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Chapter 1

INFLAMMATORY GINGIVAL HYPERPLASIA: CASE REPORT

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Introduction

Inflammatory gingival hyperplasia (IGH) is a type of gingival enlargement that appears when the tissue responds to prolonged irritation and microbial buildup. It is not a neoplastic process; instead, the gingiva becomes thicker because of an ongoing inflammatory and proliferative reaction. Clinically, the lesion often presents as a soft, swollen, reddish purple area that bleeds easily when touched. It usually remains limited to the marginal gingiva or the interdental papillae (Neville et al., 2022).

Microscopic examination typically shows a markedly thickened epithelial layer with areas of acanthosis, parakeratosis, and focal spongiosis. In the underlying connective tissue, a dense mixture of lymphocytes, plasma cells, and neutrophils is commonly found. Dilated blood vessels and increased fibroblast activity accompany these changes, creating a picture that carries features of both acute and chronic inflammation (Murakami et al., 2018).

Clinically, the most common reason for IGH development is the irritation caused by the accumulation of dental plaque. Substances released by the bacterial biofilm stimulate epithelial and connective tissue cells to produce pro-inflammatory cytokines such as IL-1β, TNF-α, and IL-6. These mediators increase vascular permeability, support edema formation, and encourage the migration of inflammatory cells (Chapple et al., 2018). If the irritant persists, fibroblasts remain active and extracellular matrix production rises, contributing to further gingival thickening (Agrawal, 2015).

The progression of IGH is influenced not only by microbial factors but also by characteristics of the host. Genetic makeup, immune reactivity, hormonal changes, mouth breathing habits, and several systemic conditions can alter how gingival tissues respond to irritation. During pregnancy, elevated levels of estrogen and progesterone make periodontal tissues more sensitive by increasing vascular permeability and enhancing fibroblast responsiveness. As a result, pregnancy associated gingival overgrowth may develop and often regresses after childbirth (Wu, Chen & Jiang, 2015; Yenen & Ataçağ, 2019).

Hormonal changes also affect the composition of the oral microbiota. Species such as *Prevotella intermedia*, which can utilize steroid derivatives, may increase in number during these periods and intensify the inflammatory reaction (Agrawal, 2015). Thus, the interaction between hormonal shifts and bacterial biofilm activity plays a major role in determining the extent of the lesion.

In some cases, IGH is accompanied by superficial fungal colonization. The moist and slightly acidic environment created by chronic inflammation allows Candida albicans to shift into its hyphal form. These filamentous

elements typically remain limited to the epithelial surface and do not invade the connective tissue, which is why they are considered secondary colonization rather than primary fungal infection (Guarner & Brandt, 2011). In chronically inflamed areas, Candida may contribute to epithelial alterations such as parakeratosis, small superficial microabscesses, or mild reactive atypia (Edel et al., 2022).

The presence of hyphal structures in histological sections indicates ongoing inflammation and continued microbial influence. Although superficial colonization may weaken the epithelial barrier and slow healing, systemic antifungal therapy is unnecessary unless deeper invasion is present (Lu & Chang, 2021; Guarner & Brandt, 2011).

Epidemiological studies show that IGH is among the most frequent reactive hyperplastic lesions in the oral cavity (Reactive Hyperplastic Lesions Study Group, 2017; Sangle et al., 2018). Its higher prevalence in women supports the role of hormonal factors. Lesions most commonly appear in anterior regions and interdental papillae. They are usually painless, though they bleed easily when irritated.

Gingival enlargement can have important consequences for periodontal health. Increased tissue volume often creates areas that retain plaque and make cleaning more difficult. Over time, secondary problems such as pseudopocket formation, gingival recession, and alveolar bone loss may develop (Murakami et al., 2018). Therefore, early recognition, professional cleaning, and effective plaque control are essential; in selected cases, surgical removal may be required.

IGH usually has a benign and reversible nature. Reactive epithelial atypia that appears in some histological samples should not be mistaken for dysplasia. For accurate diagnosis and treatment planning, histopathological evaluation remains crucial (Neville et al., 2022).

Overall, inflammatory gingival hyperplasia represents a reversible gingival enlargement shaped by microbial plaque, hormonal changes, and superficial fungal colonization. It illustrates how gingival tissues respond biologically to persistent irritation.

Case Report

A 30 year old woman with no known systemic illness came to the clinic about one month after giving birth, complaining of a slowly enlarging swelling in the left maxillary canine area. She mentioned that the area bled easily at times and caused mild discomfort.

On clinical examination, a soft, reddish and slightly swollen lesion was seen in the papillary region of the left maxillary canine. It was attached to the gingiva by a narrow pedicle and had a well defined but irregular, somewhat shiny surface. Light palpation caused immediate bleeding. The patient recalled that the swelling had appeared roughly a month after delivery and had slowly increased in size. Her oral hygiene was moderate, and a small amount of supragingival calculus was present, which was considered a possible local irritant. Vitality tests indicated that the adjacent teeth were still vital, and radiographic assessment showed no bone loss or other pathological findings (Figure 1).

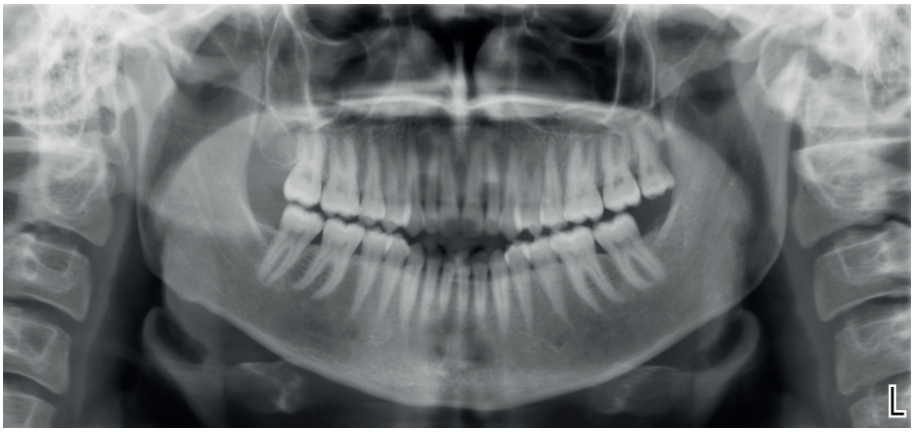

Figure 1. *Orthopantomographic view of the patient*

Considering the clinical characteristics of the lesion, a provisional diagnosis of inflammatory gingival hyperplasia was established, and an excisional biopsy was planned for definitive evaluation.

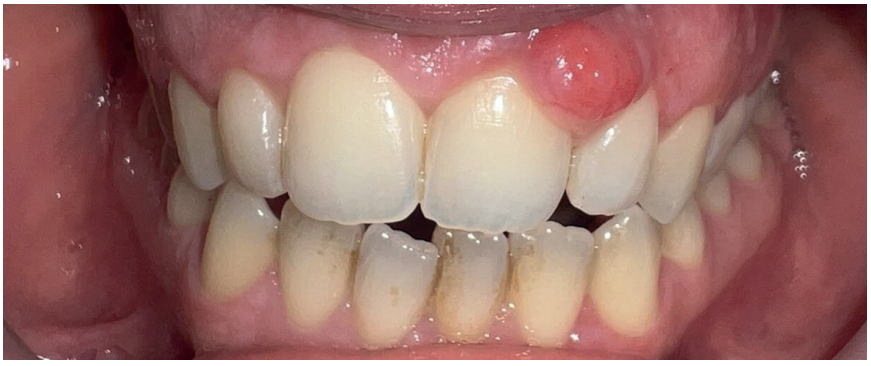

Figure 2. *Intraoral view of the patient*

Macroscopic Findings

The excisional biopsy specimen measured 0.5 × 0.4 × 0.3 cm, appeared as an irregular surfaced soft tissue fragment covered by mucosa. The tissue

was fixed in formalin and submitted to the pathology laboratory, where it was entirely processed for histopathological examination (Figure 2).

Figure 3. *Representative histopathological sample obtained from the patient*

Microscopic Findings

Microscopic examination showed that the tissue was lined with a stratified squamous epithelium that appeared acanthotic and focally thickened. In several areas, the epithelium displayed parakeratosis and patches of spongiosis. Small collections of neutrophils and superficial microabscess like areas were also noted along the epithelial surface. The connective tissue beneath the epithelium contained a dense mixture of lymphocytes and plasma cells, with noticeable vascular congestion and increased numbers of fibroblasts.

PAS staining revealed the presence of fungal hyphae limited to the epithelial surface and the superficial epithelial layers. These hyphal forms did not extend into the underlying connective tissue. The epithelium showed mild reactive atypia and some loss of cellular polarity, changes that were considered secondary to surface fungal colonization rather than a primary invasive process. Taking all these features together, the lesion was identified as inflammatory gingival hyperplasia with superficial fungal hyphal colonization.

Discussion and Conclusion

Inflammatory gingival hyperplasia (IGH) is a reactive enlargement of the gingival tissues that develops in response to persistent irritation and microbial

influence. It is not a neoplastic condition, and in many patients it appears in association with local irritants, hormonal changes, or systemic factors (Agrawal, 2015). In the present case, the fact that the lesion arose shortly after childbirth and was accompanied by superficial fungal colonization suggests that several factors contributed to the inflammatory process.

