in a single step with thicknesses of up to 4–5 mm (Kim et al., 2015; Fugolin & Pfeifer, 2017).

Bulk-fill resin composites offer advantages such as reduced treatment time, potentially lower volumetric shrinkage stress, and increased depth of cure while maintaining micromechanical properties (Guney & Yazici, 2020). The polymerization shrinkage of bulk-fill materials has been mitigated through the incorporation of stress-modulating components, including high-molecular-weight monomers such as AFM, AUDMA, BisEMA, UDMA, BisGMA, and Procrylate, as well as highly reactive photoinitiators (Fugolin & Pfeifer, 2017). Optimization of the initiator system and the addition of fillers—such as zirconium/silica, ytterbium trifluoride, proacrylate, mixed oxides, and barium aluminum silicate—have enhanced the radiopacity and depth of cure of these materials (Fugolin & Pfeifer, 2017). The depth of polymerization is further increased by reducing filler loading and/or improving filler particle size to minimize light scattering (Haugen et al., 2020).

The increasing demand for bulk-fill composites among clinicians has led to greater commercial diversity. Bulk-fill composites are available in two forms: high-viscosity and low-viscosity (Kim et al., 2015; Fugolin & Pfeifer, 2017). Generally, low-viscosity bulk-fill composites have a lower filler content; however, some materials can achieve a flowable consistency through sonic activation despite having a high filler load (e.g., SonicFill) (Tomaszewska et al., 2015).

High-Viscosity Bulk-Fill Resin Composites

High-viscosity bulk-fill composites generally have a higher filler content and can be used either to cover low-viscosity, softer bulk-fill composites or to fill the entire restoration on their own (Haugen et al., 2020; Shimokawa et al., 2019).

These high-viscosity bulk-fill composites are formulated with photoinitiator systems compatible with the wavelength of light-curing devices (Zorzin et al., 2015). These photoinitiator systems enhance the material’s translucency, allowing light to penetrate deeper layers and thereby contributing to more efficient polymerization.

The advantages of these materials include simplified restorative procedures, time savings, low polymerization shrinkage stress depending on manufacturer-specific technology, and adequate radiopacity (Silva et al., 2023; Tomaszewska et al., 2015). However, the bulk application technique may have some drawbacks, as it can be associated with adhesive bond failure and larger shrinkage vectors (Kaisarly et al., 2021).

Low-Viscosity Bulk-Fill Resin Composites

Low-viscosity bulk-fill composites generally have a lower filler content and are suitable for use as a base layer or in small restorations (Haugen et al., 2020; Shimokawa et al., 2019).

These materials are typically placed into the cavity using fine-tipped applicators and provide superior adaptation to the cavity walls, effectively reducing the risk of void formation (Silva et al., 2023).

Low-viscosity bulk-fill composites exhibit limited wear resistance, mechanical strength, and color stability (Tomaszewska et al., 2015; Haugen et al., 2020). Early low-viscosity bulk-fill composites contained a higher resin matrix and fewer fillers compared to high-viscosity bulk-fill composites, and were generally used as a base layer, requiring an additional layer of conventional resin composite or high-viscosity bulk-fill composite on top of the restoration (Van Ende et al., 2013). However, in recent years, low-viscosity bulk-fill composites that can be applied alone intraorally have also become available (Arbildo-Vega et al., 2020).

Current Developments in Bullk-fill Resin Composites

Low-Viscosity Bulk-Fill Resin Composites Requiring Sonic Activation

These composites, including SonicFill™ and SonicFill 2™, are patented restorative materials with a high filler content and special modifiers (Sybron Dental Specialties Inc., 2012). These modifiers respond to sonic energy. When sonic energy is applied using a handpiece, the modifiers reduce the viscosity by up to 87%, increasing the composite's flowability and allowing for rapid placement and excellent adaptation to cavity walls (Sybron Dental Specialties Inc., 2012). Once the sonic energy is stopped, the composite returns to a more viscous, non-flowing state, creating an ideal condition for shaping (Selvaraj et al., 2023).

Fiber-Reinforced Bulk-Fill Resin Composites

Endodontically treated teeth are more prone to fracture due to reduced strength and fracture toughness. Loss of tooth structure, along with physical features such as cusps, crests, and the arched roof of the pulp chamber, contributes to this vulnerability (Eskitaşcioğlu et al., 2002). Preparations for endodontic access cavities increase cusp deflection, thereby raising the risk of cusp fracture during function (Eskitaşcioğlu et al., 2002).

In the restoration of endodontically treated teeth, the use of an optimal material with sufficient fracture resistance is a crucial factor for post-treatment rehabilitation. Next-generation fiber-reinforced composite materials structurally and chemically strengthen the weak tooth structure (Kemaloğlu et al., 2015). Fiber-reinforced composites can help prevent fractures in endodontically treated teeth (Kemaloğlu et al., 2015). Due to their enhanced physical and mechanical properties, these composites are recommended for replacing dentin biomimetically in large cavities and endodontically treated teeth (Kemaloğlu et al., 2015). They increase mechanical retention, inhibit crack spread, and establish a strong chemical bond between the glass fibers and the resin matrix (Kemaloğlu et al., 2015).

EverX Posterior bulk-fill composite is a combination of e-glass type short fibers and barium-containing glass fillers (Eskitaşcioğlu et al., 2002). According to the manufacturer, these short fiber-reinforced composites help strengthen post-endodontic restorations by reducing the occurrence of restoration fractures (Eskitaşcioğlu et al., 2002). EverX Posterior contains multidirectional, discontinuous fibers that replace dentin, enhance strength, and increase the material's load-bearing capacity (Eskitaşcioğlu et al., 2002; Kemaloğlu et al., 2015).

Characteristics of Bullk-fill Resin Composites

Depth of Cure and Degree of Conversion

Several studies have evaluated the depth of cure of low-viscosity bulk-fill resin composites. In the literature, the average depth of cure ranges from 2.76 mm to 10.05 mm (Benetti et al., 2015; Li et al., 2015).

The depth of cure of high-viscosity bulk-fill composites has also been evaluated in various studies, with the average cure depth reported to range between 2.90 and 3.82 mm (Benetti et al., 2015; Li et al., 2015).

Compared to conventional composites, low-viscosity bulk-fill composites have been reported to exhibit greater depth of cure, while high-viscosity bulk-fill resin composites showed similar depth of cure to conventional composites in one study and greater depth in another (Benetti et al., 2015; Li et al., 2015).

Tarle et al. (2015) reported that materials containing lower-viscosity monomers (Bis-EMA, UDMA) exhibited a higher degree of conversion compared to resin composites composed solely of Bis-GMA and TEGDMA. Additionally, UDMA monomers contain a built-in photoactive group that interacts with camphorquinone to optimize the polymerization process (Li et al., 2015). The manufacturer of Tetric EvoFlow Bulk Fill has replaced camphorquinone with an alternative initiator system based on benzoyl germanium derivatives, which demonstrate higher photo-initiation activity and remain efficient even at low light intensities (commercially known as Ivocerin) (Moszner et al., 2008).

Polymerization Shrinkage

In the bulk-fill technique, as cavity depth increases, both the distance that light must penetrate to reach the lower layers and the volume of resin restorative material used in the restoration also increase (Abed et al., 2015). Therefore, according to manufacturers' claims, bulk-fill resin composites exhibit greater depth of cure and lower polymerization-induced shrinkage stress compared to conventional light-cured resin composites (Yadav & Kumar, 2019). The reduction of shrinkage stress is achieved differently across commercial products; for example, through the incorporation of stress-relieving components (e.g., Tetric N-Ceram Bulk Fill, Tetric N-Flow Bulk Fill, Tetric EvoCeram Bulk Fill), polymerization modulators (e.g., SureFil SDR), or other methods not disclosed by the manufacturers (Tarle et al., 2015; Li et al., 2015).

In the literature, polymerization shrinkage of low-viscosity bulk-fill composites has been reported to range between 2.76% and 4.4% (Leprince et al., 2014; Kim et al., 2015). The average polymerization shrinkage of low-viscosity bulk-fill composites has been found to be higher than that of conventional light-cured composites (Chesterman et al., 2017).

For high-viscosity bulk-fill composites, polymerization shrinkage has been reported to range from 0.90% to 2.63% (Leprince et al., 2014; Mulder et al., 2013). The average polymerization shrinkage of high-viscosity bulk-fill composites has also been reported to be higher compared to conventional light-cured composites (Chesterman et al., 2017).

Surface Microhardness

According to the literature, the top surface microhardness of low-viscosity bulk-fill composites has generally been reported to be lower than that of conventional light-cured composites (Chesterman et al., 2017; Flury et al., 2014; Leprince et al., 2014; Alshali et al., 2013; Abed et al., 2015; Bucuta & Ilie, 2014; Garcia et al., 2014; Tarle et al., 2015).

Findings regarding the comparison of high-viscosity bulk-fill composites with conventional light-cured composites, however, are not consistent across studies. In the investigations conducted by Alshali et al. (2013) and Abed et al. (2015), high-viscosity bulk-fill composites demonstrated lower top surface microhardness values than conventional composites. Conversely, several other studies have reported comparable microhardness values between the two material types (Chesterman et al., 2017; Flury et al., 2014; Leprince et al., 2014; Bucuta & Ilie, 2014).

In some studies, only at a 6-mm depth performed with high-viscosity bulk-fill composites exhibit greater microhardness than conventional light-cured composites, while other studies noted higher microhardness across all tested depths (Flury et al., 2014; Garcia et al., 2014).

Flexural Strength

Studies evaluating the flexural strength of low-viscosity bulk-fill composites have reported that these materials exhibit lower flexural strength compared to conventional light-cured composites (Leprince et al., 2014; Flury et al., 2014).

According to the literature, the flexural strength values of high-viscosity bulk-fill composites are comparable to those of conventional composites (Leprince et al., 2014).

Commercial name/ Manufacturer	Classification	Matrix composition	Filler types	Filler load (wt.%)	Average particle size
Filtek Bulk Fill (3M ESPE, St Paul, MN, USA)	Nanofilled High viscosity bulk-fill	AUDMA, UDMA, DDDMA	Silica, Zirconia, ytterbium trifluoride	76.5	0.004-0.1µm

	composite				
Tetric EvoCeram Bulk Fill (Ivoclar Vivadent, NY, USA)	Nano hybrid High viscosity bulk-fill composite	Bis-GMA, UDMA, bis-EMA	Barium glass, ytterbium trifluoride, mixed oxide prepolymer	82-84	550nm
Opus Bulk Fill (FGM, Joinville, SC, Brasil)	Micro hybrid High viscosity bulk-fill composite	UDMA	Silanized silica dioxide	79	0.7–1µm
X-tra fil (VOCO GmbH,	Nano hybrid High viscos	Bis-GMA, UDMA, TEGDMA	Barium-boron-	86	0.05-10µm

Cuxhaven, Germany)	ity bulk-fill comp osite		alumi nosili cate glass		
QuiXfil (Dentsply, Konstanz, Germany)	Micro hybrid High viscos ity bulk-fill comp osite	UDMA, TEGDMA, di- & trimethacry-late resins, carboxylic acid-modified methacrylate resins	Silani zed stronti um-alumi num glass with the additi on of sodiu m fluori de	86	1 - 10µm
Admira Fusion x-tra (VOCO GmbH, Cuxhaven, Germany)	Nano hybrid High viscos ity bulk-	Ormocer	Bariu m-alu minu m-sili cate glass /	84	60% of the particulate is between 20-40nm

	fill composite		Silica nanoparticles		
Tetric N-Ceram Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein)	Nano hybrid High viscosity bulk-fill composite	Bis-GMA, bis-EMA, UDMA	Barium glass, ytterbium trifluoride	75-77	0.4-0.7µm
Beautifil-Bulk Restorative (Shofu Dental Corp. Kyoto, Japan)	Giomer High viscosity bulk-fill composite	Bis-GMA, UDMA, Bis MPEPP, TEGDMA	Pre-reacted glass-ionomer based fillers/ Barium-aluminum-sili	87	Unreported

			cate glass		
Ever X Posterior Bulk-fill (GC Dental, Alsip, IL, USA)	Fiber-reinforced bulk-fill composite	Bis-GMA, TEGDMA, PMMA	Barium glass, E-glass	74.2	0,1–2,2 µm
SonicFill (Kerr Corporation, Orange, CA, USA)	Nano hybrid Low viscosity bulk-fill resin composite with sonic activation	Bis-GMA, Bis-EMA, TEGDMA	Silicon dioxide, barium glass	83.5	Unreported
SonicFill 2, (Kerr Corporation,	Nano hybrid Low	TMSPMA, Bis-EMA, bisphenol-A-	Silicon dioxid	81.3	Unreported

Orange, CA, USA)	viscosity bulk-fill resin composite with sonic activation	bis-(2 hydroxy-3-methacryloxy propyl) ether, TEGDMA	e, barium glass		
Filtek Bulk Fill Flowable (3M ESPE, St Paul, MN, USA)	Micro hybrid Low viscosity bulk-fill resin composite	Bis-GMA, UDMA, substituted dimethacrylate, (BisEMA-6), & Procrylat resins	Zirconia/silica particles & ytterbium trifluoride fillers	64.5	0.01–5µm
SureFil SDR (Dentsply Caulk, Milford, USA)	Micro hybrid Low viscosity	UDMA, EBPDMA, TEGDMA	Barium alumino-fluoro	68	4.2µm

	bulk-fill resin composite		borosilicate glass		
Tetric EvoFlow Bulk Fill (Ivoclar Vivadent, NY, USA)	Nano hybrid Low viscosity bulk-fill resin composite	Bis-GMA, Bis-EMA, TCDD	Barium glass, ytterbium trifluoride, copolymers	68.2	0.1-30µm
Omnichroma Flow Bulk (Tokuyama Dental Corporation Inc., Tokyo, Japan)	Spherical supra-nano Low viscosity bulk-fill resin	UDMA ve 1,9-nonanediol dimetakrilat	Spherical supra-nano fillers	69	260 nm

	composite				
Venus Diamond Flow Bulk (Heraeus Kulzer, Germany)	Nano hybrid Low viscosity bulk-fill resin composite	UDMA, EBADMA	Ba-Al-F glass, YbF_3, SiO_2	65	20 nm-5 µm
G-aenial Bulk Injectable (GC Dental, Alsip, IL, USA)	Nanofilled Low viscosity bulk-fill composite	Methacrylate monomer system	Barium glass	69	150 nm
Activa Bioactive Bulk Flow (Pulpdent Corp.,	Bioactive Low viscosity	Ionic bioactive resin, Elastomeric resin,	Reactive ionomer glass	56	Unreported

Watertown, MA, USA)	bulk-fill resin composite	Reactive ionomer glass, Modulus, The ionic matrix releases Ca^{2+}, PO_4^{3-}, and F^- ions	(bioactive glass)

Table 1. Commercial names, classification, and compositional characteristics of bulk-fill composites *(*AUDMA: aromatic urethane dimethacrylate; UDMA: urethane dimethacrylate; DDDMA: 12-dodecanediol dimethacrylate; Bis-GMA: bisphenol-A-glycidyl-dimethacrylate; Bis-EMA: ethoxylated bisphenol-A-dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; Bis MPEPP: 2,2-bis(4-methacryloxypolyethoxyphenyl) propane; TMSPMA: 3-trimethoxysilylpropyl methacrylate; EBPDMA: ethoxylated bisphenol A dimethacrylate; TCDD: Tetrachlorodibenzo-p-dioxin; EBADMA: Ethoxylated bisphenol A dimethacrylate; Ba-Al-F glass: Barium alumino-fluorosilicate glass; YbF_3: İterbiyum triflorür; SiO_2: Silisyum dioksit)

Conclusion

Bulk-fill resin composites have been developed to overcome the limitations associated with conventional light-cured resin composites, particularly polymerization shrinkage, depth of cure, and technique sensitivity. Advances in monomer chemistry, photoinitiator systems, and filler technology have enabled these materials to be placed in thicker increments while maintaining adequate mechanical and physical properties. Low-viscosity bulk-fill composites generally provide superior cavity adaptation and greater depth of cure, although they tend to exhibit lower microhardness and flexural strength compared with conventional composites. High-viscosity bulk-fill composites, on the other hand, demonstrate mechanical performance closer to that of traditional restorative materials, although their behavior varies depending on the specific formulation and manufacturer. Fiber-reinforced and sonic-activated bulk-fill systems further expand clinical applications by enhancing fracture resistance and improving handling characteristics. Despite the advantages of reduced working time, simplified application, and improved polymerization behavior, the performance of bulk-fill composites remains material-dependent. Therefore, clinicians should carefully consider the physical properties, clinical indications, and manufacturer recommendations of each product to achieve predictable and durable restorative outcomes.

REFERENCES

Abed, Y., Sabry, H., & Alrobeigy, N. (2015). Degree of conversion and surface hardness of bulk-fill composite versus incremental-fill composite. Tanta Dental Journal, 12, 71–80.

Almeida Junior, L. J., Penha, K. J., Souza, A. F., Lula, E. C., Magalhães, F. C., Lima, D. M., et al. (2017). Is there correlation between polymerization shrinkage, gap formation, and void in bulk fill composites? A µCT study. Brazilian Oral Research, 31, e100.

Alshali, R. Z., Silikas, N., & Satterthwaite, J. D. (2013). Degree of conversion of bulk-fill compared to conventional resin composites at two time intervals. Dental Materials, 29, e213–e217.

Al Sunbul, H., Silikas, N., & Watts, D. C. (2016). Polymerization shrinkage kinetics and shrinkage-stress in dental resin-composites. Dental Materials, 32, 998–1006.

Arbildo-Vega, H. I., Lapinska, B., Panda, S., Lamas-Lara, C., Khan, A. S., & Lukomska-Szymanska, M. (2020). Clinical effectiveness of bulk-fill and conventional resin composite restorations: Systematic review and meta-analysis. Polymers, 12, 1786. https://doi.org/10.3390/polym12081786

Braga, R. R., Ballester, R. Y., & Ferracane, J. L. (2005). Factors involved in the development of polymerization shrinkage stress in resin composites: A systematic review. Dental Materials, 21, 962–970.

Bucuta, S., & Ilie, N. (2014). Light transmittance and micromechanical properties of bulk-fill vs. conventional resin-based composites. Clinical Oral Investigations, 18, 1991–2000.

Chandrasekhar, V., Rudrapati, L., Badami, V., & Tummala, M. (2017). Incremental techniques in direct composite restoration. Journal of Conservative Dentistry, 20, 386–391.

Chesterman, J., Jowett, A., Gallacher, A., & Nixon, P. (2017). Bulk-fill resin-based composite restorative materials: A review. British Dental Journal, 222, 337–344.

Corral-Núnez, C., Vildósola-Grez, P., Bersezio-Miranda, C., Alves-Dos Campos, E., Fernández, & Godoy, E. (2015). State of the art of bulk-fill resin-based composites: A review. Revista de la Facultad de Odontología Universidad de Antioquia, 27, 177–196.

El-Damanhoury, H., & Platt, J. (2014). Polymerization shrinkage stress kinetics and related properties of bulk-fill resin composites. Operative Dentistry, 39, 374–382.

Eskitaşcioğlu, G., Belli, S., & Kalkan, M. (2002). Evaluation of two post core systems using two different methods (fracture strength test and a finite element stress analysis). Journal of Endodontics, 28, 629–633.

Flury, S., Peutzfeldt, A., & Lussi, A. (2014). Influence of increment thickness on microhardness and dentin bond strength of bulk-fill resin composites. Dental Materials, 30, 1104–1112.

Fronza, B. M., Rueggeberg, F. A., Braga, R. R., Mogilevych, B., Soares, L. E. S., Martin, A. A., et al. (2015). Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. Dental Materials, 31(12), 1542–1551.

Fugolin, A. P. P., & Pfeifer, C. S. (2017). New resins for dental composites. Journal of Dental Research, 96, 1085–1091.

Garcia, D., Yaman, P., Dennison, J., & Neiva, G. (2014). Polymerization shrinkage and depth of cure of bulk-fill flowable composite resins. Operative Dentistry, 39, 441–448.

Garoushi, S., Vallittu, P., Shinya, A., & Lassila, L. (2016). Influence of increment thickness on light transmission, degree of conversion and microhardness of bulk-fill composites. Odontology, 104(3), 291–297.

Guney, T., & Yazici, A. (2020). 24-month clinical evaluation of different bulk-fill restorative resins in class II restorations. Operative Dentistry, 45, 123–133.

Han, S. H., Sadr, A., Tagami, J., & Park, S. H. (2016). Internal adaptation of resin composites at two configurations: Influence of polymerization shrinkage and stress. Dental Materials, 32(9), 1085–1094.

Haugen, H. J., Marovic, D., Par, M., Khai Le Thieu, M., Reseland, J. E., & Johnsen, G. F. (2020). Bulk-fill composites have similar performance to conventional dental composites. International Journal of Molecular Sciences, 21, 5136.

Ilie, N., Bucuta, S., & Draenert, M. (2013). Bulk-fill resin-based composites: An in vitro assessment of their mechanical performance. Operative Dentistry, 38(6), 618–625.

Ilie, N., Schöner, C., Bücher, K., & Hickel, R. (2014). An in-vitro assessment of the shear bond strength of bulk-fill resin composites to permanent and deciduous teeth. Journal of Dentistry, 42(7), 850–855.

Jang, J., Park, S., & Hwang, I. (2015). Polymerization shrinkage and depth of cure of bulk-fill resin composites and highly filled flowable resin. Operative Dentistry, 40, 172–180.

Kaisarly, D., El Gezawi, M., Keßler, A., Rösch, P., et al. (2021). Shrinkage vectors in flowable bulk-fill and conventional composites: Bulk versus incremental application. Clinical Oral Investigations, 25, 1127–1139.

Kemaloğlu, H., Kaval, M. E., Türkün, M., & Kurt, S. M. (2015). Effect of novel restoration techniques on the fracture resistance of teeth treated endodontically: An in vitro study. Dental Materials Journal, 34, 618–622.

Kim, E. H., Jung, K. H., Son, S. A., Hur, B., et al. (2015). Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. Restorative Dentistry & Endodontics, 40, 128–135.

Kim, R. J.-Y., Kim, Y.-J., Choi, N.-S., & Lee, I. B. (2015). Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. Journal of Dentistry, 43, 430–439.

Leal, A., Paula, A., Ramalho, A., Esteves, M., Ferreira, M. M., & Carrilho, E. (2015). Roughness and microhardness of composites after different bleaching techniques. Journal of Applied Biomaterials & Functional Materials, 13(4), 381–388.

Leprince, J. G., Palin, W. M., Vanacker, J., Sabbagh, J., Devaux, J., & Leloup, G. (2014). Physico-mechanical characteristics of commercially available bulk-fill composites. Journal of Dentistry, 42, 993–1000.

Li, X., Pongprueksa, P., Van Meerbeek, B., & De Munck, J. (2015). Curing profile of bulk-fill resin-based composites. Journal of Dentistry, 43, 664–672.

Moszner, N., Fischer, U. K., Ganster, B., et al. (2008). Benzoyl germanium derivatives as novel visible light photoinitiators for dental materials. Dental Materials, 24(7), 901–907.

Mulder, R., Grobler, S. R., & Osman, Y. I. (2013). Volumetric change of flowable composite resins due to polymerization as measured with an electronic mercury dilatometer. Oral Biology and Dentistry, 1, 1.

Operative Dentistry, 45, 123–133.

Roopa, R., & Anupriya, B. (2011). Effect of four different placement techniques on marginal microleakage in class II restorations: An in vitro study. World Journal of Dentistry, 2, 111–116.

Rosatto, C., Bicalho, A., Veríssimo, C., Bragança, G., Rodrigues, M., Tantbirojn, D., et al. (2015). Mechanical properties, shrinkage stress, cuspal strain and fracture resistance of molars restored with bulk-fill composites and incremental filling technique. Journal of Dentistry, 43, 1519–1528.

Selvaraj, H., Krithikadatta, J., Shrivastava, D., et al. (2023). Fracture resistance of endodontically treated posterior teeth restored with fiber-reinforced composites: A systematic review. BMC Oral Health, 23, 566.

Shimokawa, C., Giannini, M., André, C. B., Sahadi, B. O., Faraoni, J. J., Palma-Dibb, R. G., et al. (2019). In vitro evaluation of surface properties and wear resistance of conventional and bulk-fill resin-based composites after brushing with a dentifrice. Operative Dentistry, 44(6), 637–647.

Siliva, G., Marto, C. M., Amaro, I., Coelho, A., Sousa, J., Ferreira, M. M., et al. (2023). Bulk-fill resins versus conventional resins: An umbrella review. Polymers, 15(12), 2613.

Son, S. A., Park, J. K., Seo, D. G., Ko, C. C., & Kwon, Y. H. (2017). How light attenuation and filler content affect microhardness, polymerization shrinkage and translucency of bulk-fill composites. Clinical Oral Investigations, 21(2), 559–565.

Tarle, Z., Attin, T., Marovic, D., et al. (2015). Influence of irradiation time on subsurface degree of conversion and microhardness of high-viscosity bulk-fill resin composites. Clinical Oral Investigations, 19(4), 831–840.

Tomaszewska, I. M., Kearns, J. O., Ilie, N., & Fleming, G. J. (2015). Bulk fill restoratives: To cap or not to cap–that is the question. Journal of Dentistry, 43(3), 309–316.

Van Ende, A., De Munck, J., Lise, D. P., et al. (2017). Bulk-fill composites: A review of the current literature. Journal of Adhesive Dentistry, 19(2), 95–109.

Van Ende, A., De Munck, J., Van Landuyt, K. L., Poitevin, A., et al. (2013). Bulk-filling of high C-factor posterior cavities: Effect on adhesion to cavity-bottom dentin. Dental Materials, 29, 269–277.

Versluis, A., Douglas, W., Cross, M., & Sakaguchi, R. (1996). Does an incremental filling technique reduce polymerization shrinkage stresses? Journal of Dental Research, 75, 871–878.

Yadav, R., & Kumar, M. (2019). Dental restorative composite materials: A review. Journal of Oral Bioscience, 61, 78–83.

Yenier Yurdagüven, G. (2025). Bulk Fill Resin Composites in Restorative Dentistry: A Review Article of In Vivo Studies. Dental and Medical Journal – Review, 7(3), 175–187.

Zorzin, J., Maier, E., Harre, S., Fey, T., et al. (2015). Bulk-fill resin composites: Polymerization properties and extended light curing. Dental Materials, 31, 293–301.

CHAPTER 3

THE IMPORTANCE OF THE PERIODONTAL-PROSTHETIC APPROACH IN ANTERIOR REGION AESTHETICS

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INTRODUCTION

Dental anomalies such as discolouration, shape and positional abnormalities, and morphological changes observed in the anterior region can cause aesthetic problems. Furthermore, tooth loss due to periodontal disease and trauma also constitutes a significant aesthetic and functional problem for patients. Dental trauma is most commonly seen in the upper anterior region, particularly in the incisors. A multidisciplinary approach involving surgical, orthodontic, endodontic, periodontal, and prosthetic applications may be necessary for the treatment of such problems in the anterior region.

Conservative treatment approaches should be prioritised in aesthetic restorations to preserve the natural tooth structure and ensure long-term success. Advances in restorative dental materials have contributed to the widespread use of conservative approaches in aesthetic restorations (Özbayram & Yanıkoğlu, 2016).

1. Aesthetic Zone Periodontal Biology and Soft Tissue Dynamics

1.1. Periodontal Phenotype

Periodontal tissues are one of the fundamental elements that ensure the functional and aesthetic integrity of the oral structure. The gingiva plays a critical role in maintaining oral health due to its unique biological and morphological characteristics. Today, increasing aesthetic expectations highlight the importance of gingival morphology not only in terms of periodontal health but also in terms of dental aesthetics. The success of aesthetic restorations is closely related to the thickness, contour, and phenotype of the gingival tissue, as well as the positioning of the teeth and the properties of the restorative materials.

Gingival thickness and phenotype are among the fundamental parameters that must be considered in planning periodontal treatments and predicting clinical outcomes. Findings in the literature increasingly suggest that gingival phenotype can directly influence treatment success, particularly in periodontal surgery, implant applications, aesthetic zone restorations, and regenerative treatments. Therefore, the accurate assessment of gingival structure and its integration into clinical decisions is considered a key factor in achieving optimal functional and aesthetic outcomes (Araújo & Lindhe, 2005; Chapple et al., 2013; Hatipoğlu & Hatipoğlu, 2022).

1.2. Papilla Morphology and Bone Contour

Gingival phenotype is a term used to describe the thickness of the gingiva in the bucco-lingual direction and the width of the keratinised tissue. Gingival morphology tends to mimic the underlying bone structure, indicating that gingival phenotype is directly related to the shape and structure of the bone (Araújo & Lindhe, 2005). Gingival phenotype varies between individuals and can also vary between different tooth regions in the same individual. For example, the thickness and phenotypes of the gums in the anterior teeth may differ from those in the posterior teeth, particularly in the aesthetic region (Kim et al., 2020).

The gingival phenotype varies depending on the tooth number, shape, position, and morphological characteristics of the underlying bone. Furthermore, genetic factors and environmental factors also play an important role in determining gingival phenotype. Genetic factors determine the inheritance of distinct characteristics of an individual's gingival structure, while environmental factors can have significant effects on gingival health. For example, periodontal diseases or smoking can affect the gingival phenotype (Calsina et al., 2002).

Individual characteristics such as age and gender are also important factors in shaping the gingival phenotype. Generally, atrophy and thinning of the gingival tissue can be observed with advancing age. Gender differences can also influence the gingival phenotype; some differences in gingival thickness and morphology have been reported between women and men (Furuta et al., 2011).

Research conducted in previous years has utilised various criteria to classify gingival phenotypes in order to understand the morphological diversity of periodontal tissues. This classification is generally based on two main phenotypes: thin scalloped and thick flat.

The thin scalloped phenotype is characterised by a thin gingival structure and a narrow keratinised gingival band. In this phenotype, the buccal bone thickness is generally thin, and the vertical difference between the approximal bone level and the vestibular bone level is pronounced. Furthermore, in the thin scallop phenotype, the teeth are typically long, thin, and conical in shape, with contact points located close to the incisal edge. This results in long and thin papillae (Kim et al., 2020).

On the other hand, in the thick flat phenotype, the gingiva is more voluminous and wider, and the gingival margin is thick. The buccal bone wall is thicker, and the vertical distance between the buccal bone and the approximal crest apex is shorter. In this phenotype, the teeth are generally square in shape, and the contact points are more apical and widely spaced. Therefore, the papillae are shorter and wider. In general, long and narrow teeth are associated with the thin phenotype, while wide crowns with wide proximal contacts are associated with the thick phenotype.

However, some studies have demonstrated that there is no significant relationship between the crown-to-root ratio and periodontal phenotype, or between crown morphology and bone morphology. This suggests that gingival phenotype is not only dependent on the morphological characteristics of the teeth and bone structure, but also on genetic factors and environmental influences. This diversity in gingival morphology can have important clinical implications for periodontal treatment planning and implant applications (Araújo & Lindhe, 2005; Aşık et al., 2020).

2. Periodontology-Prosthetic Planning Principles

2.1. Diagnosis and Analysis

Before commencing treatment, a comprehensive analysis process must be carried out in order to achieve aesthetically predictable and successful results. During this process, the shape, size, colour and proportional relationships between the teeth, as well as intraoral parameters such as the dental midline, buccal corridor and incisal and cervical embrasures, must be evaluated in detail. Furthermore, the analysis of soft tissue characteristics such as the gingival level, gingival contours, interdental papilla form, and gingival smile is an integral part of aesthetic planning. In addition, extraoral factors such as incisal length, incisal angle, smile line, static and dynamic positions of the lips, and smile symmetry must be taken into account. Taking into account facial morphology, the golden ratio, optical properties, and characteristics related to the patient's age and gender ensures that the planned restorations achieve a natural and aesthetic appearance that is compatible with the face. Systematically performing all these assessments prior to treatment is essential for achieving satisfactory results in terms of function, biology, and aesthetics (Fradeani & Barducci, 2008; Lombardi, 1973).

Each of these parameters plays a decisive role in creating a functional and natural smile that is compatible with facial aesthetics. In this regard, modern smile design requires an interdisciplinary approach based not only on objective aesthetic and functional criteria but also on the patient's subjective aesthetic expectations (Coachman & Calamita, 2012).

2.2. Intraoral Aesthetic Analyses

2.2.1. Shape and Size of Teeth

The shape and size of the front teeth should be in aesthetic harmony with the overall size and morphology of the face. Although it is difficult to categorise tooth shapes into definitive classes, there is a meaningful relationship between tooth and facial shapes. To achieve this aesthetic harmony, the geometric form of the face is determined, and the teeth are designed to fit this form. In 1914, Dr James Leon Williams classified face shapes into three groups: triangular, square, and ovoid, and stated that tooth shapes should also fit this classification (Çalıkkocaoğlu Senih, 1998).

Anterior tooth morphology is also related to gender. Teeth with more rounded contours are observed in women, while more angular and sharp-edged teeth are observed in men; however, these differences do not have clear boundaries.

In the aesthetic perception of teeth, not only shape but also the ratio between sizes is important. The ratios between teeth themselves and between teeth and the face are generally explained by the concept of the golden ratio. In addition, tooth colour, surface form and arrangement affect the perceived size of teeth. Light-coloured teeth appear larger than dark-coloured teeth, and teeth with flat surfaces appear wider than teeth with convex surfaces. Teeth positioned at the front appear larger and lighter in colour compared to those at the back (DOĞAN, 2020).

2.2.2. Midline

The harmony between the facial midline and the dental midline is one of the fundamental criteria in the evaluation of dental aesthetics. The dental midline is among the most important aesthetic parameters in defining the symmetry plane of the maxilla (B. P. Silva et al., 2018).

There are differing views in the literature regarding the position of the dental midline. Some researchers argue that the dental midline should coincide with the facial midline based on anatomical references such as the interincisive papilla and labial frenulum, while others state that it is not possible for these two lines to coincide completely due to anatomical and functional reasons. Furthermore, it has been reported that in the majority of individuals, the maxillary and mandibular dental midlines do not coincide (KOZAK & TUNA, 2022).

2.2.3. Buccal Corridor

The buccal corridor is defined as the space between the vestibular surfaces of the maxillary posterior teeth and the labial commissures during smiling and is classified into three groups: wide, medium, and narrow. There is no consensus in the literature regarding the effect of the buccal corridor on smile aesthetics. Some studies report that buccal corridor width affects aesthetic perception, while other studies indicate that it has no significant effect (Machado, 2014).

2.2.4. Incisal and Cervical Embrasures

As we progress from the central teeth towards the canines, the contact areas shift apically in relation to the anatomical structure. Therefore, it is aesthetically important that the transitions in the size and depth of the incisal embrasures are natural and gradual. The apical positioning of contact points should exhibit a transition that is compatible with the smile line (DOĞAN, 2020).

Furthermore, the darkness of the oral cavity should not be visible from the interproximal triangle between the contact area and the gingiva. In some cases, long contact areas extending towards the cervical region support the formation of a healthy, sharp, knife-edge interdental papilla instead of blunt tissue contours, thereby enhancing aesthetic and biological harmony (CHU et al., 2009).

2.2.5. Tooth Colour

Newly erupted teeth have a high organic content in the surface enamel layer and lower mineralisation; therefore, the enamel structure is more porous and exhibits a chalky and opaque appearance. Over time, as the surface enamel wears away, the underlying more densely mineralised structure becomes visible. Age-related enamel loss increases the optical effect of the underlying dentine tissue. Older dentine exhibits a darker colour with dominant green-blue tones, while younger dentine is observed in yellow-red tones. Furthermore, the larger pulp chamber in younger individuals contributes to the teeth being perceived as warmer and more reddish (Fondriest, 2003).

2.2.6. Golden Ratio

The golden ratio is accepted as a mathematical ratio that defines aesthetic harmony and a balanced relationship between two unequal parts. In aesthetic dentistry applications, it is frequently used as a fundamental reference in the evaluation of symmetry, visual dominance and proportion (A. D. O. Silva et al., 2022).

2.3. Extraoral Analyses

2.3.1. Incisal Length

The incisal length of the maxillary central incisors is a fundamental determining factor in creating an aesthetic smile. Once the ideal position of the incisal edge has been determined, the adjustment of the gingival levels and the creation of proportional relationships between the teeth are planned with the incisal edge as a guide.

In teeth with excessively long crowns, crown reduction may be indicated to correct a lengthened tooth appearance caused by periodontal reasons or in cases of disproportionate tooth/crown length. Conversely, incisal edge lengthening is preferred in cases of incisal wear, short crown length, or aesthetically inadequate tooth/crown ratio. The patient's age, gender, and upper lip length and slope should be considered when determining the incisal edge length. The average anatomical crown length of the maxillary central incisor is between 10.4 and 11.2 mm. With ageing, the visibility of maxillary teeth decreases due to upper lip sagging and incisal wear, while the visibility of mandibular teeth increases due to decreased lower lip tone and the effect of gravity (Gürel, 2004).