Pregnancy and the postpartum period involve major hormonal shifts, and these changes can alter the way periodontal tissues react. Increased levels of estrogen and progesterone make the vascular endothelium more permeable and allow inflammatory cells to migrate more easily into the tissue. At the same time, fibroblasts become more responsive to growth factors, which may stimulate collagen production and contribute to gingival enlargement (Wu, Chen & Jiang, 2015). Because of these effects, hormonal influences are considered an important cause of gingival overgrowth during pregnancy and the months following delivery (Yenen & Ataçağ, 2019).

The microscopic characteristics observed in this case dense lymphoplasmacytic infiltration, dilation of blood vessels, and fibroblast proliferation fit well with plaque associated chronic inflammation (Chapple et al., 2018; Murakami et al., 2018). The thickened epithelium, parakeratosis, and small neutrophilic microabscesses are typical of a reactive epithelial response to chronic irritation. These findings support the understanding that IGH is a non-neoplastic reactive lesion (Sangle et al., 2018).

The fungal hyphae seen on the epithelial surface are best interpreted as secondary colonization. *Candida albicans* can take on a hyphal form in the moist and acidic conditions created by chronic inflammation, and this is frequently observed in long standing gingival lesions (Lu & Chang, 2021; Edel et al., 2022). The key point is that the hyphae remained superficial and did not invade the underlying connective tissue, which clearly shows that this was not a primary fungal infection but rather a surface colonization linked to inflammation (Guarner & Brandt, 2011). In such cases, systemic antifungal therapy is unnecessary; improving oral hygiene and using topical agents are usually sufficient (Chapple et al., 2018).

Reports of reactive hyperplastic lesions consistently show that they are more common in women, which supports the role of hormonal factors in their development (Sangle et al., 2018). Their frequent presence in anterior regions and interdental papillae suggests that chronic plaque retention plays an important role as well (Agrawal, 2015).

This case is clinically relevant because it illustrates that postpartum inflammatory gingival hyperplasia can appear together with superficial fungal colonization. The lack of recurrence after surgical removal further

demonstrates the reactive and benign nature of the lesion. In similar cases, early debridement, consistent plaque control, and elimination of local irritants generally lead to a good treatment outcome (Chapple et al., 2018).

In conclusion, inflammatory gingival hyperplasia is a reversible gingival enlargement caused by a combination of chronic irritation, hormonal changes, and microbial factors. When superficial fungal hyphae are present, they should be regarded as a secondary finding, not an invasive infection. For this reason, histopathological evaluation remains essential, and treatment decisions should be based on both clinical and microscopic findings.

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Chapter 2

APPLICATION OF DENTAL IMPLANTS IN THE POSTERIOR SEGMENT OF THE DENTITION FOR PROSTHETIC REHABILITATION

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Dental implant procedures are widely utilized today as a preferred approach for the replacement of missing teeth in the dentition and the restoration of masticatory function. Dental implants provide an effective means of oral rehabilitation, particularly in partially or completely edentulous patients (Pennington and Parker, 2012), and the success of such treatment strategies largely depends on the effectiveness of the osseointegration process. (Feller et al., 2014) Standard dental implants promote osseointegration by establishing a broad contact surface with the surrounding bone tissue, thereby enhancing implant stability. (Renouard and Nisand, 2006; Al-Hashedi, Taiyeb Ali, and Yunus, 2014)

Tooth loss in the posterior regions (maxillary and mandibular) accelerates alveolar bone resorption and increases the proximity to critical anatomical structures such as the mandibular nerve or the maxillary sinus, thereby complicating implant placement. (Queiroz et al., 2015) When such anatomical limitations prevent direct implant placement, surgical procedures such as bone grafting and sinus lifting may become necessary. However, these procedures are associated with increased postoperative morbidity, higher treatment costs, and elevated risks of complications. (Esposito et al., 2009) Consequently, short dental implants have gained popularity as a less invasive, more cost-effective, and efficient alternative for the rehabilitation of atrophic alveolar ridges. (Sotto-Maior et al., 2015)

The definition of short dental implants varies across the literature. While some authors define short implants as those with lengths <10 mm, others set the threshold at ≤8 mm. (Renouard and Nisand, 2006; Lee et al., 2014) Recent clinical trends classify implants of ≤7 mm in length as "short" or even "extra-short". (Lee et al., 2014) Although discrepancies in the crown-to-implant ratio in such implants may increase the risk of mechanical complications, it has been reported that this is not directly associated with marginal bone loss in the peri-implant region. (Quaranta et al., 2014)

One of the key factors influencing implant success is the anatomical and biological characteristics of the implantation site. Specifically, regions with low bone density (e.g., the posterior maxilla with type IV bone) have been associated with higher implant failure rates. (Goiato et al., 2014) Although some studies have reported lower success rates for short implants in posterior regions (Misch et al., 2006), other investigations have demonstrated that short implants can achieve high long-term clinical success rates. (Anitua, Alkhraisat, and Orive, 2013; Rossi et al., 2015)

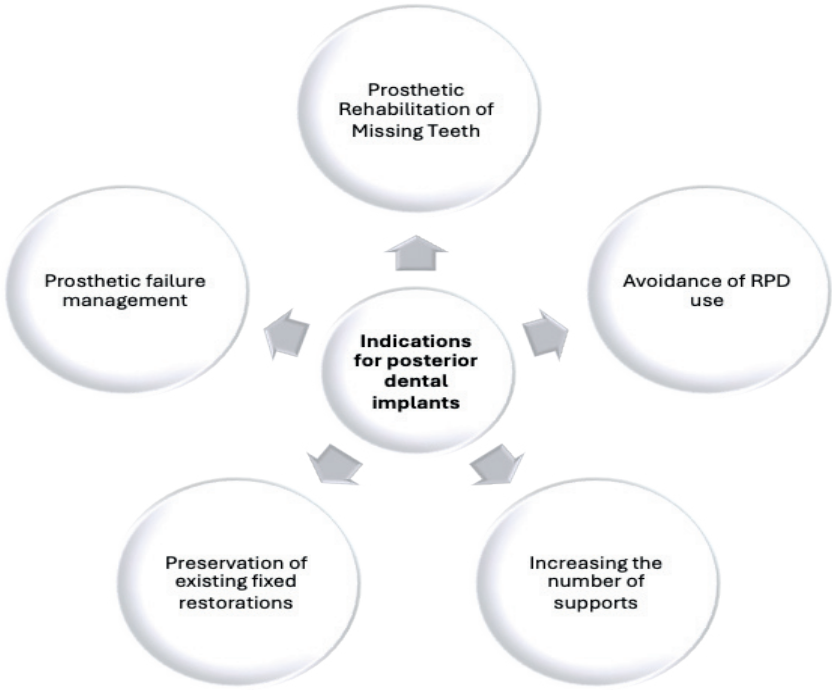

Figure 1. *Indications for posterior dental implants. (RPD: Removable Partial Denture)*

In clinical practice, when esthetic demands are not a limiting factor, the placement of the longest possible implant is generally preferred. The rationale behind this approach is to increase the implant surface area, thereby enhancing the bone-to-implant contact. Long and wide-diameter implants have been associated with higher success rates. (Mordenfeld et al., 2004) However, the posterior maxilla presents distinct anatomical and clinical challenges for implant placement. (Winkler, Morris, and Ochi, 2000)

Factors Complicating Implant Placement in the Posterior Maxillary Region	• Limited surgical access
	• Restricted visual field
	• Reduced interarch space
	• Bone resorption following tooth extraction and sinus pneumatization
	• Type IV bone density

Various modifications have been made to dental implant design and surface characteristics in order to enhance osseointegration, particularly in areas with low bone quality. The transition from smooth to roughened implant surfaces has been associated with improved long-term success rates. (Naert et al., 2002)

The clinical advantages of roughened surfaces include: (Carlsson et al., 1982)

- Increased bone-to-implant contact area
- Enhanced stabilization of the blood clot
- Stimulation of hard tissue healing

Considerations in Dental Implant Design

Posterior regions are subject to higher occlusal forces compared to anterior regions and are typically characterized by lower bone density. Therefore, one of the main approaches recommended to enhance implant success and minimize risk factors in posterior sites is to increase the surface area of the implant. Today, many implant manufacturers offer products in various lengths, and longer implants are generally preferred in anterior regions, where bone quality is typically superior. Studies have shown that implant length is a secondary parameter in terms of stress distribution. One of the most common strategies to increase the implant surface area in posterior regions is to increase the implant diameter. Although occlusal forces in these regions may rise by up to 300%, conventional implant designs only provide an approximate 30% increase in surface area. However, appropriate modifications in implant diameter and thread design can result in surface area gains exceeding 300%. Such increases contribute to the reduction of stress particularly in the crestal bone region, thereby decreasing marginal bone loss and reducing the risk of early implant failures following immediate or early loading.

Short Dental Implants

Short dental implants are defined as those with an intraosseous component of ≤8 mm. (Renouard and Nisand, 2006) These implants were primarily developed to eliminate the need for invasive primary bone augmentation procedures, such as open sinus lifting. (Renouard and Nisand, 2005) However, some studies have reported lower survival rates for short implants compared to standard-length implants placed under similar clinical conditions.

In recent years, advancements in implant surface technologies have expanded the clinical applications of short implants and led to an increase in the number of related publications. As a result, treatment options have been diversified for both totally and partially edentulous patients.

Clinical advantages of short dental implants include:

- Require less technical skill to place
- Eliminate the need for augmentation procedures, thereby reducing patient morbidity

- Easier to explant in case of failure, typically with fewer associated complications

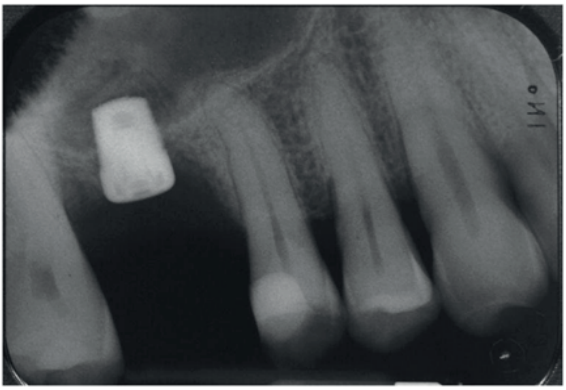

Figure 1. *Postoperative periapical radiograph following placement of an ultra-short (5 × 5 mm) sintered porous surface (SPS) dental implant. (Malchiodi et al., 2020)*

Maxillary Sinus Augmentation (MSA)

In the posterior maxilla, physiological bone resorption and pneumatization of the maxillary sinus reduce the amount of residual bone, making implant placement clinically challenging. This situation has led to the development of augmentation techniques aimed at increasing vertical bone height, thereby enabling successful implant placement. During treatment planning, the appropriate surgical technique and grafting approach should be selected based on the residual ridge height. (Jensen and Terheyden, 2009) Sinus augmentation can be performed either through a crestal or lateral approach, and may be carried out simultaneously with implant placement or in a separate session. According to the literature, general implant survival rates following sinus augmentation exceed 90%. (Del Fabbro et al., 2012; Silva et al., 2016) A systematic review reported implant survival rates of 93.7% for the lateral approach and 97.2% for the crestal approach after at least 3 years of functional loading. (Del Fabbro, Wallace, and Testori, 2013) Complications associated with sinus lifting procedures - such as Schneiderian membrane perforation, intraoperative bleeding, and infection - have been reported with low incidence. (Boffano and Forouzanfar, 2014) Despite these favorable clinical outcomes, the long healing periods required to ensure sufficient new bone formation remain a major limitation for both clinicians and patients. (Fugazzotto, 2003; Wang et al., 2016)

Vertical Ridge Augmentation

In cases of severely resorbed alveolar ridges in the posterior mandible, the available bone height is often limited by the anatomical boundaries of the mandibular canal. To facilitate the placement of standard-length dental implants, vertical ridge augmentation emerges as a viable option. This procedure also contributes to achieving a more favorable crown-to-implant ratio by reducing crown height, which would otherwise compromise oral hygiene maintenance. (Mecall and Rosenfeld, 1991) Various surgical techniques have been developed for vertical bone augmentation, including autogenous block bone grafts, distraction osteogenesis, and guided bone regeneration (GBR). (McAllister and Haghighat, 2007) Among these, autogenous block bone grafts are considered the "gold standard" due to their wide clinical application and favorable long-term outcomes. (Sanz and Vignoletti, 2015) A recent systematic review reported that implant survival and success rates in sites reconstructed with autogenous bone grafts are comparable to those achieved in native bone. (Aloy-Prósper et al., 2015) However, undesired volumetric resorption of autogenous grafts remains a significant concern for clinicians. The volumetric stability of autogenous block grafts is still debated, with substantial variability observed across clinical studies. (Johansson et al., 2001; Nkenke and Neukam, 2014; Resoy-Lozano et al., 2015) These variations are attributed to differences in study design, including donor site selection, healing duration, timing of implant placement, and use of barrier membranes. A review focusing on studies with at least 4 to 5 years of follow-up indicated that the highest degree of resorption occurs during the first year, followed by a more stable remodeling phase. (Keestra et al., 2016) As alternatives to autogenous grafts, allogenic and xenogenic block grafts have also been investigated. However, the current evidence on these materials is largely based on case series and remains insufficient to draw definitive conclusions (Waasdorp and Reynolds, 2010). Furthermore, the increased risk of complications and patient morbidity associated with vertical ridge augmentation procedures necessitates careful surgical planning. (Raghoebar et al., 2007)

Question: Short Dental Implants or Sinus Lifting with Long Implants?

Due to the anatomical position of the maxillary sinus, reduced bone height is frequently encountered in the posterior maxilla. In such cases, several treatment options are available:

- Sinus lifting followed by implant placement
- Simultaneous sinus lifting and implant placement
- Placement of short dental implants
    - ÿ Use of zygomatic implants

During clinical decision-making, risks associated with intraoperative, perioperative, and postoperative morbidity should be carefully considered. The final treatment plan should be determined based on the patient's individual condition and risk profile. When treatment protocols involving short and long dental implants are compared, the most common technical complication is screw loosening. However, there is no statistically significant difference between the two approaches in terms of this complication. Notably, while short implants have been associated with lower complication rates, the incidence of complications is significantly higher in long implants placed in combination with sinus lifting procedures. In particular, surgical complications such as intraoperative membrane perforations are observed in nearly 100% of sinus augmentation procedures, resulting in an approximately threefold increase in complication risk compared to short implants. (Thoma et al., 2015)

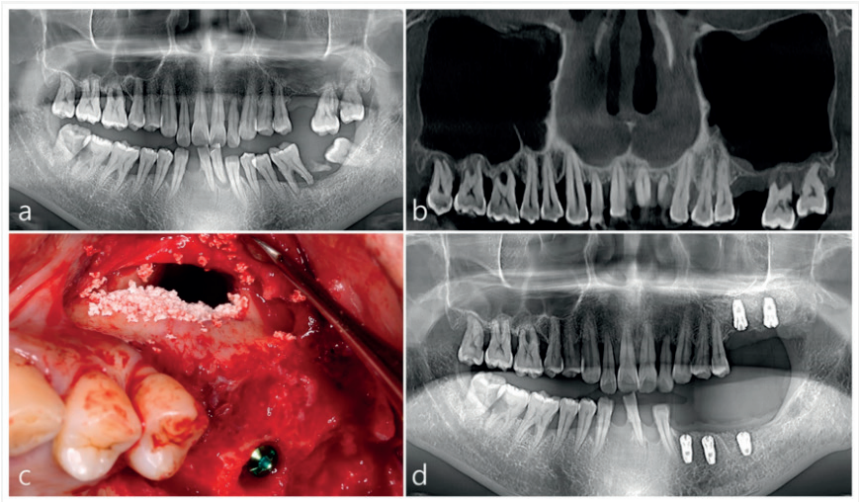

Figure 2. *Preoperative panoramic radiograph showing severe alveolar bone loss due to advanced periodontitis (a); Panoramic view of the preoperative CBCT demonstrating no mucosal thickening in the right and left maxillary sinuses (b); Schneiderian membrane perforation occurred during sinus floor elevation (c); Grafting of the sinus cavity and opening of the superior part of the lateral window; postoperative panoramic radiograph following maxillary sinus augmentation and simultaneous dental implant placement (d). (Park, W.-B., Crasto, G. J., & Kang, P. (2022) Preliminary Approach for Open Lateral Window Technique for Successful Maxillary Sinus Augmentation in the Unrepairable Wide Perforation Area of Schneiderian Membrane. Applied Sciences, 12(19), 9725)*

The available data indicate that short dental implants offer several advantages, including lower morbidity, reduced costs, and shorter treatment durations. These implants have also received favorable evaluations in terms of patient-reported outcome measures and demonstrate survival

rates comparable to those of longer implants placed following sinus lifting procedures. Accordingly, short dental implants may be considered a suitable and effective alternative for posterior maxillary rehabilitation in the short term.

Question: Short Dental Implants or Vertical Ridge Augmentation with Long Implants?

In cases of limited vertical ridge height in the posterior mandible, the primary treatment options include the following: (Simion, Jovanovic, Tinti, and Benfenati, 2001; Fontana and Simion, 2008)

- Implant placement following vertical ridge augmentation
- Simultaneous vertical augmentation and implant placement
- Placement of short dental implants

Primary vertical ridge augmentation that enables the placement of standard-length implants is often preferred due to certain advantages, such as a reduced crown-to-implant ratio, improved esthetics, and enhanced maintainability of the prosthetic suprastructure. To this end, various augmentation techniques - including guided tissue regeneration (GTR) and distraction osteogenesis - have been described. However, the reported success rates of these techniques are variable, and systematic reviews in the literature offer only limited recommendations for their routine use. The main reasons for this include a high incidence of complications and significant variability in clinical outcomes depending on the clinician's level of expertise.

In cases where the vertical ridge height reaches 6 mm, the use of short dental implants may reduce the need for commonly applied regenerative surgical interventions. Clinical studies have shown that, when compared with long implants placed in conjunction with ridge augmentation, short implants are associated with lower rates of implant loss and fewer complications.