The relationship between the incisal edge and the lower lip and the evaluation of the buccolingual inclination use the sounds ‘F’ and ‘V’ as phonetic guides; during this process, the incisors should lightly touch the lower lip. In most individuals, the incisal edge of the maxillary incisors is positioned at the wet-dry line level of the vermilion border of the lower lip. The ‘S’ sound is used to evaluate the vertical dimension and the relationship between the maxillary and mandibular incisors; it is considered ideal for the mandibular incisors to be positioned approximately 1 mm behind and 1 mm below the palatal surfaces of the maxillary incisors (Bhuvaneswaran, 2010; Fidan & Fidan, n.d.).

2.3.2. Incisal Slope and Smile Line

The imaginary curve following the incisal edges of the central and lateral incisors in the upper anterior region and the cusp tips of the canine teeth is defined as the ‘incisal slope’. In an ideal arrangement, this curve is considered to follow the lower lip contour. The incisal slope is classified into three types: positive, neutral, and negative. Positive incisal slope creates a convex curve compatible with the lower lip, with the incisal edges of the central incisors positioned below the cusp tips of the canines. Neutral incisal slope has the incisal edges of the central incisors at the same level as the cusp tips of the canines. Negative incisal inclination, on the other hand, positions the incisal edges of the central incisors above the canine cusp tips, resulting in an aesthetically unfavourable appearance (Basting et al., 2006).

The smile line is defined by the visibility of the gingival margin and the clinical crown length. In a high smile line, the entire clinical crown and varying amounts of gingiva are visible; in a medium smile line, approximately 75–100% of the clinical crown and only the interdental papilla are exposed. In a low smile line, less than 75% of the clinical crown is visible (Melo et al., 2020).

In a normal smile, 1–2 mm of gum visibility is acceptable and creates a youthful aesthetic appearance. Gum visibility exceeding 3 mm is referred to as a ‘gummy smile’ and, while not pathological, can lead to aesthetic incompatibility. This condition is more common in young adults and women and is associated with factors such as lip length, lip hypermobility, vertical maxillary excess, and delayed passive eruption (Mercado-García et al., 2021).

2.3.3. Lip Movements

In planning aesthetic restorations, it is important to evaluate the static and dynamic positions of the lips.

Static position: This refers to the state in which the perioral muscles are relatively relaxed, the lips are slightly parted, and the teeth are not in occlusion. In this position, tooth visibility is influenced by four key factors: lip length, age, race, and gender.

Upper lip length varies between 10–36 mm on average; in individuals with longer lips, maxillary tooth visibility decreases while mandibular tooth visibility increases. With age, maxillary tooth visibility decreases while mandibular tooth visibility increases; this is related to decreased perioral muscle tone, soft tissue changes, and loss of upper lip elasticity. Due to racial differences, a general decrease in maxillary tooth visibility and an increase in mandibular tooth visibility are observed. When evaluated in terms of gender, men generally have a longer upper lip, resulting in less maxillary tooth visibility compared to women; this results in approximately twice as much maxillary tooth visibility in women compared to men (Ahmad, 2005; AL-Kaisy, 2023).

Dynamic position: refers to the situation that occurs when smiling. In this position, the visibility of the maxillary teeth varies depending on the degree of contraction of the perioral muscles, the shape and size of the teeth, and the morphological characteristics of the lips.

According to Rufenacht's morphopsychological approach, it is recommended that individuals with thick and pronounced lips prefer more pronounced tooth forms that create an impression of dominance and power, while individuals with thin and taut lips should choose tooth shapes with softer lines that convey a sense of delicacy and fragility, thereby enhancing aesthetic harmony (Ahmad, 2005).

2.3.4. Smile Symmetry

Smile symmetry is an important determinant of facial symmetry and perceived facial attractiveness. To achieve an aesthetically pleasing smile, the corners of the mouth must be positioned symmetrically and proportionally in the vertical plane (SEKERTZI, 2022). In this regard, it is important to evaluate the interpupillary distance, lip support, facial symmetry and balance, along with the individual's age and gender characteristics, and to accurately reflect the data obtained in the restorative treatment plan.

2.3.5. Colour

Colour is defined as a psychophysical perception that arises in the observer as a result of the physical interaction of light energy with an object. Tooth colour is formed by the combined effect of intrinsic and extrinsic colouration; intrinsic colour depends on the light absorption and reflection properties of dentine and enamel. Colour perception is fundamentally influenced by three factors: the light source, the observer, and the object being viewed.

The colour and overall appearance of teeth are related to optical properties such as translucency, opacity, gloss, and lighting conditions. Translucency, opalescence, and fluorescence form the optical triad that is critical for achieving a natural and aesthetic tooth appearance (Joiner, 2004).

3. Periodontal Aesthetic Treatments

3.1. Gingival Leveling Methods

In ideal prosthetic restorations, it is essential that the margins of the crowns are positioned on sound tooth structure and do not damage the periodontal tissues. The relationship between periodontal tissues and restorative treatments is critical for both functional success and long-term biological compatibility. The long-term healthy survival of a restoration in the mouth is directly dependent on the preservation of the biological integrity of the surrounding periodontium (I. Js, 1977).

When restoration margins extend into the subgingival area, invading the biological width, periodontal complications such as gingivitis, clinical attachment loss, intraosseous defects, and gingival recession may occur (V. Js, 1994). Therefore, in cases where subgingival caries are present, fracture lines terminate below the gingival margin, or the clinical crown length is insufficient, a treatment approach that does not compromise the biological width is required to prepare a fixed prosthetic restoration.

To this end, gingivectomy/clinical crown lengthening, botulinum toxin-a, and lip repositioning procedures are performed to increase the clinically visible crown length of the tooth and to allow the restoration margins to be placed on sound tooth structure. This surgical procedure supports long-term success by creating an optimal balance between periodontal health and restorative requirements (Abdullah, 2013).

3.1.1. Gingivectomy

Gingivectomy is a periodontal surgical procedure in which the gingival margin, positioned coronally and above the ideal level in terms of aesthetics or function, is reshaped and brought to the correct anatomical position. Following this procedure, a new, physiological gingival margin forms around the enamel-cementum junction. Preserving biological width is crucial when planning gingivectomy; compromising this area may lead to complications such as inflammation of periodontal tissues, attachment loss, and deterioration of marginal tissue stability (Gargiulo et al., 1961; I. Js, 1977).

Gingivectomy can be performed using different surgical techniques. Traditionally performed with a scalpel, gingivectomy offers the advantage of providing clear and controlled gingival contours. However, excessive bleeding during the operation can make vision difficult, the healing period may be prolonged, and postoperative patient comfort may be lower than with other methods (Lowney, 2015).

Electrosurgery improves the clinician's field of view and makes the procedure more controlled due to the effective haemostasis it provides during the operation. Laser surgery, on the other hand, can provide superior bleeding control compared to electrosurgery, generally requires less anaesthesia, and significantly reduces postoperative patient discomfort. Furthermore, it has been reported that laser incisions provide a more sterile operating field and result in faster postoperative recovery (Ishikawa et al., 2004).

The choice of these techniques should be determined based on clinical requirements, the patient's periodontal condition, and the dentist's experience.

3.1.2. Crown Lengthening

In crown lengthening procedures, the preservation of biological width and the correct positioning of the gingival margin are fundamental objectives. Therefore, the anatomical boundaries of periodontal tissues must be carefully evaluated during treatment planning. Where necessary, bone resection procedures such as osteoplasty or osteotomy may be performed to prevent the new restorative margin from invading the biological width area (I. Js, 1977).

Crown lengthening can directly affect the aesthetic appearance as it causes the gingival margin to be moved to a more apical position and may, in some cases, necessitate the removal of supporting alveolar bone from the adjacent tooth. If the distance between the alveolar bone and the gingival margin is clinically less than 3 mm, or if the amount of attached gingiva is insufficient, it is recommended to create space with a flap operation and perform the necessary amount of bone resection (Gargiulo et al., 1961).

The primary goal in all these applications is to preserve the integrity of the biological width, which is vital for the long-term success of the restoration. Violation of the biological width can lead to undesirable complications such as chronic inflammation between the crown margin and periodontal tissues, attachment loss, and gingival recession (V. Js, 1994).

3.1.3. Botulinum Toxin Type A

Botulinum Toxin Type A (BTX-A) is a minimally invasive method widely used in cosmetic dentistry, particularly for treating gummy smiles. Clinical studies in the literature show that BTX-A has high success rates in reducing gingival visibility associated with upper lip hyperactivity. This treatment approach is advantageous because it acts quickly, carries a low risk of complications, is reversible, and does not require surgery (Mazzuco & Hexsel, 2010; Polo, 2008).

In treatment planning, the activity of the muscles causing excessive elevation of the upper lip during smiling is assessed. The surface projections of the muscles associated with upper lip elevation are determined, reference points are marked on both sides to assess symmetry, and BTX-A is injected into the relevant muscle areas. The muscles most commonly targeted in gummy smile treatment are:

-Levator Labii Superioris Alaeque Nasi (LLSAN)

-Levator Labii Superioris (LLS)

-Zygomaticus Minor

BTX-A applied to these muscles reduces muscle hyperactivity, preventing the upper lip from moving excessively upwards during smiling and thus bringing gingival visibility to an aesthetically acceptable level (Hwang et al., 2009; Suber et al., 2014).

3.1.4. Lip Repositioning

The lip repositioning procedure is a conservative, low-risk and reliable surgical approach used particularly in the treatment of a gummy smile. This method aims to restrict the movements of the muscles contributing to lip elevation (zygomaticus minor, orbicularis oris, levator anguli oris, levator labii superioris) in a manner tolerable to the patient (Muthukumar et al., 2015; Rosenblatt & Simon, 2006).

In the operative technique, the epithelial tissue extending from the mucogingival junction to the lip muscles is carefully peeled off, and the incision area is tightly sutured. As a result of this procedure, the vestibular sulcus becomes shallower, and the lip cannot move upwards, thus reducing the excessive visibility of the upper gingival margin during smiling. Lip repositioning surgery is an effective method that improves the aesthetic outcome in a minimally invasive manner without requiring bone resection (Ali et al., 2000).

This procedure is preferred, particularly because it meets aesthetic expectations without compromising biological width, and the postoperative recovery period is short with minimal patient discomfort.

4. Prosthetic Aesthetic Treatments

Rapid advances in modern technology and changing living standards have contributed significantly to the advancement of material technology in the field of dentistry. Parallel to these developments, there has been a marked increase in patients' aesthetic expectations. Thanks to advanced technology materials and digitally supported treatment approaches, it is now possible to perform restorative procedures that offer high aesthetic properties with minimal material loss, while maintaining biological and mechanical integrity and increasing functional durability. The aesthetic prosthetic planning process requires a multidisciplinary approach that aims for long-term success by comprehensively evaluating the patient's functional needs, aesthetic expectations, and biological compatibility (Li et al., 2014).

In cases of anterior tooth loss, implant-supported prostheses, removable prostheses, all-ceramic restorations, and adhesive bridges applied in accordance with the principles of minimal preparation are among the alternative treatment options.

All-ceramic restorations offer high aesthetic potential due to their advanced light transmission properties, which provide optical characteristics close to natural tooth structure. Furthermore, these materials are safely preferred in aesthetic prosthetic applications because they are biocompatible with surrounding tissues and exhibit sufficient mechanical strength to tolerate functional stresses (Özbayram & Yanıkoğlu, 2016).

Within the scope of aesthetic dentistry applications, laminate veneer restorations, which aim to improve the aesthetic appearance, particularly in the anterior region, and are applied with a conservative approach, have also gained increasing popularity in recent years (Beall, 2007).

4.1. Full Ceramic Restorations

Although full ceramic restorations largely meet aesthetic requirements, their susceptibility to fracture is among their most significant disadvantages. Consequently, the mechanical strength of full ceramic crowns varies depending on various factors. These factors include the characteristics of tooth preparation, restoration design, the type of ceramic material used, the form, thickness and length of the substructure, the substructure-superstructure connection, the crown margin and the cementation technique applied.

Adherence to traditional tooth preparation principles in all-ceramic restorations is crucial not only for ensuring adequate retention but also for balancing stress distribution on the restoration under functional and dynamic loads. To achieve ideal aesthetic results and sufficient mechanical strength, the restoration must be prepared in accordance with physiological crown contours. In this regard, it is recommended that at least 1.2–1.5 mm of enamel and dentine be removed from axial surfaces and 1.5–2.0 mm from occlusal and incisal surfaces to create sufficient space for the substructure material and superstructure ceramic. During tooth preparation, care should be taken to preserve the biological limits of the pulp and avoid excessive material loss (Ersoy, n.d.).

4.2. Laminate Veneer Restorations

Laminate veneers can be produced from composite, ceramic or acrylic-based materials and are bonded to the tooth surface using composite resin-based adhesive systems. This treatment method allows for the aesthetic rehabilitation of broken, discoloured, diastematic, malpositioned or malformed teeth, while ensuring maximum preservation of the enamel tissue. Traditionally, laminate veneers are prepared with a thickness of 0.5–1.0 mm; however, thanks to advances in material and production technologies, it is now possible to clinically apply veneers with a thickness of approximately 0.2 mm that require no preparation or minimal preparation (Blunck et al., 2020).

Whether preparation is performed in laminate veneer restorations and the depth of preparation are determined based on various clinical and individual factors. The position of the existing teeth within the arch directly affects the depth of preparation in terms of achieving ideal alignment. Preparation is necessary, especially for teeth positioned in the vestibular direction, to prevent excessively contoured and aesthetically unsuccessful restorations. Conversely, in palatally positioned teeth, it is possible to correct tooth position with PLV restorations without preparation.

The patient's age affects the proximity of the pulp to the tooth surface, determining the limits of safe preparation depth. Furthermore, the health status of the gingival and periodontal tissues plays a decisive role in the extent of preparation. However, the patient's psychological state and aesthetic expectations should be considered during treatment planning; it should not be forgotten that these factors may affect the amount of preparation and the aesthetic outcome (KARAGÖZOĞLU İrem, 2015).

Laminate veneer preparation is a minimally invasive procedure that aims to preserve the enamel structure to the maximum extent while meeting aesthetic requirements. The fundamental principle is to keep the preparation within the enamel boundaries as much as possible.

First, the position of the teeth, the degree of discolouration and the aesthetic goals are assessed. Preparation is generally limited to between 0.3 and 0.7 mm on the labial surface, and the surface is smoothed to create sufficient space for the veneer. Incisal edge preparation can be performed in accordance with the restoration plan, either by preserving the incisal edge, shortening it partially or covering it.

Preparation in the cervical region is mostly planned at the gingival level or slightly supragingival, and a clear finish line is created. Sharp corners should be avoided on axial surfaces, and rounded and smooth surfaces should be achieved. Care should be taken not to damage the pulp and soft tissues during preparation, and surface roughness should be ensured to increase the adhesive bond of the restoration (Castelnuovo et al., 2000; Cherukara et al., 2003; Walls et al., 2002).

4.3. Adhesive Bridge Restorations

Restorative approaches to treating tooth loss have shifted towards biologically respectful, conservative and aesthetic solutions with the development of minimally invasive dentistry. In this context, adhesive bridges have long been used in the rehabilitation of single tooth loss and remain a preferred restorative option today. Compared to traditional fixed bridges, they require minimal tooth preparation, allowing for the preservation of a large amount of healthy tooth structure. They can be applied with limited preparation at the enamel level or without preparation, reducing the risk of damage to biological tissues and allowing for alternative treatments in the future.

All-ceramic adhesive bridges are preferred, especially in the anterior region, as they offer aesthetic properties close to natural tooth structure thanks to their high translucency. Adhesive bridges prepared with fibre-reinforced composite resins are conservative restorations that can be applied using direct or indirect methods using glass or polyethylene fibres. They are considered a suitable treatment alternative due to their aesthetic appearance and minimally invasive properties. When selecting materials, the patient's clinical condition, aesthetic expectations, and functional requirements should be considered. Adhesive bridges, thanks to their minimally invasive and tissue-friendly properties, are among the restorative options that meet functional and aesthetic requirements, especially in single tooth deficiencies. They are preferred as a temporary or medium-term treatment alternative, especially in young patients whose growth and development are incomplete, where implant application is contraindicated (Barber & Preston, 2008; KAPLAN, n.d.; Yiğit & Erdinç, 2022).

CONCLUSION

Aesthetic dentistry is now considered a multidisciplinary field that goes beyond restorative applications alone; it requires an integrated approach encompassing periodontal tissue health, tooth-gum harmony, and facial aesthetics. In this context, the coordinated planning and implementation of periodontal aesthetic treatments and prosthetic aesthetic applications constitute a fundamental requirement for achieving successful aesthetic and functional outcomes, as well as long-term stable results.

The integration of periodontology and prosthetic dental treatment is one of the most important factors determining the sustainability of biological, functional, and aesthetic success in all restorative processes, particularly in the aesthetic zone. The treatment planning process necessitates an interdisciplinary approach that takes into account the biological limits of periodontal tissues, soft tissue architecture and dynamics, and the morphological characteristics of hard tissues. In this context, the correct and systematic application of perio-prosthetic planning principles allows for the preservation of existing tissues as well as the creation of ideal restorative and aesthetic conditions.

Consequently, comprehensive pre-treatment assessment, accurate diagnosis, detailed treatment planning, and interdisciplinary collaboration emerge as indispensable elements for the success of periodontal and prosthetic aesthetic treatments. This adopted holistic approach enables not only aesthetically satisfying results but also biologically compatible, functional, and long-lasting treatment outcomes.

REFERENCE

Abdullah, M. M. (2013). The Effects of Surgical Crown Lengthening (SCL) on Biological Width and Periodontal Tissues after Prosthodontic Procedures. *Dental Journal*, *59*(1543), 1548.

Ahmad, I. (2005). Anterior dental aesthetics: Dentofacial perspective. *British Dental Journal*, *199*(2), 81–88. https://doi.org/10.1038/sj.bdj.4812521

AL-Kaisy, N. (2023). Measurement of vertical anterior teeth display and lip position at smiling in Kurdish population. Age and gender-based evaluation. *Heliyon*, *9*(9), e19465. https://doi.org/10.1016/j.heliyon.2023.e19465

Ali, K., El-Kilanni, N., & Attia, M. (2000). Correction of Gummy Smile by Surgical Lip Repositioning with Myotomy versus Botox Injection Technique. *Al-Azhar Journal of Dentistry*, *10*(1), 131–137.