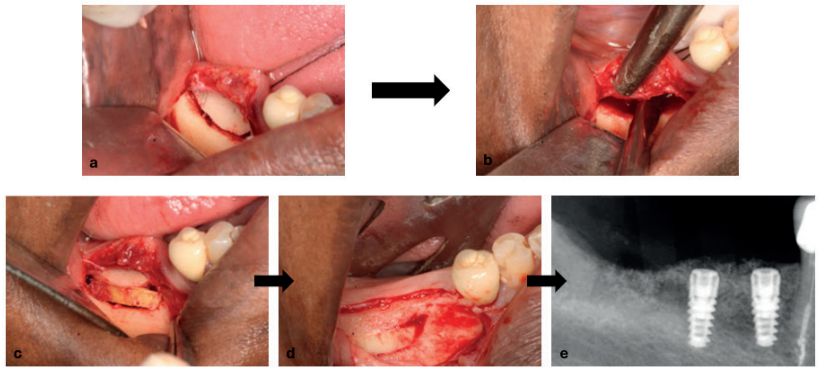

Figure 3. *Sufficient vertical height achieved following vertical augmentation in the posterior mandibular region, enabling dental implant placement. (Mathai C. P., 2012)*

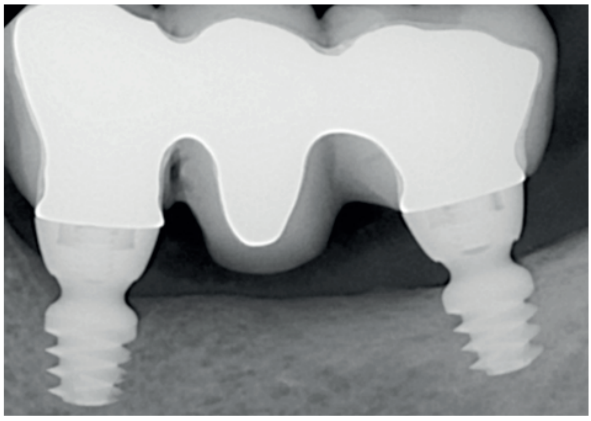

Figure 4. *Radiograph taken 2 years after functional loading of two ultra-short dental implants placed in a resorbed posterior mandible. (Hartman M., 2018)*

Treatment Approach

Treatment options such as the use of short dental implants or the placement of longer implants following prior bone augmentation are determined by a combination of factors, including the level of scientific evidence, the clinician's experience and technical skill, and the individual preferences of the patient. In this context, to guide clinicians in the decision-making process and to provide patients with comprehensive information regarding the available treatment alternatives, systematic reviews incorporating findings from randomized controlled trials focused on the posterior maxilla and mandible have been published. (Thoma, Zeltner, Hüsler, Hämmerle, and Jung, 2015)

Region (Posterior)	Vertical Bone Height	Recommended Treatment Option
Maxilla	6 - 8 mm	Short dental implant
	>8 mm	Standard-length dental implant with sinus elevation
Mandible	<8 mm	Primary vertical ridge augmentation followed by placement of a standard-length dental implant
	8 - 10 mm	Short dental implant
	>10 mm	Standard-length dental implant

Proposed treatment algorithm for posterior regions (Adapted from Thoma, Cha, and Jung, 2017)

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Chapter 3

SINUS LIFTING AND SINUS LIFTING COMPLICATIONS IN IMPLANT SURGERY

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1.INTRODUCTION

Dental implants are highly preferred treatment methods in modern dentistry, which are used to replace lost teeth to provide function and aesthetics. However, especially in the posterior regions of the upper jaw, implant placement can be complicated by various anatomical obstacles. Inadequate bone height and enlargement of the maxillary sinus, which are frequently encountered in this region, may limit implant placement (Testori, 2020). The maxillary sinus in the upper jaw tends to expand downwards after tooth loss; this condition is called sinus pneumatisation. This anatomical change leads to a significant decrease in alveolar bone height over time, making implant placement difficult.(Sbordone, 2012). The sinus lifting procedure, which was developed to overcome this problem, involves the application of bone graft in conjunction with the elevation of the sinus floor. Thus, the sinus membrane is raised while simultaneously stimulating new bone formation and providing sufficient volume for implant placement (Pjetursson et al., 2008).

In this review, the basic principles, indications, application techniques and possible complications of sinus floor elevation surgery in dental implant surgery are discussed.

2. SINUS FIBRING IN IMPLANT SURGERY

2.1 Dental Implant Definition

Dental implants are biocompatible artificial tooth roots, usually made of titanium or titanium alloys and surgically implanted into the alveolar or basal bone to meet the functional, aesthetic and phonetic requirements of teeth lost due to various etiological factors.(Misch's Contemporary Implant Dentistry E-Book: Misch's Contemporary Implant ... - Randolph Resnik - Google Books, n.d.) Dental implants osteointegrate with bone.

2.1.1.1.Osteointegration Definition

Osteointegration is the process of forming a stable and functional connection between the dental implant surface and living bone tissue, which provides direct contact at the microscopic level and does not contain any connective tissue barrier. This biological event is critical for the long-term success of the implant in the bone. (Brånemark et al., 1977) Modern dental implants are artificial roots made of biocompatible materials that are stabilised by osseointegration after insertion into the alveolar bone and compensate for tooth deficiencies functionally and aesthetically. Today, materials such as titanium and zirconia are used; implant surfaces are modified at microscopic and nanometric levels to improve cellular response at the bone-implant interface (Buser et al., 2017). Modern implant systems aim not only the

restoration of missing teeth, but also peri-implant soft tissue stability and long-term biological compatibility (Albrektsson et al., 2014). Innovations in the field of implantology provide positive effects on patient satisfaction and treatment success with the development of implant surface topographies, connection systems and prosthetic components (Misch, 2020).

2.2 Purpose of Sinus Lifting in Dental Implant Surgery

In dental implant surgery, one of the anatomical formations that may cause limitations in implant surgery in the posterior maxilla is the maxillary sinus. The maxillary sinus is an air-filled cavity in the upper jaw bone and can cause significant anatomical limitations in dental implant surgery.(Tatum, 1986) Especially in the posterior maxilla (posterior region of the upper jaw), bone height may decrease after tooth loss, which may make implant placement difficult. In this case, additional surgical procedures such as sinus floor elevation (sinus lifting) may be required.(Esposito et al., 2014) When implant placement is not possible due to insufficient bone height, a sinus lifting (maxillary sinus augmentation) procedure is performed. This procedure aims to create sufficient bone volume by elevating the sinus floor and adding bone graft.

When performing a surgical procedure such as sinus lifting, we need to have sufficient knowledge of the anatomy of the maxillary sinus.

2.3Maxillary Sinus

2.3.1 Maxillary Sinus Anatomy

The maxillary sinus is a pyramidal cavity on the side of the nasal cavity, with its base adjacent to the nasal cavity and its apex towards the zygoma (cheekbone). There are several recesses in the sinus: the alveolar recess close to the roots of the teeth, the zygomatic recess extending laterally, the palatine recess between the nasal and oral cavities (a continuation of the alveolar recess) and the infraorbital recess at the top, close to the lower part of the eye socket. (Whyte & Boeddinghaus, 2019)

The oval or slit-shaped opening, called the ostium, is a structure that provides drainage of the sinus contents, is located in the upper region of the medial (inner) wall of the maxillary sinus and acts as a physiological drainage pathway.(Garg & Quiñones, 1997) The length of this opening can vary from 18 mm to 35 mm, with an average of 25.6 mm.(Gosau et al., 2009)

2.3.1.1.1 Blood supply:

Posterior Superior Alveolar Artery (PSAA): A branch of the maxillary artery, the PSAA supplies the lateral wall of the maxillary sinus and the Schneiderian membrane (Solar et al., 1999a).

Infraorbital Artery The infraorbital artery, which also originates from the maxillary artery, contributes to the blood supply of the sinus area by anastomosing with the PSAA. (Solar et al., 1999b)

Posterior Lateral Nasal Artery: This artery also plays a role in the blood supply of the maxillary sinus and should be considered during surgical procedures.

2.3.1.2 Innervation:

Posterior Superior Alveolar Nerve**:** As a branch of the maxillary nerve, it distributes to the lateral wall of the maxillary sinus and provides innervation of the sinus mucosa.

Middle and Anterior Superior Alveolar Nerves: These nerves also play a role in the innervation of the maxillary sinus mucosa and are important during sinus surgery. (Kasahara et al., 2016)

These anatomical structures should be carefully evaluated during surgical procedures involving the maxillary sinus.

TABLE 1: Neural Innervation of the Maxillary Sinus *(Alshamrani et al., 2023a)*

Nerve	Innervation Area
PSA + MSA nerves	Posterior (back) wall of the sinus
ASA nerve	Anterior (front) wall of the sinus
IO limit	Upper wall of the sinus and part of the medial (inner) wall
GP border	The lower wall of the sinus and the ostium (drainage opening) area

2.4 Sinus Lifting

2.4.1 Purpose of Sinus Lifting

The aim is to create the necessary bone height and volume to ensure stable and functional placement of dental implants. Two different surgical approaches are usually used to achieve this goal:

2.4.2 One-stage and Two-stage Implementation of Sinus Lifting Procedure

In the one-stage method, the dental implants are placed in the same surgical session along with the elevation of the sinus floor. This method is preferred when adequate primary stability can be achieved.(Peleg et al., 1998) Various treatment options have been used in the posterior maxilla to overcome the problem of insufficient bone quantity. The most conservative treatment option would be to place short implants to avoid entering the sinus cavity. However, placement of short implants still requires at least 6 mm of residual bone height. Another way to avoid grafting of the maxillary sinus would be to place sloping implants mesial or distal to the sinus cavity if there is sufficient

bone in these areas. Also, extra long zygomatic implants can be placed in the lateral part of the zygomatic bone.(Pjetursson & Lang, 2014)

In contrast, in the two-stage technique, bone augmentation is performed first and the implant is placed with a second surgery after the graft maturation process is completed. This approach is favoured when residual bone height is insufficient and primary stability is not possible.(Peleg et al., 1998)

2.5 Graft Types Used in Sinus Lifting Surgery

Bone grafting procedures are applied to promote new bone formation and various biomaterials such as autografts, allografts, xenografts, alloplastic materials and growth factors can be used in maxillary sinus augmentation. Autogenous grafts, i.e. bone tissues taken from the same individual, are still considered as the "gold standard" with their osteoinductive and osteoconductive properties as well as their osteogenic potential thanks to the living cells they contain. This type of graft not only provides a rapid healing process, but also shows high resistance to infections. However, the morbidity at the donor site and the risk of unpredictable resorption over time have led to the development of synthetic grafts as an alternative to this material. Allogeneic grafts derived from another individual of the same species have osteoconductive and osteoinductive properties, whereas xenografts derived from a different species have only osteoconductive capacity. Alloplastic graft materials, whether of natural or synthetic origin, show only osteoconductive properties.(Alshamrani et al., 2023a)

2.6 Sinus Lifting Techniques in Dental Implant Surgery

2.6.1 Lateral Window Technique

This technique is a reliable and common method used to elevate the maxillary sinus floor in dental implant applications. This technique aims to increase the bone volume required for implant placement in patients with insufficient bone height in the posterior maxilla.

2.6.1.1 Application Process of Lateral Window Technique:

Incision and Flap Removal: In the posterior region of the maxilla, an incision is made in the gingival tissue, the mucoperiosteal flap is lifted and the lateral wall of the maxilla is exposed.

Creation of the Lateral Window: An oval or rectangular window is opened in the lateral wall of the maxillary sinus. Through this window, the sinus membrane (Schneiderian membrane) is carefully exposed.

Removal of the Sinus Membrane: The Schneiderian membrane is carefully separated from the underlying bone and lifted superiorly, creating a new cavity in the sinus floor.

Placement of the Graft Material: A bone graft, usually consisting of autograft, allograft, xenograft or synthetic materials, is placed into the created cavity. This graft supports new bone formation and prepares a suitable ground for the implant.

Healing Process: After grafting, the area is closed and a period of 4 to 12 months is usually allowed for healing. During this time, the graft material integrates with the natural bone and forms an infrastructure suitable for implant placement.

2.6.1.2 Advantages:

High Success Rate: The lateral window technique is known for its high success rates in patients with insufficient bone height in the posterior maxilla.

Large Bone Volume Increase: This method provides a larger bone volume increase compared to other techniques, which allows the placement of longer implants.

2.6.1.3 Disadvantages:

Invasiveness: The technique is more invasive than other sinus lift methods, and therefore the risk of postoperative discomfort and complications may be increased.

Risk of Complications: Complications such as perforation of the sinus membrane may occur, which requires the surgeon's experience and attention. (Cheon et al., 2020; Pjetursson et al., 2012; Valentini & Artzi, 2023)

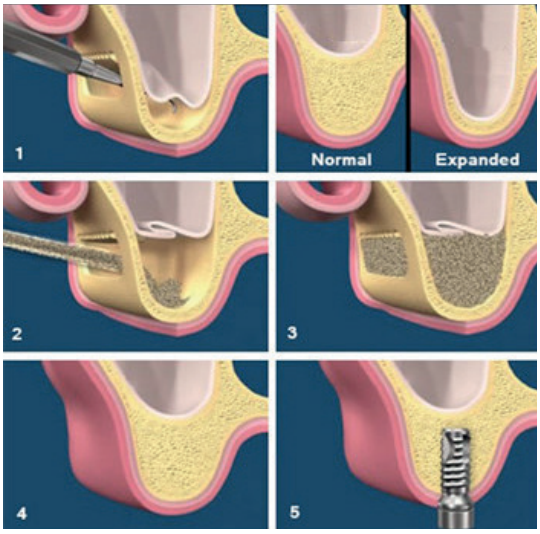


Figure 1. *(Sofia D. Petrov, 2014)*

2.6.2Sinus Lifting Technique with Osteotome

Before the procedure, panoramic radiography and preferably cone beam computed tomography (CBCT) are used to assess the status of the sinus and residual bone height.(Rosen et al., 1999.(Rosen et al., 1999) A minimum bone height of 5 mm is recommended) Local anaesthesia is applied. A crestal or paracretal incision is made and the mucosa is removed.(Summers, 1994) The implant bed is prepared with special osteotome instruments instead of a spiral drill. Osteotomes are used in order according to their diameter. When the sinus floor is approached, the bone is carefully advanced without breaking. (Woo & Le, 2004). The graft material is placed on the tip of the osteotome and gently impacted (with a mallet), which raises the sinus membrane upwards. The implant is placed directly on the raised sinus floor.

It is usually performed in one stage, but if the primary stability is insufficient, it can be postponed to the second stage.(Pjetursson et al., 2008). The tissue is closed appropriately and the implant is integrated with the bone by waiting an average of 4-6 months.(Wallace & Froum, 2003)

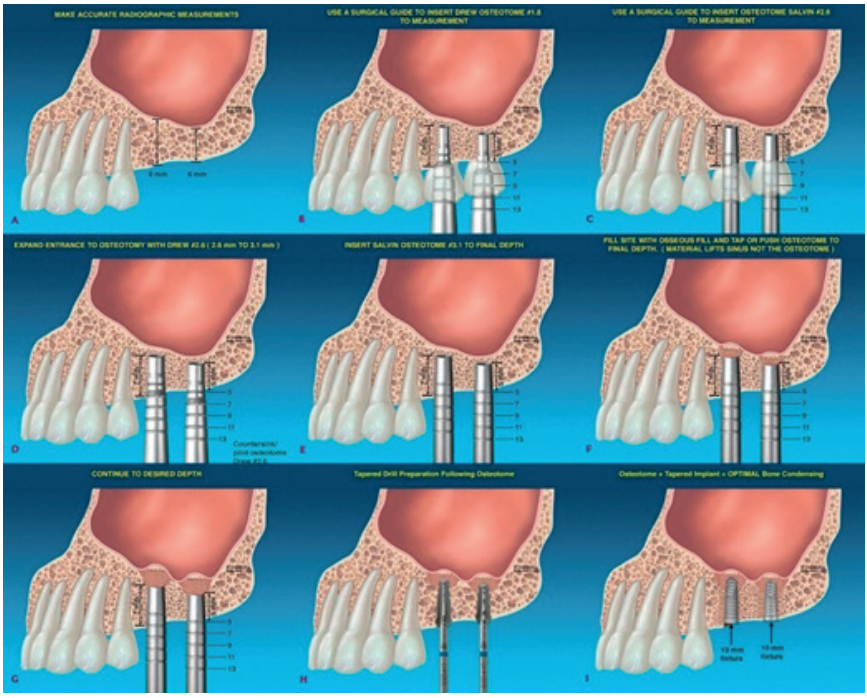


Figure 2. *(Sofia D. Petrov, 2014)*

2.6.3 Sine Lifting Technique with Hydraulic or Pressurised System

The procedure is performed under local anaesthesia and is usually performed through a crestal incision. The surgical field is opened by lifting

the mucoperiosteal flap. Osteotomy is performed up to the sinus floor with spiral burs. In order not to damage the membrane, the last 1-2 mm of the osteotomy is performed with low speed or by hand with special burs.(Sotirakis & Gonshor, 2005) Sterile saline solution is slowly introduced through a special syringe inserted into the osteotomy canal. This fluid gently lifts the membrane upwards and sinus lifting is achieved. Hydraulic pressure reduces the risk of rupture by providing a homogeneous distribution on the membrane.(Chen & Cha, 2020) It has been reported that new bone formation can be observed without a graft as well as placing graft material in the cavity formed after the membrane is raised. Likewise, if primary stability can be achieved, the implant is placed in the same session.

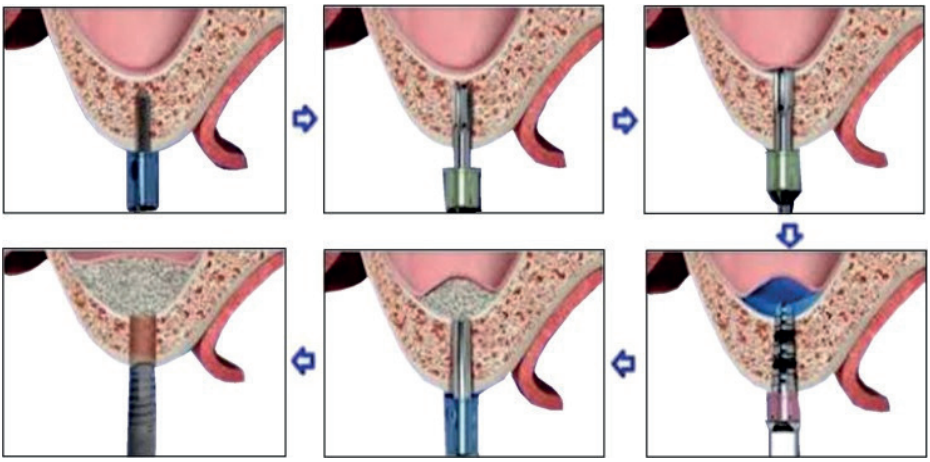


Figure 3. *(Gandhi Y., 2017)*

2.6.4.Balloon Sinus Lifting Technique

In this technique, the sinus membrane is carefully elevated with the help of a balloon, which provides sufficient bone height for implant placement. The balloon technique is one of the preferred methods, especially in patients with insufficient residual bone height. Access to the sinus area is gained through a crestal or lateral window approach. After carefully separating the sinus membrane, the deflated balloon device is inserted into the sinus cavity. The balloon is slowly inflated with sterile saline solution and the membrane is gently elevated. This method minimises the risk of membrane rupture as much as possible and provides a controlled elevation.(Sharanappa et al., 2024)