Araújo, M. G., & Lindhe, J. (2005). Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *Journal of Clinical Periodontology*, *32*(2), 212–218.

Aşık, E., Şener, E., Şen, B. G. B., & Becerik, S. (2020). Dişeti Fenotipinin Önemi ve Belirleme Yöntemleri. *Ege Üniversitesi Diş Hekimliği Fakültesi Dergisi*, *41*(3), 255–262.

Barber, M. W., & Preston, A. J. (2008). An update on resin-bonded bridges. *The European Journal of Prosthodontics and Restorative Dentistry*, *16*(1), 2–9.

Basting, R. T., Trindade, R. S., & Flório, F. M. (2006). Comparative Study of Smile Analysis by Subjective and Computerized

Methods. *Operative Dentistry*, *31*(6), 652–659. https://doi.org/10.2341/06-24

Beall, A. E. (2007). Can a New Smile Make You Look More Intelligent and Successful? *Dental Clinics of North America*, *51*(2), 289–297. https://doi.org/10.1016/j.cden.2007.02.002

Bhuvaneswaran, M. (2010). Principles of smile design. *Journal of Conservative Dentistry*, *13*(4), 225. https://doi.org/10.4103/0972-0707.73387

Blunck, U., Fischer, S., Hajtó, J., Frei, S., & Frankenberger, R. (2020). Ceramic laminate veneers: effect of preparation design and ceramic thickness on fracture resistance and marginal quality in vitro. *Clinical Oral Investigations*, *24*(8), 2745–2754. https://doi.org/10.1007/s00784-019-03136-z

çalıkkocaoğlu senih. (1998). *Dişsiz Hastaların Protetik Tedavisi:Klasik Tam Protezler*.

Calsina, G., Ramón, J., & Echeverría, J. (2002). Effects of smoking on periodontal tissues. *Journal of Clinical Periodontology*, *29*(8), 771–776.

Castelnuovo, J., Tjan, A. H. L., Phillips, K., Nicholls, J. I., & Kois, J. C. (2000). Fracture load and mode of failure of ceramic veneers with different preparations. *The Journal of Prosthetic Dentistry*, *83*(2), 171–180. https://doi.org/10.1016/S0022-3913(00)80009-8

Chapple, I. L. C., Genco, R., & Workshop*, W. G. 2 of the J. E. (2013). Diabetes and periodontal diseases: consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. *Journal of Periodontology*, *84*, S106–S112.

Cherukara, G. ., Seymour, K. ., Zou, L., & Samarawickrama, D. Y. . (2003). Geographic distribution of porcelain veneer preparation depth with various clinical techniques. *The Journal of Prosthetic Dentistry*, *89*(6), 544–550. https://doi.org/10.1016/S0022-3913(03)00215-4

CHU, S. J., TAN, J. H., STAPPERT, C. F. J., & TARNOW, D. P. (2009). Gingival Zenith Positions and Levels of the Maxillary Anterior Dentition. *Journal of Esthetic and Restorative Dentistry*, *21*(2), 113–120. https://doi.org/10.1111/j.1708-8240.2009.00242.x

Coachman, C., & Calamita, M. (2012). Digital Smile Design: A Tool for Treatment Planning and Communication in Esthetic Dentistry. *Quintessence of Dental Technology (QDT)*, *35*.

DOĞAN, A. N. (2020). DİJİTAL GÜLÜŞ TASARIMI: KULLANILAN SİSTEMLER VE AVANTAJLARI. *Sağlık Bilimleri Dergisi*, *29*(2), 138–143. https://doi.org/10.34108/eujhs.551381

Ersoy, A. E. (n.d.). *Diş Hekimliğinde Sabit Protezler*.

Fidan, S., & Fidan, M. (n.d.). *Diş Hekimliğinde Gülümseme Estetiği*.

Fondriest, J. (2003). Shade matching in restorative dentistry: the science and strategies. *The International Journal of Periodontics & Restorative Dentistry*, *23*(5), 467–479. http://www.ncbi.nlm.nih.gov/pubmed/14620121

Fradeani, M., & Barducci, G. (2008). *Esthetic rehabilitation in fixed prosthodontics*. Quintessence Publishing Company.

Furuta, M., Ekuni, D., Irie, K., Azuma, T., Tomofuji, T., Ogura, T., & Morita, M. (2011). Sex differences in gingivitis relate to interaction of oral health behaviors in young people. *Journal of Periodontology*, *82*(4), 558–565.

Gargiulo, A. W., Wentz, F. M., & Orban, B. (1961). Dimensions and relations of the dentogingival junction in humans. *The Journal of Periodontology*, *32*(3), 261–267.

Gürel, G. (2004). *Porselen Laminate Veneer Bilim ve Sanatı*. Quintessence yayıncılık.

Hatipoğlu, H., & Hatipoğlu, M. G. (2022). Diş Eti Fenotipi ve Diş Hekimliğinde Oynadığı Rol. *Sağlık Akademisi Kastamonu*, *7*(1), 181–196.

Hwang, W.-S., Hur, M.-S., Hu, K.-S., Song, W.-C., Koh, K.-S., Baik, H.-S., Kim, S.-T., Kim, H.-J., & Lee, K.-J. (2009). Surface anatomy of the lip elevator muscles for the treatment of gummy smile using botulinum toxin. *The Angle Orthodontist*, *79*(1), 70–77.

Ishikawa, I., Aoki, A., & Takasaki, A. A. (2004). Potential applications of Erbium: YAG laser in periodontics. *Journal of Periodontal Research*, *39*(4), 275–285.

Joiner, A. (2004). Tooth colour: a review of the literature. *Journal of Dentistry*, *32*, 3–12. https://doi.org/10.1016/j.jdent.2003.10.013

Js, I. (1977). The" biologic width"--a concept in periodontics and restorative dentistry. *Alpha Omegan*, *70*, 62–65.

Js, V. (1994). The dimensions of the human dentogingival junction. *Int J Periodontics Restorative Dent*, *14*, 154–165.

KAPLAN, S. A. (n.d.). ADEZİV KÖPRÜLER. *RESTORATİF DİŞ TEDAVİSİ*, 17.

KARAGÖZOĞLU İrem. (2015). *MİNİMAL İNVAZİV YÖNTEMLERLE HAZIRLANAN PORSELEN LAMİNALARIN DİŞE UYUMLARININ İNCELENMESİ VE KLİNİK TAKİBİ*.

Kim, D. M., Bassir, S. H., & Nguyen, T. T. (2020). Effect of gingival phenotype on the maintenance of periodontal health: An American Academy of Periodontology best evidence review. *Journal of Periodontology*, *91*(3), 311–338.

KOZAK, E., & TUNA, S. H. (2022). Dental Orta Hat Simetri-Asimetrisinin Dentofasiyal Estetik Algı Üzerine Etkisi. *Süleyman Demirel Üniversitesi Sağlık Bilimleri Dergisi*, *13*(2), 263–270. https://doi.org/10.22312/sdusbed.1067023

Li, R. W. K., Chow, T. W., & Matinlinna, J. P. (2014). Ceramic dental biomaterials and CAD/CAM technology: State of the art. *Journal of Prosthodontic Research*, *58*(4), 208–216. https://doi.org/10.1016/j.jpor.2014.07.003

Lombardi, R. E. (1973). The principles of visual perception and their clinical application to denture esthetics. *The Journal of Prosthetic Dentistry*, *29*(4), 358–382. https://doi.org/10.1016/S0022-3913(73)80013-7

Lowney, C. (2015). *Book review: Carranza's clinical periodontology*. Nature Publishing Group UK London.

Machado, A. W. (2014). 10 commandments of smile esthetics. *Dental Press Journal of Orthodontics*, *19*(4), 136–157. https://doi.org/10.1590/2176-9451.19.4.136-157.sar

Mazzuco, R., & Hexsel, D. (2010). Gummy smile and botulinum toxin: a new approach based on the gingival exposure area. *Journal of* *the American Academy of Dermatology*, *63*(6), 1042–1051.

Melo, M., Ata-Ali, J., Ata-Ali, F., Bulsei, M., Grella, P., Cobo, T., & Martínez-González, J. M. (2020). Evaluation of the maxillary midline, curve of the upper lip, smile line and tooth shape: a prospective study of 140 Caucasian patients. *BMC Oral Health*, *20*(1), 42. https://doi.org/10.1186/s12903-020-1031-y

Mercado-García, J., Rosso, P., Gonzalvez-García, M., Colina, J., & Fernández, J. M. (2021). Gummy Smile: Mercado-Rosso Classification System and Dynamic Restructuring with Hyaluronic Acid. *Aesthetic Plastic Surgery*, *45*(5), 2338–2349. https://doi.org/10.1007/s00266-021-02169-8

Muthukumar, S., Natarajan, S., Madhankumar, S., & Sampathkumar, J. (2015). Lip repositioning surgery for correction of excessive gingival display. *Journal of Pharmacy and Bioallied Sciences*, *7*(Suppl 2), S794–S796.

Özbayram, Ö., & Yanıkoğlu, N. (2016). ÖN BÖLGE ESTETİĞİNİN PROTETİK RESTORASYONLARLA DÜZENLENMESİ: ALTI OLGU SUNUMU. *Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi*, 42–45.

Polo, M. (2008). Botulinum toxin type A (Botox) for the neuromuscular correction of excessive gingival display on smiling (gummy smile). *American Journal of Orthodontics and Dentofacial Orthopedics*, *133*(2), 195–203.

Rosenblatt, A., & Simon, Z. (2006). Lip repositioning for reduction of excessive gingival display: a clinical report. *International Journal of Periodontics & Restorative Dentistry*, *26*(5).

SEKERTZI, S. (2022). Ortodontik Tedavide Gülümseme Estetiğinin Değerlendirilmesi. *Aydın Dental Journal*, *8*(2), 143–157.

Silva, A. D. O., Fabre, H. S. C., Ursi, W. J. S., Hoeppner, M. G., & Do Amaral, A. L. M. (2022). Anterior Upper Teeth Golden Proportion Analysis with Millimetric Templates: An Invention Developed at Londrina State University. *International Journal of Dentistry*, *2022*, 1–10. https://doi.org/10.1155/2022/1520812

Silva, B. P., Jiménez-Castellanos, E., Stanley, K., Mahn, E., Coachman, C., & Finkel, S. (2018). Layperson's perception of axial midline angulation in asymmetric faces. *Journal of Esthetic and Restorative Dentistry*, *30*(2), 119–125. https://doi.org/10.1111/jerd.12347

Suber, J. S., Dinh, T. P., Prince, M. D., & Smith, P. D. (2014). OnabotulinumtoxinA for the treatment of a "gummy smile." *Aesthetic Surgery Journal*, *34*(3), 432–437.

Walls, A. W. G., Steele, J. G., & Wassell, R. W. (2002). Crowns and other extra-coronal restorations: Porcelain laminate veneers. *British Dental Journal*, *193*(2), 73–82. https://doi.org/10.1038/sj.bdj.4801489

Yiğit, E., & Erdinç, G. (2022). Fiber ile Güçlendirilmiş Adeziv Köprüler: İki Olgu Sunumu. *Unika Sağlık Bilimleri Dergisi*, *2*(2), 274–282.

CHAPTER 4

NANOTECHNOLOGY IN ORAL HYGIENE PRODUCTS: THE FUTURE OF TOOTHPASTES AND MOUTHWASHES

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INTRODUCTION

Dental caries is a widespread health problem affecting millions of people worldwide. Despite significant advances in early diagnosis and treatment modalities, dental caries remains the most prevalent chronic bacterial disease. According to data collected in 2017 from 195 countries by the Global Burden of Disease study, approximately 2.3 billion adults are affected by dental caries, while more than 530 million children experience caries in their primary dentition (Sari et al., 2022). Effective control of bacterial biofilms on tooth surfaces is of paramount importance for preventing dental caries and other oral health problems (Chen et al., 2021).

Oral hygiene is one of the fundamental pillars of individual health. It encompasses regular and systematic self-care practices, as well as professional interventions, aimed at preserving the health of the oral cavity, preventing the onset or progression of dental and periodontal diseases, and maintaining the functional integrity of the masticatory system (Chanthavisouk et al., 2024).

Oral care products have evolved significantly to address the multifactorial nature of bacterial biofilms. Toothpastes, mouthwashes, and adjunctive home-care tools constitute the core of daily oral hygiene practices, while these are supplemented when necessary by topical fluoride gels, potent antiseptic solutions, and specialized formulations designed for dentin hypersensitivity or early-stage periodontal problems (Gurgel-Juarez et al., 2020).

Evidence shows that microbial activity plays a decisive role in the development of caries and biofilm formation, and that conventional oral care products (particularly fluoride-based strategies) can at times be insufficient for achieving full biofilm control. Therefore, there is a growing need for next generation solutions that enhance antibacterial effectiveness, specifically target biofilm architecture, and possess the potential to repair enamel tissue.

Nanotechnology has become a significant area of research in recent years, offering innovative applications in oral hygiene products. Its advantages stem from the high surface area, unique chemical properties, and biological interaction capacity of nanoparticles, enabling the development of novel formulations that enhance the therapeutic efficacy of oral care products.

In this review, the fundamental components of current oral hygiene products and their roles in biofilm control are first examined, followed by an analysis of the antibacterial, remineralizing, and therapeutic effects of various nanoparticles incorporated into these formulations. The potential innovations that nanotechnology-enhanced oral care strategies may offer in the future are also evaluated. In this context, a detailed understanding of the components of the most commonly used oral hygiene products is essential for appreciating the advantages conferred by nanotechnology integration.

Conventional Oral Hygiene Products: Toothpastes and Mouthwashes

Toothpaste is a semi-gel formulation applied to a toothbrush and used to maintain oral hygiene, preserve dental health, and prevent discoloration or the development of caries (El-Khordagui et al., 2021). Today, a wide variety of toothpastes designed for different purposes are available on the market, each containing its own unique formulation; however, certain ingredients may serve multiple functions.

A substantial portion of toothpaste formulations consists of abrasive agents, such as hydroxyapatite, calcium carbonate, silica, and aluminum hydroxide, used to clean and polish tooth surfaces. Caries preventive components include sodium bicarbonate, xylitol, calcium and phosphate additives, and approximately 1450 ppm fluoride, all of which contribute to enamel remineralization by accelerating the formation of fluorapatite. In addition, antibacterial agents such as fluoride, silver, zinc chloride, triclosan, stannous ions, and essential oils help reduce plaque accumulation and the risk of gingivitis while also partially limiting caries development. Formulations may also contain antiplaque substances including sodium lauryl sulfate, triclosan, zinc and stannous ions, and chlorhexidine (Vranić et al., 2004).

Whitening agents such as papain and sodium bicarbonate help remove surface stains, while solvents like water and alcohol facilitate the formation of a homogeneous mixture and prevent the paste from drying out. Surfactants that promote foaming support plaque and debris removal, whereas humectants such as xylitol, glycerol, sorbitol, propylene glycol, and polyethylene glycol maintain the soft, creamy consistency of the paste. Desensitizing agents including arginine, potassium nitrate, and strontium chloride help reduce dentin hypersensitivity, while anticalculus compounds, such as zinc citrate, pyrophosphates, urea derivatives, and sodium polyphosphate, limit tartar formation. Flavoring agents like xylitol, sorbitol, glycerol, and sodium saccharin enhance the taste profile of the toothpaste, and coloring agents provide a more appealing appearance (Moharamzadeh, 2016).

Mouthwashes, similar to toothpastes, have been used for many years to control plaque formation, prevent periodontal diseases, and eliminate oral malodor. Their formulations contain a wide range of compounds with antibacterial, anti-inflammatory, remineralization-enhancing, or cleansing properties.

Solvents such as water, ethanol, and glycerin form the basis of mouthwash formulations by allowing active ingredients to dissolve and helping the product maintain a homogeneous structure. In addition, antimicrobial agents (including chlorhexidine, triclosan, sodium fluoride, and essential oils such as menthol and eucalyptus) suppress bacterial proliferation and thereby limit plaque formation. Humectants such as glycerol, sorbitol, xylitol, and butylene glycol help maintain moisture balance in oral tissues and contribute to the stability of the formulation. Surfactants and foaming agents, including sodium lauryl sulfate and cocamidopropyl betaine, enhance the foaming capacity of the mouthwash and strengthen its cleansing effect (Radzki et al., 2022).

Antiplaque and antitartar agents such as pyrophosphates, zinc, and stannous formulations inhibit the formation of dental plaque, while sweeteners including xylitol, saccharin, and aspartame improve the product's taste. Desensitizing agents such as potassium nitrate and strontium chloride help reduce dentin hypersensitivity, whereas whitening components, such as hydrogen peroxide, papain, and sodium bicarbonate, assist in removing surface stains and enhancing tooth brightness. Deodorizing substances containing zinc ions and essential oils neutralize volatile sulfur compounds, thereby refreshing the breath. Preservatives such as sodium benzoate, methylparaben, and propylparaben extend the product's shelf life, while flavoring agents including menthol, mint, and eucalyptus provide a sensation of freshness.

In addition, coloring agents enhance the visual appearance of the product, while thickening and stabilizing agents help maintain the viscosity of the formulation and ensure the uniform distribution of its components. Through the combination of these compounds, mouthwashes serve as an adjunct to toothbrushing and flossing, supporting oral hygiene and contributing to the maintenance of overall oral health when used regularly (Yazicioglu et al., 2024).

Although current formulations provide a certain level of effectiveness, the complex structure of dental biofilm necessitates more advanced solutions. At this point, nanotechnology emerges as a significant area of innovation.

Nanoparticle Integration

The incorporation of nanotechnology into oral care products has markedly enhanced the therapeutic efficacy of toothpastes and mouthwashes. Nanoparticles play an active role in multiple mechanisms, including the prevention of dental caries, the remineralization of enamel tissue, and the provision of antibacterial protection (Abedi et al., 2024).

The oral cavity harbors a wide range of microorganisms, and bacteria such as *Streptococcus mutans*, *P. gingivalis*, and *S. oralis* play key roles in the development of both dental caries and periodontal diseases (Rezaei et al., 2023). Therefore, metal nanoparticles, with their unique physical and chemical properties, are regarded as powerful alternatives for managing oral diseases caused by bacterial activity.

Many metallic nanoparticles exhibit both antimicrobial and anti-inflammatory properties. *S. mutans,* in particular, plays a critical role in the initiation of dental caries by forming biofilm on tooth surfaces.

Silver nanoparticles (AgNPs) effectively inhibit *S.mutans* by disrupting the bacterial cell membrane and interfering with essential enzymatic activities (Al-Fahham et al., 2023). It has been reported that silver nanoparticles synthesized using lemon peel exhibit a broader antibacterial inhibition zone compared to commercial products when incorporated into toothpaste formulations (Ahmed & Salama, 2020).