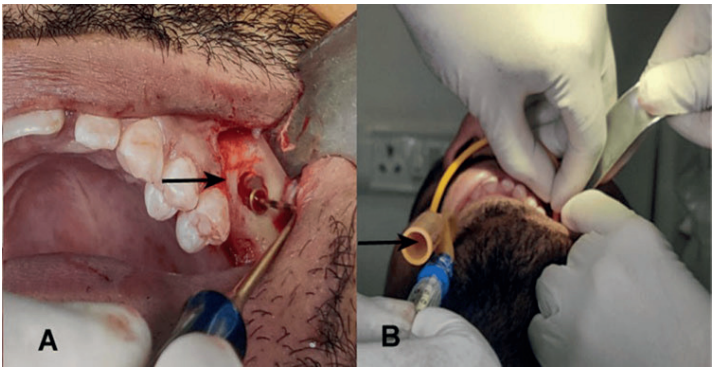


Photo 1.*Lateral window approach for maxillary sinus (A) and*

Photo 2. Ballooning technique for sinus elevation using a number 6 paediatric Foley catheter (B).(Sharanappa et al., 2024)

2.6.5 Sinus Lifting with Piezoelectric Devices

Access to the sinus region is provided by a crestal or lateral window approach. In the lateral window approach, a window is opened in the sinus wall using piezoelectric devices. These devices minimise the risk of damage to the sinus membrane while precisely cutting the bone tissue.

Piezoelectric devices precisely cut bone tissue while reducing the risk of damage to soft tissues. This minimises the risk of perforation of the sinus membrane. The sinus membrane is carefully elevated using special piezoelectric tips. This method reduces the risk of perforation of the membrane and provides a controlled elevation.(Alsharekh et al., 2024) Research shows that osteotomies with piezoelectric devices provide less postoperative pain and better mouth opening compared to conventional rotary instruments.(Martins, 2021)

Table 2: *Comparison of sinus lifting techniques is tabulated below.(Del Fabbro et al., 2004; He et al., 2013; Wallace & Froum, 2003)*

Technical Name	Approach Type	Indication (Bone Height)	Advantages	Disadvantages
Lateral Window Technique	Lateral	< 4 mm	Large graft volume, high success	Invasive, risk of perforation, long recovery time
Osteotome (Transcrestal) Technique	Krestal	4-6 mm	Minimally invasive, short-term	Limited visibility, membrane may rupture
Hydraulic Method	Krestal	4-6 mm	More controlled membrane pavement	Additional equipment may be required
Balloon Sinus Lifting	Krestal	4-6 mm	Reduces trauma, low risk of rupture	Implementation may be limited, costly
Piezoelectric Assisted Technique	Lateral	< 5 mm	Safer bone cutting	Operation time may be prolonged

3.SINUS LIFT COMPLICATIONS

3.1Intraoperative Complications

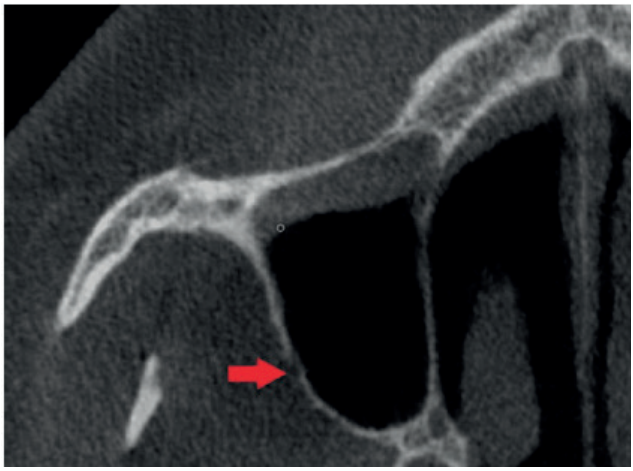
In sinus lifting procedures, complications such as bleeding, swelling and infection may occur after surgery. Apart from this, we can list the complications seen during surgery as follows: Rupture of the Schinederian membrane, escape of the dental implant into the sinus, septal division in the sinus cavity.

3.1.1 Rupture of the Schinederian membrane

Rupture of the Schneiderian membrane is among the complications of sinus lifting that we encounter because it poses a risk to the postoperative success of the bone graft. When we encounter a perforated Schneiderian membrane, the location and size of the perforated area play an important role in complication management. After the perforation occurs, the physician should avoid excessive forces and pressures that may increase the size of the perforation. If the size of the perforation is small, folding it together with the membrane is sufficient for treatment. If the size of the perforation is large, after careful suturing, fibrin glue is adapted and the bioabsorbable membrane is placed only on the surface of the sutured schneiderian membrane. The sinus walls are not completely closed, as we want a continuous blood flow within the bone. The "Loma Linda pouch", which is used to repair the maxillary sinus membrane during sinus grafting procedures, has appeared on the market. The collagen membrane is peeled into the perforated area and inserted into the maxillary sinus with a curette. The collagen membrane is then sutured through the accessible window to create a pouch that isolates the graft material. With this method, the graft material is prevented from entering the sinus cavity after perforation treatment. The flaps are then adapted. With this technique, graft isolation is also provided.(Devameena et al., 2020)

3.1.2 Alveolar-antral artery

Posterior superior alveolar artery and infraorbital artery are connected arteries. However, extraosseous anastomosis is seen in 44% of studies. Bleeding of the alveolar-antral artery is a major complication of sinus lifting implants. In order to minimise this complication rate, posterior access to the bone antrostomy has an important place in studies. In sinus lifting procedures, CBCT has an important place in the visualisation of the level at which the artery progresses. The diameter of the artery is another important consideration. If the diameter is less than 1 mm, the complication rate in sinus lift procedures decreases. If the diameter of the artery is 2-3 mm or larger, the bleeding problem, the severity of the complication, and the need for arterial ligation increase. Both the diameter and course of the artery should be assessed by CBCT as shown.(Alshamrani et al., 2023b)



Figur. 4 : evaluation of the course of the maxillary atheroma on CBCT

3.1.3 Displacement of the Dental Implant into the Maxillary Sinus

Migration of dental implants into the maxillary sinus cavity usually occurs due to surgical technical inadequacies or anatomical variations. This complication may occur due to factors such as implant placement in the posterior maxilla without sinus augmentation, insufficient knowledge and experience of the anatomical structures of the maxillary sinus, unrecognised and untreated antral floor perforations during osteotomy, and excessive mechanical force applied to the implant during internal sinus lifting procedures.

There are three main surgical approaches for the removal of implants displaced into the sinus cavity: removal of the implant from the alveolar region by transalveolar aspiration, classical Caldwell-Luc antrostomy and functional endoscopic sinus surgery (FESS). The concept of modern endoscopic sinus surgery was first described by Messerklinger in 1960 and this technique was introduced into clinical practice in the United States in 1985.(Alshamrani et al., 2023b)

3.1.4 Presence of Maxillary Sinus Septa

The maxillary sinus septa were first mentioned by Underwood in 1910. The majority of septa are located between the second premolar and the first molar. The presence of septa complicates sinus lift surgery. The complete division of the sinus by the septa is managed by multiple lateral windows created to bypass the septa (Devameena et al., 2020).

3.1.5 Damage to neighbouring structures:

Trauma to adjacent tooth roots or soft tissues during the operation may cause neural or periodontal complications.(Kim & Jang, 2019)

3.1.6 Fractures of the crestal or sinus wall:

In alveolar crests with volume loss, bone fractures may develop as a result of excessive force application and this may delay implant application.(Kim & Jang, 2019)

3.1.7 Extraction of Posterior Teeth

Alveolar bone reposition and maxillary sinus prolapse have been associated with extraction of posterior teeth. It has been found that the sinus membrane and the roots of the posterior teeth can be associated, especially when a single posterior tooth is missing, the risk of perforation increases. However, the probability of perforation is reduced when two neighbouring teeth are missing. This decrease may be due to the presence of sinus pneumatisation in a small area with irregular sinus floor shape (Alshamrani et al., 2023).

When sinus graft complications are evaluated in detail in a short time, the risk of complications decreases. The incidence of infection after sinus lifting varies between 2% and 5.6%.

3.2 Postoperative Complications

3.2.1Infection

The infection usually does not occur within the sinus, but in the grafted area under the sinus membrane. Sometimes the infection spreads into the sinus and manifests as pan-sinusitis. Testori Tziano has formulated recommendations based on clinical questions answered by a panel of experts (periodontist, implantologist, maxillofacial surgeon, ear, nose, throat and microbiologist).

The clinical consensus explained that common postoperative symptoms may include swelling, ecchymosis, mild to moderate discomfort and minor nosebleeds. Symptoms usually resolve within 3 weeks. They recommended prophylaxis and postoperative regimen based on clinical experience and indirect evidence

Antibiotic prophylaxis and postoperative medications should be managed with a multidisciplinary approach if symptoms persist for more than 3 weeks and associated pus discharge, fistula, discharges from the throat and nose, flap separation and suppuration. Functional endoscopy may be recommended in combination with sinus surgery, oral approach with removal of bone, graft and implant. Microbial testing is usually recommended a few days after pharmacological treatment (Kim & Jang, 2019).