Although studies on gold nanoparticles (AuNPs) are more limited, some toothpaste formulations have been reported to exhibit antimicrobial activity against gram positive bacteria in particular. This finding suggests that AuNPs may serve as a promising component for future oral care formulations.

Another important group of nanoparticles in oral care is phosphate-based nanoparticles. Hydroxyapatite nanoparticles (HAp NPs), in particular, are of significant clinical value because they represent the primary mineral component of enamel tissue (O'Hagan-Wong et al., 2022). These particles repair enamel loss and reduce the risk of caries and sensitivity through their capacity to remineralize the enamel surface. In addition, when incorporated into toothpastes and mouthwashes at concentrations of up to 10%, HAp NPs exhibit a significant whitening effect and produce results comparable to those of commercial whitening agents (Shang et al., 2022).

Florea and colleagues (Florea et al., 2023), developed a novel toothpaste combining nano-hydroxyapatite (nHAp) with birch extract to achieve both remineralizing and antibacterial effects. Among the 11 formulations prepared in different variations, those containing nHAp were reported to significantly restore enamel structure within 10 days. The P5 formulation, which incorporated both nHAp and birch extract, stood out due to its balanced dual action. However, it was observed that in some formulations, nHAp delayed the release of the active components of the birch extract, slightly slowing the onset of antibacterial activity.

Ionescu and colleagues (Ionescu et al., 2020), evaluated two commercial toothpastes containing nano-hydroxyapatite enriched with metal ions in terms of early biofilm formation. When comparing the α toothpaste, which included Zn-carbonate, with the β toothpaste, which contained fluoride, magnesium, and strontium, the β formulation demonstrated a stronger antibacterial effect. This outcome is thought to result primarily from the combined action of fluoride and strontium. Additionally, both toothpastes were reported to leave minor deposits on enamel and composite surfaces, potentially contributing to the prevention of secondary caries. With regular use, the β formulation in particular shows strong potential to improve oral health by reducing harmful biofilm.

Amaechi and colleagues (Amaechi et al., 2018), compared various nHAp-containing toothpastes with a well-established desensitizing toothpaste formulated with CSPS. The formulations containing 15% nHAp and 10% nHAp combined with potassium nitrate were found to be as effective as CSPS in reducing dentin hypersensitivity. In contrast, the formulation containing 10% nHAp alone demonstrated a slightly weaker performance, particularly with respect to thermal sensitivity.

Silica nanoparticles have also been investigated in recent years for their applications in oral care. Barma and colleagues (Barma et al., 2020), evaluated the effects of silica NP containing mouthwashes against bacteria such as *S. mutans*, *S. aureus*, and *E. faecalis*, and observed significant antibacterial activity at higher concentrations. However, because the study did not include gram negative bacteria, further research is required.

Wang and colleagues (Wang et al., 2024), developed a novel nanoparticle system termed nMS-nAg-Chx. This structure composed of silica, silver nanoparticles, and chlorhexidine suppresses cariogenic bacteria while promoting the growth of non-pathogenic species, thereby shifting the biofilm toward a healthier microbial composition. Such a system holds potential for future use in anticaries toothpaste or mouthwash formulations.

Finally, the potential of silica nanoparticles to enhance adhesion on oral surfaces has been investigated by Aspinall and colleagues (Aspinall & Khutoryanskiy, 2023). Toothpastes containing silica nanoparticles modified with functional groups such as chitosan, acryloyl, and phenylboronic acid have been shown to adhere much more strongly to the oral mucosa. This mucoadhesive property may enhance the effectiveness of the product by allowing active agents to remain in the oral cavity for a longer duration.

Nanoparticles offer substantial therapeutic potential by markedly enhancing the antibacterial, remineralizing, and biofilm modulating effects of toothpastes and mouthwashes. However, this progress also introduces several critical concerns. In particular, uncertainties regarding biocompatibility, long-term safety, and manufacturing standards present challenges to the full integration of this technology into clinical practice. Therefore, to ensure the sustainable realization of the broad clinical advantages promised by nanoparticles, it is essential to examine in detail the existing challenges and the requirements for future development.

Challenges and Future Perspectives

Despite the rapid advancements in nanotechnology, its full integration into the field of dentistry still faces significant obstacles. Foremost among these is the need for comprehensive evaluation of the long-term biocompatibility, potential toxic effects, and environmental implications of nanomaterials. Due to their extremely small size and high surface reactivity, nanoparticles may interact with biological systems in uncontrolled ways, potentially causing cellular damage, inflammation, or allergic reactions within oral tissues (Wu et al., 2020).

Therefore, predicting the behavior of nanomaterials within biological environments remains challenging, and extensive research is required to ensure patient safety (Ozak & Ozkan, 2013). Furthermore, the potential systemic effects that may arise from the gradual accumulation of these particles in the body are not yet fully understood, representing a possible health risk (De Matteis & Rinaldi, 2018).

Establishing clear standards by regulatory authorities is crucial for the safe use of nanotechnology-based dental applications. Every stage from manufacturing processes to clinical application protocols must be explicitly defined. In addition, the high cost of nanomaterials, the specialized equipment required to apply these products, and the need for additional training among healthcare professionals currently limit the widespread adoption of nanotechnology in clinical practice (Jandt & Watts, 2020).

Future research must focus on developing more durable, biocompatible, and multifunctional nanomaterials. In addition, exploring new applications of nanotechnology in dental diagnosis and treatment presents considerable potential. Notably, in implantology, surface modifications using nanotechnology may enhance implant osseointegration and long-term stability; while in preventive dentistry, nano-coatings may offer stronger protection against caries and erosion. These innovations are expected to become major areas of focus in the coming years (Upadhyay, 2013).

CONCLUSION

The integration of nanotechnology into oral care products provides a powerful therapeutic capacity that surpasses traditional formulations, offering significant advantages in caries prevention, biofilm control, and remineralization processes. Silver, gold, hydroxyapatite, and silica nanoparticles are reshaping modern oral hygiene through their multifaceted effects, including enhanced antibacterial activity, enamel surface repair, and modulation of biofilm structure. Nevertheless, comprehensive data are still needed regarding the biocompatibility, long-term safety, and environmental impact of these nanoparticles. Strengthening toxicity assessments, standardized manufacturing processes, and regulatory frameworks is essential to ensure the safe and widespread adoption of nanotechnology in clinical practice.

Overall, nanotechnology-enhanced oral care products hold transformative potential for the future of preventive dentistry; however, realizing this potential in clinical practice will depend on the rapid advancement of research focusing on safety, efficacy, and sustainability.

KAYNAKLAR

Abedi, M., Ghasemi, Y., & Nemati, M. M. (2024). Nanotechnology in toothpaste: Fundamentals, trends, and safety. In Heliyon. https://doi.org/10.1016/j.heliyon.2024.e24949

Ahmed, M. E., & Salama, K. (2020). A comparison of the effects of lemon peel -silver nanoparticles versus brand toothpastes and mouthwashes on staphylococcus spp. Isolated from teeth caries. Iraqi Journal of Science. https://doi.org/10.24996/ijs.2020.61.8.6

Al-Fahham, B. M., Mohamed, R. A., Al-Talqani, J. M. T., Fahad, A. H., & Haider, J. (2023). Evaluating Antimicrobial Effectiveness of Gold Nanoparticles against Streptococcus oralis. International Journal of Dentistry. https://doi.org/10.1155/2023/9935556

Amaechi, B. T., Lemke, K. C., Saha, S., & Gelfond, J. (2018). Clinical Efficacy in Relieving Dentin Hypersensitivity of Nanohydroxyapatite-containing Cream: A Randomized Controlled Trial. The Open Dentistry Journal. https://doi.org/10.2174/1874210601812010572

Aspinall, S. R., & Khutoryanskiy, V. V. (2023). Surface Modification of Silica Particles with Adhesive Functional Groups or Their Coating with Chitosan to Improve the Retention of Toothpastes in the Mouth. Langmuir. https://doi.org/10.1021/acs.langmuir.2c03269

Barma, M. D., Kannan, S. D., Indiran, M. A., Rajeshkumar, S., & Kumar, R. P. (2020). Antibacterial Activity of Mouthwash Incorporated with Silica Nanoparticles against S. aureus, S. mutans, E. faecalis: An in-vitro Study. Journal of Pharmaceutical Research International. https://doi.org/10.9734/jpri/2020/v32i1630646

Chanthavisouk, P., Ingleshwar, A., Theis-Mahon, N., & Paulson, D. R. (2024). The oral health impact of dental hygiene and dental therapy populations: a systematic review. Journal of Evidence-Based Dental Practice. https://doi.org/10.1016/j.jebdp.2023.101949

Chen, L., Al-Bayatee, S., Khurshid, Z., Shavandi, A., Brunton, P., & Ratnayake, J. (2021). Hydroxyapatite in oral care products—a review. In Materials. https://doi.org/10.3390/ma14174865

De Matteis, V., & Rinaldi, R. (2018). Toxicity assessment in the nanoparticle era. In Advances in Experimental Medicine and Biology. https://doi.org/10.1007/978-3-319-72041-8_1

El-Khordagui, L., Badawey, S. E., & Heikal, L. A. (2021). Application of biosurfactants in the production of personal care products, and household detergents and industrial and institutional cleaners. In Green Sustainable Process for Chemical and Environmental Engineering and Science: Microbially-Derived Biosurfactants for Improving Sustainability in Industry. https://doi.org/10.1016/B978-0-12-823380-1.00005-8

Florea, A. D., Dobrota, C. T., Carpa, R., Racz, C. P., Tomoaia, G., Mocanu, A., Avram, A., Soritau, O., Pop, L. C., & Tomoaia-Cotisel, M. (2023). Optimization of Functional Toothpaste Formulation Containing Nano-Hydroxyapatite and Birch Extract for Daily Oral Care. Materials. https://doi.org/10.3390/ma16227143

Gurgel-Juarez, N., Perrier, M. F., Hoffmann, T., Lannin, N., Jolliffe, L., Lee, R., Brosseau, L., & Flowers, H. (2020). Guideline recommendations for oral care after acquired brain injury: Protocol for a systematic review. In JMIR Research Protocols. https://doi.org/10.2196/17249

Ionescu, A. C., Cazzaniga, G., Ottobelli, M., Garcia-Godoy, F., & Brambilla, E. (2020). Substituted nano-hydroxyapatite toothpastes reduce biofilm formation on enamel and resin-based composite surfaces. Journal of Functional Biomaterials. https://doi.org/10.3390/jfb11020036

Jandt, K. D., & Watts, D. C. (2020). Nanotechnology in dentistry: Present and future perspectives on dental nanomaterials. In Dental Materials. https://doi.org/10.1016/j.dental.2020.08.006

Moharamzadeh, K. (2016). Biocompatibility of oral care products. In Biocompatibility of Dental Biomaterials. https://doi.org/10.1016/B978-0-08-100884-3.00008-4

O'Hagan-Wong, K., Enax, J., Meyer, F., & Ganss, B. (2022). The use of hydroxyapatite toothpaste to prevent dental caries. In Odontology. https://doi.org/10.1007/s10266-021-00675-4

Ozak, S. T., & Ozkan, P. (2013). Nanotechnology and dentistry. European Journal of Dentistry.

Radzki, D., Wilhelm-Węglarz, M., Pruska, K., Kusiak, A., & Ordyniec-Kwaśnica, I. (2022). A Fresh Look at Mouthwashes—What Is Inside and What Is It for? International Journal of Environmental Research and Public Health. https://doi.org/10.3390/ijerph19073926

Rezaei, T., Mehramouz, B., Gholizadeh, P., Yousefi, L., Ganbarov, K., Ghotaslou, R., Taghizadeh, S., & Kafil, H. S. (2023). Factors Associated with Streptococcus mutans Pathogenicity in the Oral Cavity. Biointerface Research in Applied Chemistry. https://doi.org/10.33263/BRIAC134.368

Sari, M., Ramadhanti, D. M., Amalina, R., Chotimah, Ana, I. D., & Yusuf, Y. (2022). Development of a hydroxyapatite nanoparticle-based gel for enamel remineralization —A physicochemical properties and cell viability assay analysis. Dental Materials Journal. https://doi.org/10.4012/dmj.2021-102

Shang, R., Kaisarly, D., & Kunzelmann, K. H. (2022). Tooth whitening with an experimental toothpaste containing hydroxyapatite nanoparticles. BMC Oral Health. https://doi.org/10.1186/s12903-022-02266-3

Upadhyay, Y. (2013). Current State and Future Perspectives of Nanotechnology In Dentistry. IOSR Journal of Pharmacy (IOSRPHR). https://doi.org/10.9790/3013-0309-68-71

Vranić, E., Lacević, A., Mehmedagić, A., & Uzunović, A. (2004). Formulation ingredients for toothpastes and mouthwashes. In Bosnian journal of basic medical sciences / Udruzenje basicnih mediciniskih znanosti = Association of Basic Medical Sciences. https://doi.org/10.17305/bjbms.2004.3362

Wang, S., Fang, L., Zhou, H., Wang, M., Zheng, H., Wang, Y., Weir, M. D., Masri, R., Oates, T. W., Cheng, L., Xu, H. H. K., & Liu, F. (2024). Silica nanoparticles containing nano-silver and chlorhexidine respond to pH to suppress biofilm acids and modulate biofilms toward a non-cariogenic composition. Dental Materials. https://doi.org/10.1016/j.dental.2023.11.006

Wu, Y. H., Ho, S. Y., Wang, B. J., & Wang, Y. J. (2020). The recent progress in nanotoxicology and nanosafety from the point of view of both toxicology and ecotoxicology. In International Journal of Molecular Sciences. https://doi.org/10.3390/ijms21124209

Yazicioglu, O., Ucuncu, M. K., & Guven, K. (2024). Ingredients in Commercially Available Mouthwashes. International Dental Journal. https://doi.org/10.1016/j.identj.2023.08.004

CHAPTER 5

PERSONALISED MEDICAL APPLICATIONS IN THE DIAGNOSIS AND TREATMENT OF PERIODONTAL DISEASES

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INTRODUCTION

Over the past two decades, rapid advances in molecular biology and information technologies have led tok a profound transformation in the field of medicine. The development of genetic analysis techniques, the widespread use of bioinformatics tools, and the integration of big data analytics into healthcare have enabled the advancement of personalised medicine. Personalised medicine is a model that aims to develop diagnostic ant therapeutic approaches based on each patient's genetic background, environmental exposures, ant lifestyle characteristics (Ginsburg et al., 2009; Maughan et al., 2017).

Periodontal diseases are complex inflammatory conditions that arise from the interaction between microbial factors that trigger inflammatory processes and activate host defense mechanisms, along with individual genetic susceptibility and environmental influences. Conventional periodontal diagnostic ant treatment protocols generally involve standardized procedures applied uniformly to all patients (Loos et al., 2020). However, due to the multifactorial nature of periodontal diseases, a one-size-fits-all treatment approach is often insufficient. Instead, the development of more effective and targeted treatment strategies based on individual patient characteristics is warranted. Such an approach enables the prevention of disease progression and the optimization of treatment outcomes through innovative and patient-centered methodologies.

In periodontal diseases, the personalised medicine model aims to establish customized diagnostic ant therapeutic plans based on patients' individual risk factors, biomarker profiles and genetic characteristics. Currently, the use of advanced biotechnological tools and artificial intelligence–based decision support systems allows for a more accurate assessment of disease susceptibility, early diagnosis and prognosis. These advancements facilitate more effective management of periodontal diseases and contribute to the development of patient-specific, targeted and preventive healthcare strategies (Ebersole et al., 2024; Gomathi et al., 2019).

In this review, we discuss the role and future potential of the personalised medicine model in the diagnosis, treatment, prevention, and maintenance of periodontal diseases.

Digital and Computer Assisted Personalised Medicine Aplications for the Diagnosis of Periodontal Diseases

Periodontitis is a complex inflammatory disease that is common in our society, causing aesthetic and functional problems in individuals and potentially negatively affecting systemic health. Although bacteria are the primary cause of periodontal disease genetic, immunological, and environmental factors that alter the host's inflammatory response also affect the rate and severity of disease progression. Therefore, in order to make an accurate periodontal diagnosis and plan treatment and maintenance, it is important to evaluate each patient individually for risk factors in conjunction with a clinical examination. In the 2017 classification of periodontal and peri-implant diseases, smoking and diabetes, which are risk factors affecting the progression rate of periodontitis, were included in the grading criteria for periodontitis, and this grading has enabled the implementation of personalised medicine (Papapanou et al., 2018; Tonetti et al., 2018). For periodontal diagnosis to be truly individualized, it is necessary to obtain information from different levels of sources related to genetic, microbial, immunological, environmental and behavioral factors associated with disease pathogenesis and to process this information. Obtaining and processing such a high level of data is only possible using digital and computer-assisted technology. Periodontal diseases are associated with systemic diseases and negatively affect patients' chewing and speaking functions and quality of life; therefore, periodontal status requires a more comprehensive assessment that goes beyond traditional measurements (Papapanou et al., 2017). Although traditional methods are used in periodontal examination, more data is needed to classify diseases more specifically and accurately in line with individual medical practices. The use of digital and computer-assisted systems to analyze large amounts of data optimizes diagnosis, treatment and patient follow-up. The limitations of routine clinical and radiographic examination methods make objective evaluation difficult (Korgaonkar et al., 2024; Gürsoy et al., 2024). Although attempts are made to overcome some of these limitations by utilizing electronic and computer-assisted systems, it should be borne in mind that differences in equipment and software may complicate standardized assessment, despite rapid technological advances. It should be remembered that periodontal diagnosis, determined in light of clinical parameters can be made after the biological onset of the disease process and the subsequent appearance of clinical symptoms (Salvi et al., 2023). Considering the course of periodontal diseases, routine clinical and radiographic examinations may show the results of a previously occurred deterioration in host defense rather than disease activity (Gürsoy et al.,2024; Salvi et al.,2023).

The use of early periodontal diagnosis tools can enable the early detection of periodontal diseases and facilitate disease management to reduce tooth loss. Artificial intelligence mimics human intelligence functions such as learning, problem solving and decision making. In dentistry, it is used in image analysis, disease prediction, and risk assessment. In periodontology, it is possible to make early diagnoses and provide personalised treatment based on patient records, images, and microbiome data.

Digital and computer-assisted tools facilitate the storage of patient records, save time, and enable the sharing of data among colleagues (Akalın et al., 2020). While NLP models such as ChatGPT can generate longer and higher-quality texts in medical history records, they carry a risk of error (Baker et al., 2024).