3.2.2 Sinusitis Formation:

After surgery, inflammation may develop in the sinus mucosa and sinusitis may occur. This risk is higher in individuals with a history of chronic sinusitis. (Fischer et al., 2023)

3.2.3 Graft Displacement:

When the applied graft material is positioned without sufficient stability, it may move towards the sinus cavity. This may cause the graft to lose its function.(On et al., 2019)

3.2.4 Oroantral Fistula Formation:

When a pathological opening occurs between the mouth and the sinus, this can lead to fluid passages and recurrent infections.(Fischer et al., 2023)

3.2.5 Implant Losses:

If proper bone formation is not achieved after sinus lifting or if factors such as membrane damage develop, osseointegration of the implant may be interrupted and the implant may fail.(Stacchi et al., 2022)

3.2.6 Haemosynus

Haemosynus is a rare clinical picture characterised by blood accumulation in the paranasal sinus cavities. It usually develops due to trauma, tumoural lesions, surgical interventions or vascular anomalies (Kim et al., 2019). Although the maxillary sinus is the most commonly affected area, haemosynus can also be seen in the frontal, ethmoid and sphenoid sinuses. Clinically, patients often present with headache, facial pain, nasal obstruction and rarely epistaxis. However, symptoms are often non-specific and diagnosis may be difficult without radiological imaging.

Computerised tomography (CT) and magnetic resonance imaging (MRI) play an important role in the diagnosis of haemosinus. While homogenous hyperdensity is observed in the sinus on CT, hyperintense images on T1-weighted sequences and hypo- or isointense images on T2-weighted sequences are obtained on MRI. These findings suggest chronic blood accumulation in the sinus (Kim et al., 2019)

4.CONCLUSION

Today, dental implant applications are recognised as one of the treatment options with high success rates both functionally and aesthetically. However, especially in the posterior region of the maxilla, factors such as the anatomical position of the maxillary sinus and sinus pneumatisation after tooth loss limit implant applications due to the lack of sufficient bone volume. Sinus lifting procedures developed to overcome these difficulties aim to increase the vertical bone height required for implant placement.

Sinus lifting is an effective and common surgical technique that makes dental implant placement possible. The success of this method is directly related to the correct indication, proper application of the surgical technique and careful follow-up of the patient in the postoperative period.

Each of the sinus lifting techniques examined in this thesis addresses different clinical indications and carries the risk of complications. While the lateral window technique is preferred especially in cases where the residual bone height is less than 4 mm, osteotome, hydraulic, balloon and piezoelectric techniques are less invasive approaches. Since each technique has its own indications, application difficulties and complication risks, it is extremely important to choose the most appropriate method by making a patient-based evaluation. The most common complications include Schneiderian membrane perforation, sinusitis, infection of the graft material and implant failure. However, these risks can be eliminated as much as possible with appropriate surgical planning, careful technical application and taking precautions against complications.

In conclusion, the sinus lifting procedure is a reliable and long-term successful method to overcome the problem of bone insufficiency in dental implant applications. In order to increase clinical success, it is of great importance to increase the level of knowledge and experience of surgeons and to inform patients before and after the procedure.

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Chapter 4

ORAL PYOGENİC GRANULOMA: CASE REPORT

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Introduction

Pyogenic granuloma (PG) is a common reactive vascular lesion, usually seen in the oral cavity and less frequently on the skin or other mucosal sites. Clinically, it often presents as a bright red or purplish nodule that grows quickly and bleeds easily. Despite its name, the lesion does not contain pus and does not show true granulomatous inflammation, so the traditional term is somewhat misleading (Jafarzadeh, Sanatkhani & Mohtasham, 2006). For this reason, many recent publications prefer the term lobular capillary hemangioma (LCH) (Epivatianos et al., 2005).

Over the years, PG has been described using different names, such as *granuloma pediculatum benignum*, *vascular epulis*, *hemangiomatous granuloma*, and the well known pregnancy associated variant, *granuloma gravidarum* (Epivatianos et al., 2005). Although an exact prevalence is not established, PG develops most commonly on the gingiva, particularly in the anterior maxilla (Jafarzadeh et al., 2006; Al-Khateeb & Ababneh, 2003). In the study by Lawoyin et al. (1997), 74% of cases were located on the gingiva. Its higher incidence in women supports the role of hormonal influences in its formation. The pregnancy related subtype shows a marked increase during gestation. PG may occur at any age but is most often reported between the second and fifth decades and shows a clear female predominance (Epivatianos et al., 2005).

Clinically, PG usually develops over a period of weeks as a rapidly enlarging, red or dark purple, sessile or pedunculated soft tissue mass. While the gingiva is the most common site, lesions may also appear on the lips, buccal mucosa, tongue, hard palate, or occasionally around dental implants (Lomelí Martínez et al., 2023). Ulceration of the surface is frequent, and because PG is highly vascular, even minor trauma such as brushing or chewing can cause bleeding. Although typically painless, many patients seek treatment due to bleeding episodes, swelling, or esthetic concerns (Jafarzadeh et al., 2006).

Because PG grows quickly and often has a reddish lobular appearance, it may resemble malignant or pseudomalignant conditions. The differential diagnosis includes peripheral giant cell granuloma, peripheral ossifying fibroma, hemangioma, vascular malformations, metastatic nodules, and superficially invasive squamous cell carcinoma. Nevertheless, PG is a benign lesion and has no metastatic potential (Jafarzadeh et al., 2006).

The development of PG is thought to be multifactorial. No single cause has been confirmed, but low grade chronic irritation and microtrauma such as calculus deposits, ill fitting restorations, orthodontic appliances, or prosthetic irritation play a major role (The Open Dentistry Journal, 2012). These irritants stimulate a reactive vascular proliferation within the connective tissue.

Hormonal factors are also significant. Elevated estrogen and progesterone levels during pregnancy promote angiogenesis by increasing the expression of growth factors such as VEGF and bFGF (Vara et al., 2017). Molecular studies have shown increased levels of VEGF, bFGF, and markers of the angiopoietin Tie2 pathway in PG tissue, supporting the concept that the lesion represents a biologically driven vascular proliferation rather than a purely reactive overgrowth (Lomelí Martínez et al., 2023). In addition, drugs such as calcineurin inhibitors (cyclosporine, tacrolimus), calcium channel blockers (nifedipine), and retinoids have been associated with PG development through similar mechanisms (Lomelí Martínez et al., 2023).

Histologically, PG is composed of numerous newly formed capillaries surrounded by fibroblastic cells and inflammatory infiltrates within a granulation tissue like stroma (Toida et al., 2003). Since no pus is present, the term "pyogenic" is inaccurate. Two main histologic types are recognized: the lobular capillary hemangioma (LCH) variant, which shows a lobular vascular architecture, and the non-LCH type, where vascular proliferation is more diffuse (Epivatianos et al., 2005). The surface is often ulcerated and covered by a fibrin layer, and the subepithelial tissue commonly shows edema, inflammation, and a dense capillary network features that explain the lesion's tendency to bleed and recur.

The standard treatment for PG is complete surgical excision along with elimination of local irritants such as plaque, calculus, faulty restorations, or orthodontic components (Al-Khateeb & Ababneh, 2003). When excision includes adequate margins, recurrence is uncommon. Other therapeutic options such as laser excision, cryotherapy, or sclerotherapy have also been reported with favorable outcomes (Vara et al., 2017). Recurrence rates vary between 5% and 16% and are usually linked to incomplete removal or persistent trauma (Lawoyin et al., 1997).

The pregnancy related form (*granuloma gravidarum*) often regresses spontaneously after hormonal levels return to normal postpartum, although large or frequently bleeding lesions may still require surgical intervention (Jafarzadeh et al., 2006).

Although PG is benign, its rapid growth, tendency to bleed, and esthetic impact require careful evaluation. The combination of trauma, hormonal influences, and enhanced angiogenesis forms the core of its pathogenesis. A better understanding of these biological mechanisms may help refine classification and improve management strategies for vascular lesions of the oral cavity.

Case Report

A 53 year old woman with a known history of systemic hypertension presented about two months after giving birth, complaining of swelling and occasional bleeding in the gingiva around the mandibular right canine (tooth 43). She explained that she had no oral symptoms during pregnancy and only noticed the swelling sometime after delivery. Her medical history included regular antihypertensive therapy, and no other systemic or local predisposing factors were identified. The patient also denied any recent trauma, orthodontic appliances, prosthetic irritation, or similar local causes that could explain the lesion (Figure 1).