In a study analyzing the electronic dental records of over 27,000 patients, an artificial intelligence model predicting periodontal disease risk showed 72% accuracy (Patel et al., 2022). These results show that artificial intelligence is promising for processing patient records and periodontal diagnosis. While radiographic evaluation is important in periodontal examination, two-dimensional images have limitations. Therefore, three-dimensional imaging methods such as CBCT (cone beam computed tomography) and MRI (magnetic resonance imaging) have emerged as alternative diagnostic tools. Although CBCT provides higher diagnostic accuracy, it is only recommended in necessary cases due to radiation exposure (Haas et al., 2018). Artificial intelligence, particularly CNN (neuronal network with a neuron) based deep learning models, can accurately detect periodontal bone loss, periodontitis classification, gum health, and plaque presence from radiographic and clinical photographs (Kurt-Bayrakdar et al., 2023)

Traditional and artificial intelligence-based applications using mathematical algorithms for individual periodontal risk assessment were tested (Pitchika et al., 2024; Polizzi et al., 2024). ANN (artificial neural network) and decision tree models provided higher specificity and sensitivity than other models. A tool trained with XG Boost detected five-year treatment outcomes with higher accuracy using electronic health records (Patel et al., 2023). The algorithms associated kidney disorders, mental disorders, neurodegenerative diseases and hematological cancers with increased periodontal risk. While current tools evaluate parameters such as smoking, diabetes, bleeding on probing and pocket depth, multi-omic and microbiome analyses have not been integrated (Pitchika et al., 2024). The use of biomarkers may enable more predictive and personalized forecasts in the future.

Smartphone applications improve periodontal parameters through oral hygiene education, motivation, and reminders for follow-up appointments (Purba et al., 2024; Hartono et al., 2024). Artificial intelligence-supported applications analyze photos and videos taken at home to provide personalized recommendations and early diagnosis. Systems such as Dental Monitoring™ improve treatment outcomes and quality of life through feedback (Caruso et al., 2021). Mobile applications facilitate the tracking of patient data and contribute to personalised treatment plans for dentists.

Sensors based on micro and nanotechnology can be used for analyses performed inside or outside the mouth, enabling the detection of biomolecules across a wide range, from ions to cells (Korgaonkar et al., 2024). However, dynamic conditions exist in the mouth that can lead to inaccurate measurements due to contamination, such as bleeding, food debris, high levels of protein and the presence of proteolytic enzymes. These problems can be addressed by methods such as applying selective coatings that do not allow macromolecules to pass onto the sensors, using biocompatible materials and encapsulating the sensors. These problems have been largely overcome by methods such as applying selective coatings that do not allow macromolecules to pass onto the sensors, using biocompatible materials and encapsulating the sensors (Kim et al., 2014).

The use of sensors with high sensitivity and selectivity is essential for accurate and reliable measurements. The expansion of digital databases, combined with artificial intelligence, could benefit this field in the future by enabling the diagnosis of rare disease variants and the prompt implementation of the most accurate treatment plans. In addition to medical records, the development of digital databases should utilize behavioral data obtained from wearable technologies and smartphone applications, physical, chemical, and microbiological measurement data that can be obtained from intraoral and extraoral sensors and data obtained from multi-omic tests and microbiota analyses as sources. Furthermore, obtaining, processing, and analyzing large-scale data sets is necessary to personalize periodontology practice. Digital and computer-assisted systems not only facilitate the collection of data from different levels, but also optimize the analysis of this data, which is difficult and time-consuming to perform manually. Rapid technological developments in this field are expected to significantly transform the future management of periodontal disease by responding to current needs.

Oral Microbiome with Personalized Medicene Approch in the Diagnosis and Prognosis of Periodontal Diseases

Periodontal diseases, defined as common and chronic conditions, are inflammatory diseases characterized by the destruction of the supporting tissues surrounding the teeth (Pihlstrom et al., 2005). Today, it is known that they not only threaten the health of teeth and gums but can also have serious effects on systemic health. Therefore, the accurate diagnosis and treatment of periodontal diseases are crucial for controlling existing systemic diseases. Various methods have been used in the diagnosis and treatment of periodontal diseases. Traditional methods have not been fully successful due to the failure to consider environmental and genetic factors. Therefore, the use of molecular techniques, genetic tests and microbiome analyses, which can be classified as advanced investigations, is important for the early diagnosis, prognosis, and determination of individualized treatments for periodontitis.

The oral microbiome is a dynamic, living community composed of microorganisms such as bacteria, viruses, fungi, protozoa, and archaea that can be found in the oral cavity. As one of the most densely populated microbial ecosystems in the human body, it plays a critical role in both oral health and systemic health. Aagaard et al. suggested that the oral microbiome, which has quite different functions and has the opportunity to colonize and spread on epithelial surfaces in this area, begins to take shape even before birth, during intrauterine life (Aagaard et al., 2014). The oral microbiome is dominated by bacteria, along with yeast-like dimorphic fungi such as Candida albicans and Candida nonalbicans species (Homayouni et al., 2023). The oral cavity is a complex ecosystem that harbors over 700 bacterial species (Deo et al., 2019). In healthy individuals, the species in the oral microbiota and different oral ecological niches (teeth, gingiva, supragingival and subgingival plaque, gingival sulcus, tongue, cheeks, hard and soft palate structures, tonsils) are in a state of homeostasis. However, disruption of this balance leads to dysbiosis of microorganisms commonly seen in periodontal diseases and oral pathologies and potential pathogenic species can play a role in the etiology of many systemic diseases in the body (Han et al., 2013).

In the pathogenesis of periodontal diseases, certain species, particularly Porphyromonas gingivalis (P. gingivalis), Tannerella forsythia (T. forsythia) and Treponema denticola (T. denticola), are known to play a prominent role as periodontopathogenic species (Holt et al., 2005). It has been suggested that P. gingivalis in particular may be closely related to systemic diseases and may not only trigger inflammation but also stimulate the immune system, creating a chronic infection environment (Li et al., 2022). It is known that dysbiosis of the oral microbiome not only increases the local inflammatory response but also triggers systemic inflammation (DeGruttola et al., 2016). In recent years, studies have focused on the diagnostic and therapeutic potential of the oral microbiome. Microbiome analyses are an emerging field that opens new horizons in the early diagnosis of periodontal diseases, the selection of treatment processes, and the creation of personalized treatment plans. Detailed characterization of the human microbiome profile in health and disease enables its use as diagnostic biomarkers for many diseases and facilitates the diagnosis of numerous conditions, including inflammatory, neurological, and metabolic diseases, and even cancer. However, it is difficult and complex to precisely define what constitutes a healthy microbiome in different human populations because an individual's microbiota can be influenced by age, ethnicity, diet, lifestyle, exercise, smoking, environmental factors, and many other factors (Shanahan et al., 2021). Genetic and molecular methods such as CRISPR/Cas9 have the potential to regulate specific genetic traits in the oral microbiome. It is thought that such approaches could be used in the future to identify virulence factors of pathogenic bacteria.

Personalized medicine states that each individual's molecular, physiological, environmental, and behavioral characteristics are different and advocates that each patient should be examined at many levels, including genomic, biochemical and behavioral that treatments specific to the individual should be applied based on the information obtained from this examination (Goetz et al., 2018). Individualized oral and dental care interventions should be monitored and recorded on an individualized basis rather than community-based surveillance. To this end, one of the most widely used translational studies is the use of saliva as a biomarker in the assessment and monitoring of periodontal health (Salivaomics) (Wong et al., 2012).

Probiotics promote the growth of beneficial microorganisms in the mouth, thereby suppressing pathogens. Prebiotics, on the other hand, support the nutrition and growth of these beneficial microorganisms. Probiotics and prebiotics selected according to individuals' microbiome profiles play an important role in improving oral health. The application of probiotics has been reported to contribute to the healing of periodontal tissues by preventing the colonization of subgingival pathogens (Iniesta et al., 2012). In addition, probiotics can reduce inflammatory mediators such as IL-1β and TNF-α and slow the progression of periodontal diseases (Szkaradkiewicz et al., 2014).

The use of artificial intelligence (AI) in personalized medicine approaches is becoming increasingly widespread. The use of artificial intelligence in medicine helps to expand healthcare services, enable patient-centered treatments, make changes in personalized treatments, and improve treatment plans. AI is now being used to analyze a patient's microbiome profile, predict the progression of an existing disease, and determine the most appropriate treatment. Advances in artificial intelligence will increase the accuracy of the analyses used in personalized treatments and make these treatments more effective.

In the future, oral microbiome analysis is expected to become a routine diagnostic tool in daily dental practice. Furthermore, holistic models that evaluate genetic predispositions, lifestyle factors and microbiome profiles together may provide more effective results in the prevention and treatment of periodontal diseases. Furthermore, microbiome analysis and personalized medicine applications will emerge as a promising field in the diagnosis and treatment of periodontal diseases, and scientific developments in this area will contribute to the development of more effective and personalized treatment methods in the future.

Biomarkers in the Diagnosis and Prognosis of Periodontal Diseases in the Perspecitive of İndividualized Medicine Approch

Periodontal diseases are inflammatory diseases characterized by the destruction of teeth and surrounding tissues, triggered by microbial factors that activate host defense mechanisms through inflammatory processes. The immune inflammatory response in periodontitis has a complex structure, involving both innate and adaptive immune components. Despite all the complex molecular and cellular events involved in the development of periodontal disease, its diagnosis and post-treatment follow-up are still performed using clinical and radiographic evaluations. However, these have low sensitivity and the measurements can be subjective (Buduneli et al., 2011). The use of biomarkers within the new classification of periodontal and peri-implant diseases has been accepted as the first step towards adopting the concept of personalized medicine in periodontology (Tonetti et al., 2018). Individualized periodontal diagnostic approaches continue to evolve in line with advances in microbiology, biochemistry, immunology, molecular biology, genetics and connective tissue biology (Tonetti et al., 2018). Studies in different "omic" disciplines focus on defining a molecular relationship associated with periodontitis (Moussa et al., 2022). This molecular signature can be found at the DNA, RNA, protein or metabolite level and may have the potential to predict the development of periodontal disease, assess its prognosis, and monitor the effectiveness of periodontal treatment (Trindade et al., 2014). Additionally, biomarkers enable the real-time monitoring of biological processes by evaluating regulatory molecules synthesized and released by cells and tissues in response to genetic and epigenetic factors (Biomarkers Definitions Working et al., 2001).

While biomarkers indicate health status, disease, and/or response to treatment, they must also be reliable and validated in clinical studies. Numerous studies have shown that interleukin-1beta (IL-1β), IL-2, IL-6, IL-8, IL-17, and tumor necrosis factor-alpha (TNF-α) are reliable inflammatory biomarkers in patients with different periodontal diseases and that these biomarker levels decrease significantly after periodontal treatments such as scaling and root planing. One of the most studied biomarkers, IL-1β, is a potent bone-resorbing cytokine known as an osteoclast-activating factor. Previous reports have shown that IL-1β levels are elevated in active areas of periodontal disease and decrease following periodontal treatment.

In periodontal diseases, it has been demonstrated that MCP-1 and MCP-4 levels increase as the disease progresses and decrease after treatment. These findings suggest that both chemokines may be potential biomarkers reflecting disease severity. Pentraxin-3 is considered an important biomarker for monitoring inflammatory processes in periodontal tissues. Meta-analysis results have revealed that IL-1β, IL-4, IL-6, IL-17, interferon-gamma, and MCP-1 levels in individuals with periodontitis show significant differences compared to healthy individuals.

Adipokines such as visfatin, leptin, adiponectin, and resistin have been evaluated as biomarkers specific to periodontal disease. Studies have shown that visfatin concentrations increase in proportion to disease severity and decrease after non-surgical periodontal treatment (Raghavendra et al., 2012; Wu et al., 2015).

Matrix Metalloproteinases (MMPs) are enzymes that degrade extracellular matrix proteins and are regulated by TIMPs. In periodontal diseases, the disruption of the MMP/TIMP balance accelerates tissue destruction and inflammation. While MMP-9 is particularly associated with disease severity, MMP-8 is considered a strong biomarker for periodontitis due to its high sensitivity (Leppilahti et al., 2014; Rathnayake et al., 2017). The decrease in MMP levels observed after periodontal treatment indicates that tissue destruction can be controlled.

miRNAs studied as biomarkers in periodontal diseases play an important role in regulating cellular mechanisms related to inflammation, tissue destruction, and healing during the disease process. The most studied periodontal biomarkers are miR-146a, miR-203, miR-223, and miR-23a.

Gingival crevicular fluid is considered a mirror reflecting an individual's periodontal health status and is seen as a valuable diagnostic tool for assessing and monitoring periodontal health (Gupta et al., 2012).The diagnostic potential of GCF has been comprehensively demonstrated by the wide range of biomarkers identified in its composition. A correlation has been demonstrated between protease and collagenase levels in GCF and pocket depth values associated with periodontal disease. The study identified 247 proteins that were up-regulated and 128 proteins that were down-regulated, revealing distinct protein profiles between gingivitis and periodontitis (Ahmad et al., 2024). These data highlight that saliva could be a valuable biological fluid for proteomic analyses in periodontal diseases.

Saliva contains various biomolecules that may aid in diagnosis and prognosis, such as metabolites, proteins, mRNA, DNA, enzymes, hormones, antibodies, antimicrobial components, and growth factors. IL-1β, MMP-8, IL-6, and MMP-9 are the most frequently analyzed biomarkers in saliva, followed by IL-8, TIMP-1, IL-10, and MMP-3; increased levels of these biomarkers have been determined in periodontitis cases. Furthermore, elevated levels of IL-1, IL-6, IL-8, and IL-12 have been observed in the saliva of patients with peri-implantitis (Melguizo-Rodríguez et al., 2020).

The personalized medicine approach enables the development of more sensitive and individualized strategies for the diagnosis and prognosis of periodontal diseases. Furthermore, the use of biomarkers plays a critical role not only in diagnosis but also in predicting disease severity, course and response to treatment. Although no periodontal biomarkers are currently used in clinical practice, it is believed that biomarker-focused individualized approaches will be effective in providing patient-centered solutions in the future.

The Role of Lifestyle and Risk Factors in İndividual Periodontal Treatment Approaches

Periodontal diseases are known to be complex diseases with multifactorial origins and variable treatment outcomes. Although bacteria are the primary etiological factor in periodontal diseases, the individual's inflammatory response, along with other modifying and predisposing factors, determines the clinical course and outcome of the disease (Highfield et al., 2009). Individual differences, such as environmental and genetic factors, play an important role in the progression of the disease. The same treatment plan may not yield the same results for every individual; in other words, there is no single correct approach. In this context, periodontal treatment is inherently individualized and difficult to standardize and optimize (Kikuchi et al., 2022). Personalized medicine tailors oral health care practices and products to the specific needs of each patient. 4 The concept of “P4 medicine” an extension of personalized medicine, incorporates predictive, personalized, preventive and participatory characteristics.

Individualized periodontology is part of the “4P” approach to treatment, which considers individual genetic characteristics, environmental factors, lifestyles and behaviors.

Environmental factors such as different lifestyles and educational levels as well as socioeconomic status, are recognized as playing significant roles in the clinical improvement of periodontal diseases. Different lifestyles such as tobacco, alcohol, medical drugs, uncontrolled diabetes, obesity, malnutrition, cardiovascular diseases, and psychological stress, must be considered in this context (Chapple et al., 2017). Since the risk and its effect can vary greatly from person to person, knowing the risk factors can be effective in the diagnosis and treatment of periodontitis pathobiology (Bartold et al., 2018).

It is known that tobacco use, in all its different and known forms, is one of the most important risk factors affecting the frequency and progression of PH in peri-implant tissues (Johnson et al., 2007; Ryder et al., 2018). Numerous studies in the literature have found that smokers have an increase in Escherichia coli and Candida species, microorganisms that cause superinfection, a lower reduction in the number of periodontal pathogens after scaling and root planing, a poorer response to systemic antibiotic treatment, and a shorter time to return to pathogenic flora after the reduction in gingival inflammation (Kamma et al., 1999; Joshi et al., 2014). Acute or chronic exposure to tobacco components through smoking can cause significant changes in the oral microflora. Numerous studies have shown that in individuals with periodontitis who smoke, the levels of receptor activator of nuclear factor kB ligand (RANKL), an effective stimulator of bone destruction, are high in gingival crevicular fluid and serum, whereas the levels of osteoprotegerin, a bone-protective factor, are low (Söder et al., 2002; Ozçaka et al., 2010). Furthermore, in all surgical and non-surgical treatments, the response to treatment is significantly higher in non-smoking patients than in smokers. Individual periodontal treatment approaches for tobacco-using patients include systemic-local antimicrobial treatments, host modulation treatments, and personalized smoking cessation strategies (Ryder et al., 2018). Currently, in the literature, only tetracycline group antibiotics are preferred for widespread use due to their effects in suppressing the destructive host response in smokers.

Psychological stress, cardiovascular diseases, diabetes and obesity are known to be risk factors for periodontal diseases. Studies show that individuals under stress have a higher risk of developing periodontal diseases. Psychological stress, cardiovascular diseases, diabetes and obesity are known to be risk factors for periodontal diseases. Studies have shown that individuals under stress are more likely to smoke and less likely to brush their teeth and visit the dentist. While the acute stress response is critical for survival, repeated or chronic exposure to stressors can have harmful effects on the nervous and endocrine systems and immune function. Numerous studies have investigated the relationship between salivary cortisol, interleukin-1 beta, interleukin-6 levels and periodontitis (Cakmak et al., 2016; Mengel et al., 2002). Salivary cortisol is an acute stress biomarker and it has been noted that determining its possible causal relationship with periodontal status is difficult.

Malnutrition causes salivary gland hypofunction, impaired immunity and the dominance of anaerobic organisms in the oral microbial ecology (Enwonwu et al., 2001). Epidemiological studies have proven that micronutrient deficiencies affect biological mechanisms such as oxidative stress, inflammation, collagen structure, and bone mineralization. Careful classification of participants is important to assess the benefits of supplemental nutrition for periodontitis and periodontal treatment. Pregnancy, smoking, and alcohol consumption are factors that can cause micronutrient depletion. As evidence-based information increases, it appears that a pragmatic approach to nutritional recommendations for patients at high risk for periodontitis will be in line with the recommendations of the World Health Organization (WHO) (World Health Organization et al., 2002).

Diabetes Mellitus (DM) is a global epidemic disease with increasing prevalence worldwide. Diabetes is one of the most important risk factors for periodontitis. In the current literature, periodontal diseases are considered a common complication of Type 1 and Type 2 diabetes (Löe et al., 1993). Looking at the relationship between DM and periodontal diseases from the opposite perspective, in the periodontitis process, both the release of proinflammatory cytokines and the entry of periodontal bacteria and components into the systemic circulation result in low-grade systemic inflammation. For this reason, periodontitis is an important risk factor for the progression of other chronic diseases such as atherosclerosis, cardiovascular diseases, rheumatoid arthritis, and diabetes (Chapple et al., 2017; Herrmann et al 2015; George et al., 2022; Ryder et al., 2010). Diabetes control should be ensured and necessary consultations should be made before periodontal treatment to avoid causing hypo- and/or hyperglycemia. Oral hygiene recommendations should be given to diabetic individuals with periodontitis and mechanical debridement and supportive periodontal treatments should be applied. For many patients, the treatment goal is to achieve and maintain glycated hemoglobin (HbA1c) below 8%.

Obesity is a common and rapidly increasing disease frequently seen in adults and children in many countries. It leads to various complications such as cardiovascular diseases, diabetes mellitus, lung diseases, and an increased risk of malignancy (Smith et al., 2016; Apovian et al., 2016). Two long-term clinical studies conducted in children and adults on the incidence and progression of periodontal disease in obese cases have shown that obesity increases the progression of periodontal diseases (Suvan et al., 2018). To improve the response to periodontal treatment and reduce inflammation, dentists should advise obese patients on lifestyle changes, dietary treatment, behavioral therapy, drug treatments and surgical procedures (George et al., 2022)

Cardiovascular diseases are one of the leading causes of death worldwide and their main etiologies are obesity and diabetes. Periodontitis and atherosclerosis share common pathways associated with persistent inflammation (Björkegren et al., 2022). Patients with moderate to severe periodontitis should be informed that they may have a higher risk of developing CVD compared to periodontally healthy adults and medical monitoring should be provided for periodontitis patients with one or more CVD risk factors. Medical and dental professionals should collaborate to control common risk factors for PH and CVD, such as hyperlipidemia, hypertension, smoking and metabolic syndrome in patients with both conditions (Sanz et al., 2020).

Nonsurgical İndividual Periodontal Treatment Approach

Periodontitis, which is commonly seen in society, poses a significant health burden. It is characterized by bleeding gums, periodontal pocket formation, clinical attachment loss, and alveolar bone resorption observed on radiographs (Papapanou et al., 2018). The goal of traditional periodontal treatment is to eliminate deep periodontal pockets, stop gum bleeding and ensure effective plaque control. Nonsurgical periodontal treatment (NSPT), which forms the basis of periodontal treatment, is the first step recommended for controlling periodontal infections. A uniform treatment approach, which does not involve the individual's role in tissue destruction triggered by a bacterial agent but resulting from the person's immune-inflammatory response, is successful in some patients but unsuccessful in others. Therefore, individual inflammatory responses and related factors must be considered in treatment of periodontal diseases (Bartold et al., 2018).

The use of oral antibiotics in combination with mechanical debridement may help control periodontal pathogens in cases of resistant periodontitis. Both broad-spectrum and narrow-spectrum antibiotics have been used alone or in combination, in addition to CDPT. Studies have shown that the additional use of systemic antibiotics to enhance the effectiveness of mechanical treatment provides a statistically significant benefit on clinical parameters. According to the findings of a recent systematic review and meta-analysis evaluating the effects of systemic antibiotic use in periodontal treatment, the combination of metronidazole and amoxicillin has been found to produce statistically significant improvements in pocket depth, bleeding on probing, and clinical attachment gain (Teughels et al., 2020). Systemic antimicrobial use may cause effects such as dysbiosis, gastrointestinal problems, development of drug resistance, and toxicity. These disadvantages are not observed in local drug delivery systems that allow non-invasive delivery of the drug to the subgingival pocket. In these systems, two or more drugs from different categories can be delivered to the periodontal pocket simultaneously. Fibrils, films, nanoparticles, microparticles, gels and irrigants are forms of local drug delivery (Sanz et al., 2020). Fibrils placed peripherally in the periodontal pocket are carrier systems into which the active material is impregnated. The best-known fibril system, Actisite®, contains 25% tetracycline hydrochloride (HCl) and can maintain a constant concentration in GCF for 10 days. The use of these local applications has been reported to provide statistically significant benefits in terms of pocket depth reduction and short-term clinical attachment gain (Akıncıbay et al., 2007). In individualized periodontal treatment approaches, the use of locally applied sustained-release antimicrobials should always be preferred as an adjunct to CDPT in patients with grade A or B periodontitis, in deep and localized periodontal pockets, in patients with periodontitis unresponsive to conventional treatment, in patients with peri-implantitis, and in grade I-II furcation lesions (Sufaru et al., 2023).

Ozone has various uses in many disorders due to its antibacterial, immunostimulatory, analgesic, antihypnotic, detoxifying, bioenergetic, and biosynthetic effects. Ozone (O3) has been used in different forms in the treatment of periodontal disease. For example in two different studies where ozone in gas form was applied in addition to CDPT, no improvement in clinical parameters was observed at 3 months post-treatment, but at 12 months, a significant improvement was observed in the ozone-treated group compared to the group that did not receive ozone. Another application form, ozonated gel, has been observed in a recent study to provide additional benefits when used in conjunction with CDPT in periodontitis patients with type 2 diabetes (Barahim et al., 2024).

Probiotics are defined by the WHO as “live microorganisms that confer a health benefit on the host when administered in adequate amounts.” The most commonly used microorganisms as probiotics are lactobacilli and bifidobacteria. Ausenda et al., in a recent systematic review, reported that the use of probiotics in addition to initial periodontal treatment is effective in clinical attachment gain and pocket depth reduction, especially if the application period is long. The authors noted that improvement was statistically significant when L. reuteri was used in a daily double dose, in tablet form (Ausenda et al., 2023). Propolis, also known as bee glue, is a resinous product with a wide range of therapeutic effects, including anti-inflammatory, antimicrobial, immunomodulatory, antitumor, anticancer, and antiulcer properties. The anti-inflammatory effect of propolis has been reported because inflammasomes such as Toll-like receptor 4 (TLR4) and

Myeloid Differentiation Primary Response (MyD88) lead to the downregulation of proinflammatory cytokines (Zulhendri et al., 2022).

While antimicrobial therapies, including KYD, target bacteria in periodontitis treatment, host modulation therapy targets the host response such as matrix metalloproteinases (MMPs) and inflammatory cytokines. With the new classification of periodontal diseases, modulating the host response has become a new focus. The new two-dimensional classification system, which includes stage and grade, highlights the host response in individual disease and individual treatment (Papapanou et al., 2018). The non-antimicrobial property of doxycycline in periodontitis is based on the inhibition of collagenase activity in gingival tissues and gingival crevicular fluid. Subantimicrobial dose doxycycline (SDD) reduces both connective tissue destruction and alveolar bone resorption. SDD (Periostat®) is the only FDA-approved MMP inhibitor that can be used in addition to CDPT. The American Dental Association (ADA) has reported that nonsurgical periodontal treatment, when used alone or in combination with SDD for 3-9 months, is the most evidence-based treatment for periodontitis in terms of safety and efficacy (Smiley et al., 2015). The complement system can act synergistically with Toll-like receptor (TLR) cells to increase the production of inflammatory cytokines such as IL-17, which exacerbate bone loss and periodontitis. Interventional strategies targeting TLR signaling, such as the use of mesenchymal stem cells or TLR agonists, may have the potential to modulate immune responses in periodontal disease (Behm et al., 2020).

Gene therapy is used to control periodontal diseases and reconstruct damaged tissues by altering the genetic properties of cells. Combined with tissue engineering, this method enables the transfer of genes that support regeneration and repair to target cells. The transfer of genes such as BMP-2, BMP-7, and PDGF-BB using adenoviral vectors enhances bone and tissue healing and the use of PDGF has been approved by the FDA. Additionally, bacteriophage-based gene therapies offer a new approach to combating biofilm-forming pathogens. However, cell source selection, matrix integration and control of gene expression remain clinical challenges.

Epstein-Barr (EBV), sitomegalovirüs (CMV) ve herpesvirüs (HPV) plays a role in the etiology of periodontal disease. Systemic valacyclovir treatment has been reported to reduce EBV viral load and improve the clinical condition of periodontal lesions and when used in conjunction with non-surgical full-mouth debridement, it has been reported to yield positive results in stage 2 periodontitis (Prato et al., 2002). Acyclovir is effective in the early stages of herpetic infection, and antiviral treatments have been reported to yield positive results in stage 2 periodontitis when used (Balaji et al., 2021). In resistant periodontitis cases, antiviral agents can be applied in conjunction with mechanical debridement. In addition, antiviral mouthwashes and functional nanoparticles are being investigated as new therapeutic agents.

Porphyromonas gingivalis is one of the most common pathogens of periodontal disease. Bacterial fimbriae, lipopolysaccharides and gingipains have been investigated as vaccine targets, but whole-cell vaccines have failed to provide long-term immunity. Cell-free protein synthesis systems and plasmid DNA-based approaches have shown promising results in developing protective antibody responses against P. gingivalis (Huang et al., 2019; Kawabata et al., 1999). However, maintaining long-term immunity and ensuring efficacy against multiple pathogens remains a significant challenge (Kudyar et al., 2011).

Epigenetic mechanisms such as DNA methylation and histone modifications have been associated with differential expression in TNF-α, TLR, CCL25, and IL-17C genes (Zhang et al., 2013; Schulz et al., 2016). P. gingivalis infection disrupts epithelial barrier integrity by reducing the integrity of junctional proteins and trans-epithelial electrical resistance (Casadesús et al., 2006; Groeger et al., 2010). These findings indicate that epigenetic changes play a role in the development of periodontal disease.

İndividual Applications in Regenerative Periodontal Surgical Treatment

The periodontium is a highly complex and specialized organ surrounding the tooth, composed of four mesenchymal tissues (Nuñez et al., 2019). Although this organ is resistant to chewing forces and capable of adaptation, it can respond quite sensitively to inflammation caused by bacterial biofilm. This response results in the gradual destruction of the tooth's supporting tissues. This condition can lead to periodontitis, characterized by irreversible alveolar bone loss and periodontal pocket formation around the teeth. The goal is to regenerate periodontal tissues to restore the anatomy and functionality of damaged periodontal tissues. Successful periodontal regeneration requires surgical periodontal treatments that ensure principles such as primary closure, angiogenesis, space maintenance, and stability.

Periodontal tissue regeneration is a complex biological process that occurs in a specific sequence and timing to ensure proper wound healing. The use of biologically compatible materials is of great importance in this process. In this context, autogenous bone grafts are considered the gold standard (Ausenda et al., 2019). Autogenous grafts obtained from intraoral or extraoral donor sites have shown successful clinical and radiographic results in periodontal bone defects (Alshujaa et al., 2024). However it has disadvantages such as the need for a second surgical site, prolonged operation time, and inability to obtain sufficient graft material (Ausenda et al., 2019). Autogenous tooth graft obtained from extracted teeth stands out as an innovative alternative due to its lack of additional surgery requirements and biochemical compatibilit (Janjua et al., 2022; Kim et al., 2014). Furthermore it has been demonstrated that these grafts are resorbed over time and replaced by quality bone (Kim et al., 2014). However, it is noted that the long-term clinical outcomes of this method have not yet been sufficiently evaluated.

Advances in stem cell biology and regenerative medicine have made mesenchymal stem cell (MSC)-based tissue engineering a promising approach in periodontal regeneration (Chen et al., 2009; Zhang et al., 2012). MSCs can be obtained from odontogenic (dental pulp, PDL, gingiva, deciduous teeth, apical papilla, dental follicle) and non-odontogenic sources (Gao et al., 2024). PDL stem cells, in particular, stand out due to their ability to differentiate into different cell types and support tissue regeneration Additionally, it has been demonstrated that orally derived MSCs can be reprogrammed into pluripotent stem cells (Park et al., 2008). Following periodontal injury, the ideal healing outcome aims at the regeneration of alveolar bone, cementum and the periodontal ligament (PDL) (Nyman et al., 1982). PDL-derived stem cells have gained particular attention due to their ability to differentiate into multiple cell types and to support tissue regeneration (Seo et al., 2004). However, inflammatory conditions may limit this regenerative process. It has been demonstrated that MSCs contribute to regeneration by maintaining tissue homeostasis, and that PDL derived MSCs can be transplanted into periodontal defects without inducing immune-related adverse effects (Bartoldet al., 2006; Ferrarotti et al., 2018). Nevertheless, the limited availability of MSCs and the risk of age-related functional decline have led to increasing interest in induced pluripotent stem cells (iPSCs) as an alternative regenerative approach In this context, endogenous regenerative technology has been developed, which is based on the mobilization of resident stem cells through the application of bioactive factors (Liu et al., 2019). Platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) are effective biological materials that support cell recruitment and periodontal regeneration through their high content of growth factors (Xu et al.,2019; Chen et al., 2010).

Autologous platelet concentrates (APCs), such as PRP and PRF, are biologically active products rich in growth factors and are widely used to enhance wound healing and tissue regeneration (Quirynen et al., 2023). The combined use of PRP with autogenous or xenogeneic graft materials has been shown to improve bone density and periodontal healing outcomes (Marx et al.,1998; Hanna et al., 2004). PRF, a second-generation APC obtained without the use of anticoagulants, has demonstrated significant improvements in clinical attachment level (CAL), probing depth (PD), and radiographic bone fill (RBF) (Mijiritsky et al., 2021). Concentrated growth factor (CGF) has exhibited superior regenerative outcomes compared to PRF, owing to its denser fibrin matrix and higher growth factor content (Alshujaa et al., 2024). The newly developed platelet-rich bone fibrin (PRBF) technology, characterized by its calcium-supported structure, provides sustained release of growth factors and represents a safe and effective regenerative alternative in periodontal therapy (Anitua et al., 2007).

Bioprinting technology represents an innovative approach in periodontal regeneration aimed at the simultaneous and coordinated formation of cementum, periodontal ligament and alveolar bone (Yang et al., 2023). This technique enables the three-dimensional (3D) printing of living cells in combination with biomaterials, allowing for precise spatial organization of regenerative components (Sufaru et al., 2022). Patient-specific 3D scaffolds offer biocompatible, mechanically stable structures that are conducive to cell adhesion, proliferation and differentiation (Rasperini et al., 2015). Moreover, multiphasic scaffolds, when combined with different cell types, support multilayered tissue regeneration by mimicking the hierarchical structure of periodontal tissues (Park et al., 2014). Consequently, 3D bioprinting is considered a promising technology for achieving personalized and predictable periodontal tissue regeneration (Sonika et al., 2023).

Another method used for guided bone regeneration (GBR) in alveolar bone deficiencies of the periodontium resulting from periodontal disease, trauma, or congenital defects is bone augmentation using customized titanium meshes fabricated by 3D printing technology (Li et al., 2021). In a case series, favorable outcomes were reported for both horizontal and vertical defects following treatment with patient-specific titanium meshes produced through a digital workflow to achieve bone regeneration (De Santis et al., 2021). Particularly in implant therapy, satisfactory results have been obtained with GBR procedures performed using individualized titanium meshes (Tallarico et al., 2020). As evidenced by the existing literature, customized titanium meshes are primarily utilized in the regeneration of large bone defects. However, there is currently limited evidence regarding their application in the treatment of interdental defects.

REFERENCES

Aagaard K, Ma J, Antony KM, Ganu R, Petrosino J, Versalovic J. The placenta harbors a unique microbiome. Sci Transl Med. 2014;6:237-265.

Ahmad P, Escalante Herrera A, Marin LM, Siqueira WL. Progression from healthy periodontium to gingivitis and periodontitis: Insights from bioinformatics driven proteomics A systematic review with meta-analysis. J Periodontal Res.2024.

Akalın B, Veranyurt Ü. Sağlıkta dijitalleşme ve yapay zekâ. SDÜ Sağlık Yönetimi Dergisi. 2020;2:128-137.

Akıncıbay H, Senel S, Yetkin Ay Z. Application of chitosan gel in the treatment of chronic periodontitis. J Biomed Mater Res Part B Appl Biomater.2007;80:290-296.

Alshujaa B, Talmac AC, Altindal D, Alsafadi A, Ertugrul AS. Clinical and radiographic evaluation of the use of PRF, cGF and autogenous bone in the treatment of periodontal intrabony defects: Treatment of periodontal defect by using autologous products. J Periodontol. 2024;95(8):729-739.

Anitua E, Sánchez M, orive G, Andía I. The potential impact of the preparation rich in growth factors (PRGF) in different medical fields. Biomaterials.2007;28(31):4551-60.

Ausenda F, Barbera E, Cotti E, Romeo E, Natto ZS, Valente NA. Clinical, microbiological and immunological short, medium and long-term effects of different strains of probiotics as an adjunct to non-surgical periodontal therapy in patients with periodontitis. Systematic review with meta-analysis. J Dent Sci Rev. 2023;59:62-103.

Ausenda F, Rasperini G, Acunzo R, Gorbunkova A, Pagni G. New perspectivesin the use of biomaterials for periodontal regeneration. materials (Basel).2019;12(13):2197.

Baker HP, Dwyer E, Kalidoss S, Hynes K, Wolf J, Strelzow JA. ChatGPT'sability to assist with clinical documentation: a randomized controlled trial. J Am Acad Orthop Surg.2024;32:123-9.

Balaji TM, Varadarajan S, Sujatha G, Muruganandhan J, Shanmugapriya R, Raj AT. Necrotizing periodontal diseases in human immunodeficiencyvirus-infected patients receiving highly active antiretroviral therapy: A Review Disease a Month. 2021;67:101168.

Barahim AA, Shemais N, Mousa A, Darhous M. Clinical and radiographic evaluation of nonsurgical therapy with and without ozone gel application in controlled type 2 diabetic patients with periodontitis: a randomized controlled clinical trial. BMC Oral Health. 2024; 25;24(1):1435.

Barros SP, Offenbacher S. Modifiable risk factors in periodontal disease: epigenetic regulation of gene expression in the inflammatory response. Periodontol 2000. 2014;64(1):95-110.

Bartold PM. Lifestyle and periodontitis: The emergence of personalized periodontics Periodontology 2000. 2018;78(1): 7-11.

Bartold PM, Shi S, Gronthos S. Stem cells and periodontal regeneration. Periodontol 2000. 2006;40:164-72.

Behm C, Blufstein A, Gahn J, Kubin B, Moritz A, Rausch-Fan X. Continuing effect of cytokines and toll-like receptor agonists on indoleamine-2,3-dioxygenase-1 in human periodontal ligament stem/stromal cells. Cells.2020;9:2696.

Biomarkers Definitions Working G. Biomarkers and surrogate endpoints: preferred definitions and conceptual framework. Clin Pharmacol Ther. 2001;69(3):89-95.

Buduneli N, Kinane DF. Host-derived diagnostic markers related to soft tissue destruction and bone degradation in periodontitis. J Clin Periodontol. 2011;38(11):85-105.

Casadesús J, Low D. Epigenetic gene regulation in the bacterial world. Microbiol Mol Biol Rev. 2006;70(3):830-56.

Caruso S, Caruso S, Pellegrino M, Skafi R, Nota A, Tecco S. A knowledge-based algorithm for automatic monitoring of orthodontic treatment: the den-tal monitoring system. Two cases. Sensors. 2021;21:185.

Chapple IL, Bouchard P, Cagetti MG, Campus G, Carra MC, Cocco F. Interaction of lifestyle, behaviour or systemic diseases with dental caries and periodontal diseases: Consensus report of group 2 of the joint EFP/ORCA Workshop on the boundaries between caries and periodontal diseases. J Clin Periodontol. 2017; 44(18): 39-51.

Chen Fm, Shelton RM, Jin Y, Chapple IL. Localized delivery of growth factorsfor periodontal tissue regeneration: role, strategies, and perspectives. Med Res Rev. 2009;29(3):472-513.

Chen FM, Zhang J, Zhang M, An Y, Chen F, Wu ZF. A review on endogenousregenerative technology in periodontal regenerative medicine. Biomaterials.2010;31(31):7892-927.

DeGruttola AK, Low D, Mizoguchi A, Mizoguchi E. Current Understanding of Dysbiosis in Disease in Human and Animal Models. Inflamm Bowel Dis. 2016;22:1137-1150.

Deo PN, Deshmukh R. Oral microbiome: Unveiling the fundamentals. J Oral Maxillofac Pathol. 2019;23:122-8.

De Santis D, Gelpi F, Verlato G, Luciano U, Torroni L, Antonucci N. Digital customized titanium mesh for bone regeneration of vertical, horizontal and combined defects: A case Series. medicina. 2021;57(1):60.

Ebersole JL, Hasturk H, Huber M.Realizing the clinical utility of saliv a for monitoringoral diseases. Periodontol 2000. 2024;95(1):203-19.

Ferrarotti F, Romano F, Gamba MN, Quirico A, Giraudi M, Audagna M. Human intrabony defect regeneration with micrografts containing dental pulpstem cells: A randomized controlled clinical trial. J clin Periodontol.2018;45(7):841-50.

Gao P, Kajiya M, Motoike S, Ikeya M, Yang J. Application of mesenchymal stem/stromal cells in periodontal regeneration: opportunities and challenges. J Dent Sci Rev. 2024;60:95-108.

Ginsburg GS, Willard HF. Genomic and personalized medicine: found ations andapplications. Transl Res.2009;154(6):277-87.

Goetz LH, Schork NJ. Personalized medicine: motivation, challenges, and progress. Fertil Steril 2018;109:952-963.

Gomathi GD, Gopalakrishnan S, Sudhakar U. Personalised medicine a recent revolution in periodontics. İnternational Journal of Per iodontogy and Implantology. 2019;4(3):69-72.

Groeger S, Doman E, Chakraborty T, Meyle J. Effects of Porphyromonas gingivalis infection on human gingival epithelial barrier function in vitro. Eur J Oral Scie. 2010;118:582-8

Gupta G. Gingival crevicular fluid as a periodontal diagnostic indicator: Host derived enzymes and tissue breakdown products. J Med Life.2012;5(4):390-7.

Gürsoy UK, Özdemir Kabalak M, Gürsoy M. Advances in periodontal biomarkers. Adv Clin Chem. 2024;120:145-68.

Haas LF, Zimmermann GS, De Luca Canto G, Flores-Mir C, Corrêa M. Precision of cone beam CT to assess periodontal bone defects: a systematic review and meta-analysis. Dentomaxillofac Radiol. 2018;47:2017008.

Hajjo R, Sabbah DA, Al Bawab AQ. Unlocking the potential of the human microbiome for identifying disease diagnostic biomarkers. Diagnostics (Basel)2022;12(7):1742.

Hanna R, Trejo Pm, Weltman RL. Treatment of intrabony defects with bovine-derived xenograft alone and in combination with platelet-rich plasma: a randomized clinical trial. J Periodontol. 2004;75(12):1668-77.

Han YW, Wang X. Mobile microbiome: oral bacteria in extra-oral infectionsand inflammation. J Dent Res 2013;92:485-91.

Highfield J. Diagnosis and classification of periodontal disease. Australian Dental Journal. 2009;54 (l):11-26.

Holt SC, Ebersole JL. Porphyromonas gingivalis, treponema denticola, andtannerella forsythia: the "red complex", a prototype polybacterial pathogeni consortium in periodontitis. Periodontol 2000. 2005;38:72-122.

Homayouni Rad A, Pourjafar H, Mirzakhani E. A comprehensive review of the application of probiotics and postbiotics in oral health. Front Cell Infect Microbiol. 2023;13:1120995.

Iniesta M, Herrera D, Montero E. Probiotic effects of orally administeredLactobacillus reuteri-containing tablets on the subgingival and salivary microbiota in patients with gingivitis. A randomized clinical trial. J Clin Periodontol. 2012;39:736-44.

Iwata T, Yamato m, Washio K, Yoshida T, Tsumanuma Y, Yamada A. Periodontal regeneration with autologous periodontal ligament-derived cell sheets-A safety and efficacy study in ten patients. Regen Ther. 2018;9:38-44.

Janjua OS, Qureshi SM, Shaikh MS, Alnazzawi A, Rodriguez-Lozano FJ, Pecci-Lloret MP. Autogenous tooth bone grafts for repair and regeneration of maxillofacial defects: A Narrative Review. Int J Environ Res Public Health.2022;19(6):36-90.

Johnson GK, Guthmiller JM. The Impact of cigarette smoking on periodontal disease and treatment. Periodontology 2000. 2007;44(1):178-94.

Joshi V, Matthews C, Aspiras M, De Jager M, Ward M, Kumar P. Smoking decreases structural and functional resilience in the subgingival ecosystem. J Clin Periodontol. 2014;41(11):1037-47

Kamma JJ, Nakou M, Baehni PC. Clinical and microbiological characteris tics of smokers with early onset periodontitis. J Clin Periodontal Res. 1999;34 (1): 25-33.

Kikuchi T, Hayashi JI, Mitani A. Next generation examination, diagnosis, and personalized medicine in periodontal disease. J Pers Med. 2022; 12(10):1743.

Pudakalkatti PS, Baheti AS, Hattarki SA, Kambali SS. Personalized medicine in dentistry. J Orofac Sci. 2017; 9(1): 3-6.

Kim J, Campbell AS, De Ávila BEF, Wang j. Wearable biosensors for health care monitoring. Nat Biotechnol. 2019;37:389-406.

Kim YK, Kim SG, Bae JH, Um IW, Oh JS, jeong KI. Guided bone regeneration using autogenous tooth bone graft in implant therapy: case series. Implant Dent. 2014;23(2):138-43.

Kim YK, Um IW, murata m. Tooth bank system for bone regeneration safety report. Journal of Hard Tissue Biology. 2014;23(3):371-6.

Korgaonkar J, Tarman AY, Koydemir HC, Chukkapalli SS. Periodontal disease and emerging point-of-care technologies for its diagnosis. Lab Chip.2024;24:3326-46.

Kudyar N, Dani N, Mahale S. Periodontal vaccine: A dream or reality. J İndian Soc Periodontol. 2011;15(2):115-20.

Kurt-Bayrakdar S, Uğurlu M, Yavuz MB, Sail N, Bayrakdar İş, Çelik Ö. Detection of tooth numbering, frenulum attachment, gingival overgrowth, andgingival inflammation signs on dental photographs using convolutional neural network algorithms: a retrospective study. Quintessence ınt. 2023;54.

Ledesma-martínez E, Mendoza-Núñez Vm, Santiago-osorio E. Mesenchymal stem cells for periodontal tissue regeneration in elderly patients. J Gerontol A Biol Sci med Sci. 2019;74(9):1351-8.

Leppilahti JM, Hernandez-rios PA, Gamonal JA. Matrix metalloproteinases and myeloperoxidase in gingival crevicular fluid provide site-specificdiagnostic value for chronic periodontitis. J Clin Periodontol. 2014;41(4):348-56.

Liu J, Ruan J, Weir MD, Ren K, Schneider A, Wang P. Periodontal bone-ligament-cementum regeneration via scaffolds and stem cells. Cells.2019;8(6):537.

Li C, Yu R, Ding Y. Association between porphyromonas gingivalis and systemic diseases: Focus on T cells-mediated adaptive immunity. Front Cell Infect Microbiol. 2022;12:1026457.

Li L, Wang C, Li X, Fu G, Chen D, Huang Y. Research on the dimensional accuracy of customized bone augmentation combined with 3D-printing individualized titanium mesh: A retrospective case series study. Clin Implant Dent Relat Res. 2021;23(1):5-18.

Loos BG, Van Dyke TE. The roleof inflammation and genetics in peri odontal disease. Periodontol 2000. 2020;83(1):26-39.

Maughan T. The Promise and the Hype of'Personalised medicine'.New Bioeth. 2017;23(1):13-20.

Melguizo-rodríguez L, Costela-ruiz VJ, Manzano-Moreno FJ, Ruiz C, Illescas-Montes R. Salivary biomarkers and their application in the diagnosis and monitoring of the most common oral pathologies. Int J Mol Sci. 2020;21(14):5173.

Mijiritsky E, Assaf HD, Peleg O, Shacham M, Cerroni L, mangani L. Use of PRP, PRF and cGF in Periodontal Regeneration and Facial Rejuvenation; A Narrative Review. Biology (Basel). 2021;10(4):317.

Moussa DG, Ahmad P, Mansour TA, Siqueira WL. Current State and Challenges of the Global Outcomes of Dental Caries research in the Meta Omics Era. Front Cell Infect Microbiol. 2022;12:887-907.

Nyman S, Lindhe J, Karring T, Rylander H. New attachment following surgical treatment of human periodontal disease. J Clin Periodontol. 1982;9(4):290-6.

Nuñez J, Vignoletti F, caffesse RG, Sanz M. Cellular therapy in periodontal re-generation. Periodontol 2000. 2019;79(1):107-16.

Ozçaka O, Nalbantsoy A, Köse T, Buduneli N. Plasma osteoprotegerin levels are decreased in smoker chronic periodontitis patients. Aust Dent J. 2010;55(4): 405-10.

Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH. Periodontitis: consensus report of workgroup 2 of the 2017 world Workshop on the classification of periodontal and peri-implant diseases and conditions. J Periodontol. 2018;89:173-82.

Papapanou PN, Susin C. Periodontitis epidemiology: is periodontitis under recognized, over-siagnosed, or both? Periodontol 2000. 2017;75:45-51.

Park BR, Ma JK, Park KB, Hong KW. Recapitulation of genomewide association study on chronic periodontitis in a Korean population. Biomed Sci Lett.2017;23(2):133-7.

Park CH, Rios HF, Taut AD, Padialmolina M, Flanagan CL, Pilipchuk SP. Image-based, fiber guiding scaffolds: a platform for regenerating tissue inter-faces. Tissue Eng Part c methods. 2014;20(7):533-42.

Park IH, Zhao R, West JA, Yabuuchi A, Huo H, Ince TA. Reprogramming of human somatic cells to pluripotency with defined factors. Nature. 2008;451(7175):141-6.

Patel JS, Patel K, Vo H, Jiannan L, Tellez MM, Albandar J. Enhancingan A-empowered Periodontal CDSS and comparing with traditional perio-risk assessment tools. AMıA Annu Symp Proc; 2023.846-55.

Patel JS, Su C, Tellez M, Albandar JM, Rao R, Iyer V. Developing andtesting a prediction model for periodontal disease using machine learningand big electronic dental record data. Front Artif Intell. 2022;5:979525.

Pihlstrom BL, Michalowicz BS, Johnson NW. Periodontal diseases. Lancet.2005;366:1809-20.

Pitchika V, Büttner M, Schwendicke F. Artificial intelligence and personalized diagnostics in periodontology: a narrative review. Periodontol 2000. 2024;95:220-31.

Polizzi A, Quinzi V Lo Giudice A, Marzo G, Leonardi R, Isola G. Accuracy ofartificial intelligence models in the prediction of periodontitis: a systematic review. JDR Clin Trans Res. 2024.

Prato GP, Rotundo R, Magnani C, Ficarra G. Viral etiology of gingival recession. A case report. J. Periodontol. 2002;73:10-14.

Purba MR, Putra MM, Sulijaya B, Widaryono A, Hartono V, Setiadharma Y. Effect of mobile app-based oral hygiene instructions on clinical parameters oral bacterial diversity, and composition of subgingival microbiota in periodontitis patients. J oral Microbiol. 2024;16:2372206.

Raghavendra NM, Pradeep AR, Kathariya R, Sharma A, Rao NS, Naik SB. Effect of non surgical periodontal therapy on gingival crevicular fluid andserum visfatin concentration in periodontal health and disease. Dis Markers.2012;32(6):383-392.

Rasperini G, Pilipchuk SP, Flanagan CL, Park CH, Pagni G, Hollister SJ. 3D-printed bioresorbable scaffold for periodontal repair. J Dent Res. 2015;94(9):153-7.

Rathnayake N, Gieselmann Dr, Heikkinen AM, Tervahartiala T, Sorsa T. Salivary Diagnostics Point of Care diagnostics of MMP-8 in dentistry and medicine. Diagnostics. 2017;7(1):7.10

Ryder MI. Comparison of neutrophil functions in aggressive and chronic periodontitis. Periodontol 2000. 2010;53 (1):124-37.

Ryder MI, Couch ET, Chaffee BW. Personalized periodontal treatment for the tobacco- and alcohol-using patient. Periodontol 2000. 2018;78(1):3046.

Salvi GE, Roccuzzo A, Imber JC, Stähli A, Klinge B, Lang NP. Clinical periodontal diagnosis. Periodontol 2000. 2023.

Sanz M, Herrera D, Kebschull M, Chapple I, Jepsen S, Beglundh T. EFP Workshop Participants and Methodological Consultants. Treatment of stage I-III periodontitis The EFP S3 level clinical practice guideline. J Clin Periodontol. 2020;47(22):4-60.

Schulz S, Immel UD, Just L, Schaller HG, Gläser C, Reichert S. Epigenetic characteristics in inflammatory candidate genes in aggressive periodontitis. Hum Immunol. 2016;77(1):71-75.

Shanahan F, Ghosh TS, O'Toole PW. The Healthy Microbiome-What Is the Definition of a Healthy Gut Microbiome? Gastroenterology. 2021;160:483-94.

Smiley CJ, Tracy SL, Abt E, Michalowicz BS, John MT, Gunsolley J. Evidence-based clinical practice guideline on the nonsurgical treatment of chronic periodontitis by means of scaling and root planing with or without ad-juncts. J Am Dent Assoc. 2015;146(7):525-35.

Sonika S, Esther Nalini H, Renuka Devi R. Quintessential commence of three dimensional printing in periodontal regeneration-A review. Saudi Dent J.2023;35(7):876-82.

Söder B, Jin LJ, Wickholm S. Granulocyte elastase, matrix metalloproteinase-8 and prostoglandin E2 in gingival crevicular fluid in matched clinical sites in smokers and non smokers with persistent periodontitis. J Clin Periodontol.2002; 29(5): 384-91.

Sufaru IG, Macovei G, Stoleriu S, Martu MA, Luchian I, Kappenberg-Nitescu Dc. 3D Printed and bioprinted membranes and scaffolds for the periodontal tissue regeneration: A Narrative Review. membranes (Basel).2022;12(9):902.

Sanz M, Herrera D, Kebschull M, Chapple ı, Jepsen S, Beglundh T. EFP Workshop Participants and Methodological Consultants. Treatment of stage I-III periodontitis The EFP S3 level clinical practice guideline. J Clin Periodontol. 2020;47(22):4-60.

Seo Bm, Miura M, Gronthos S, Bartold Pm, Batouli S, Brahim J. Investigation of multipotent postnatal stem cells from human periodontal ligament. Lancet. 2004;364(9429):149-55.

Szkaradkiewicz AK, Stopa J, Karpinski TM. Effect of oral administration involving a probiotic strain of Lactobacillus reuteri on pro-inflammatory cytokine response in patients with chronic periodontitis. Arch Immunol Ther Exp. 2014;62:495-500.

Teughels W, Feres M, Oud V, Martín C, Matesanz P, Herrera D. Adjunctive effect of systemic antimicrobials in periodontitis therapy: A systematic reviewand meta-analysis. J Clin Periodontol. 2020;47 (22):257-81.

Trindade F, Oppenheim FG, Helmerhorst EJ, Amado F, Gomes PS, vitorinor. Uncovering the molecular networks in periodontitis. Proteomics Clin Appl.2014;8(9-10):748-61.

Tonetti MS, Greenwell H, Kornman KS. Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. J Periodontol. 2018;89:159-72.

Wong DT. Salivaomics. J Am Dent Assoc 2012;143:19-24.

Wu Y, Chen L, Wei B, Luo K, Yan F. Effect of non-surgical periodontal treatment on visfatin concentrations in serum and gingival crevicular fluid of patients with chronic periodontitis and type 2 diabetes mellitus. J Periodontol. 2015;86(6):795-800.

Xu XY, Li X, Wang J, He XT, Sun HH, Chen FM. Concise review: periodontal tissue regeneration using stem cells: Strategies and Translational considerations. Stem cells Transl Med. 2019;8(4):392-403.

Yang X, Ma Y, Wang X, Yuan S, Huo F, Yi G. A 3D-Bioprinted functional module based on decellularized extracellular matrix bioink for periodontal regeneration. Adv Sci. 2023;10(5):e2205041.

Zhang J, An Y, Gao LN, Zhang YJ, Jin Y, Chen FM. The effect of aging on the pluripotential capacity and regenerative potential of human periodontal ligament stem cells. Biomaterials. 2012;33(29):6974-86.

Zhang S, Barros SP, Moretti AJ. Epigenetic regulation of TNF-A expression in periodontal disease. J Periodontol. 2013;84(11):1606-16.

Zulhendri F, Lesmana R, Tandean S, Christoper A, Chandrasekaran K, Irsyamı. Recent Update on the Anti-ınflammatory Activities of Propolis. Molecules. 2022;27(23):8473.

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