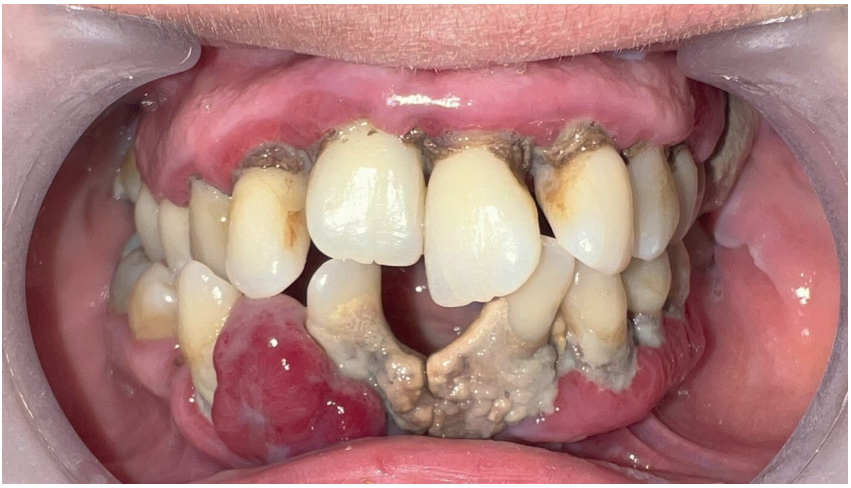

Figure 1. *Intraoral view of the patient*

During the clinical examination, a pedunculated, reddish, and somewhat elastic soft tissue mass with a smooth and shiny surface was seen in the area of the mandibular right canine. The lesion measured roughly 1.5 × 1.0 cm. It bled easily when touched, and there was mild gingival enlargement in the surrounding tissues. The patient did not report any pain or sensitivity in the region. Because the lesion had developed fairly quickly, the initial clinical differential diagnosis included pyogenic granüloma considering the possibility of a postpartum (granuloma gravidarum) variant along with peripheral giant cell granuloma and peripheral ossifying fibroma (Figure 2).

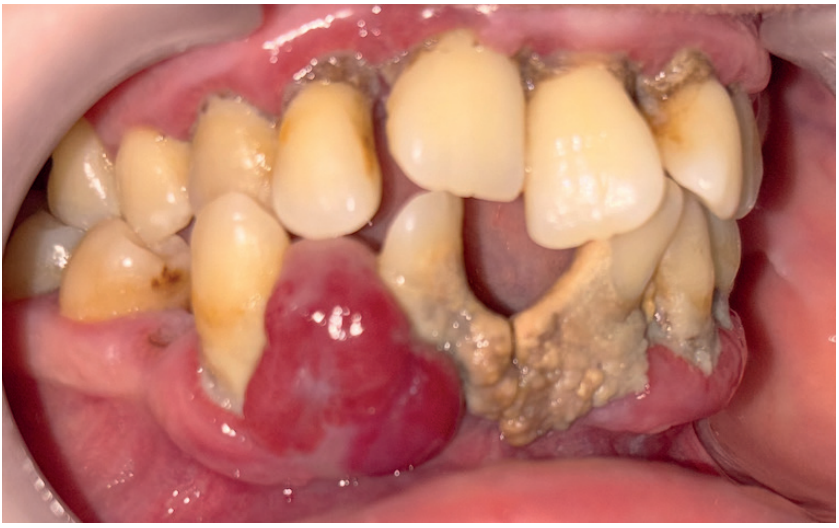

Figure 2. *Intraoral view of the patient*

Radiographic examination showed localized alveolar bone loss in the affected area, most likely related to plaque accumulation, but there was no sign of root resorption. The lesion was removed surgically under local anesthesia, and care was taken to excise it completely with clean margins. The tissue specimen was then submitted for histopathologic evaluation.

On gross inspection, the excised sample measured about 1.5 × 1.0 × 0.9 cm. It had a pinkish white color, an elastic consistency, and was covered by mucosa that included a few small ulcerated spots.

Microscopically, the surface was lined by parakeratinized stratified squamous epithelium, and some areas showed ulceration with surface exudate and accumulated debris. The underlying connective tissue displayed prominent capillary proliferation, with numerous small vessels lined by endothelial cells and containing erythrocytes. The stroma showed edema, a mild infiltration of lymphocytes and plasma cells, and an overall granulation tissue like pattern. These findings supported the diagnosis of a lobular capillary hemangioma–type pyogenic granuloma. Postoperative healing progressed without complications (Figure 3).

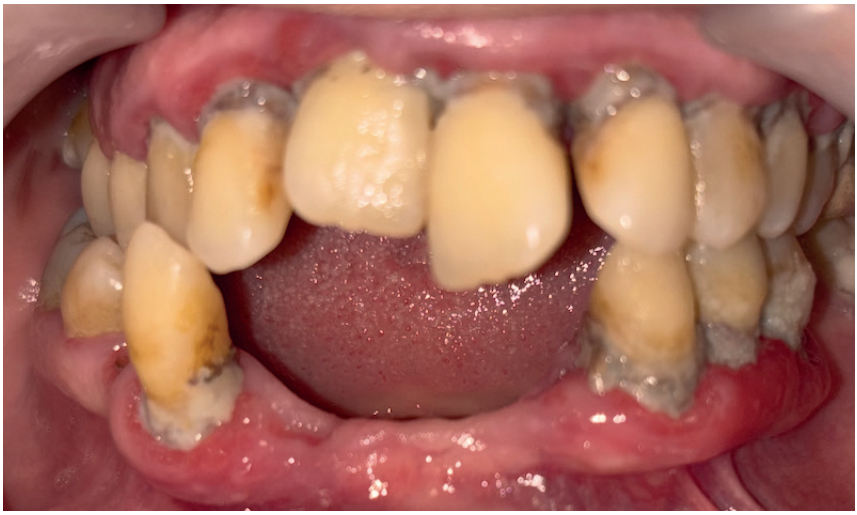

Figure 3. *Postoperative intraoral view of the patient*

The patient received oral hygiene instruction, and elimination of local irritative factors was recommended. No recurrence or residual lesion was observed at the three and six month follow up visits.

Discussion and Conclusion

Pyogenic granuloma (PG) is a benign lesion that develops through multiple contributing factors and is mainly characterized by marked vascular growth. Both clinically and microscopically, it resembles an exaggerated granulation tissue response and is often linked to local trauma, plaque accumulation, hormonal changes, or certain medications (Sharma, Sharma & Verma, 2019). It is generally believed that minor trauma triggers an inflammatory reaction that activates endothelial cells and increases the release of growth factors such as VEGF and bFGF, which help drive the lobular capillary proliferation typical of PG (Vara et al., 2017).

In the present case, the appearance of the lesion during the postpartum period suggests that hormonal changes alone may not fully explain its development. The patient's systemic hypertension and ongoing use of antihypertensive medication could also have played a role. Earlier reports have noted that some antihypertensive agents particularly calcium channel blockers and calcineurin inhibitors may influence VEGF expression and contribute to gingival enlargement or PG like lesions (Martínez et al., 2023). These medications may also alter endothelial function and inflammatory responses, potentially helping maintain vascular hyperplasia (Seyedmajidi et al., 2015). Such factors may explain why the lesion persisted even after normal hormone levels were restored postpartum.

During pregnancy, increased estrogen and progesterone levels enhance VEGF and bFGF expression and stimulate endothelial proliferation (Vara et al., 2017). Estrogen is also known to increase nitric oxide synthesis, promoting vasodilation and supporting angiogenesis (Martínez et al., 2023). When this angiogenic activity does not fully regress after delivery, it may persist as a postpartum granuloma gravidarum type lesion. Supporting this view, Saghafi et al. (2011) reported high expression levels of VEGF, CD31, and Ki-67 in PG specimens, indicating active angiogenesis and cellular proliferation. These findings suggest that PG is not only a reactive lesion but also reflects an angioproliferative process (Seyedmajidi et al., 2015).

Histopathologically, the current case showed parakeratinized stratified squamous epithelium with areas of surface ulceration, along with dense capillary growth, endothelial proliferation, and granulation tissue formation features that fit the classical description by Toida et al. (2003). Toida and colleagues further distinguished between lobular capillary hemangioma (LCH) and non-LCH patterns, noting that these subtypes may differ in clinical behavior and recurrence tendencies. The presence of erythrocyte filled vascular channels explains why the lesion bled so easily during clinical examination.

Beyond hormonal and vascular changes, systemic hypertension and the patient's antihypertensive therapy may also have influenced endothelial behavior. Seyedmajidi et al. (2015) found increased ICAM-1 and VCAM-1 expression in PG tissue, which was associated with inflammatory cell infiltration and endothelial activation. These pathways may support persistent inflammation and continued reactive vascular proliferation (Sharma et al., 2019).

The patient healed uneventfully after surgery and showed no recurrence at three or six month follow up. Recurrence in the literature ranges from 5% to 16%, most often related to incomplete excision or continued local irritation. The positive outcome in this case likely reflects complete surgical removal and good postoperative plaque control (Sharma et al., 2019; Martínez et al., 2023; Vara et al., 2017). Although methods such as cryotherapy and laser excision have been suggested as alternatives, conventional surgical excision remains the most reliable option due to its low recurrence rate (Martínez et al., 2023).

This case demonstrates that postpartum PG cannot be attributed solely to hormonal influences. Vascular reactivity, endothelial changes, systemic hypertension, and medication related factors may work together to create a favorable environment for the lesion to develop (Martínez et al., 2023; Saghafi et al., 2011). Seyedmajidi et al. (2015) also suggested that higher expression of angiogenic markers may be associated with recurrence, highlighting the potential role of biomarker based prognosis in the future.

For gingival enlargements arising in the postpartum period, correlating histopathological findings with clinical data is crucial for an accurate diagnosis. Although PG is benign, its rapid growth, tendency to bleed, and vascular nature necessitate distinction from peripheral giant cell granuloma, ossifying fibroma, and vascular malformations (Toida et al., 2003). A comprehensive assessment of the patient's systemic status is equally important to minimize recurrence (Sharma et al., 2019).

Surgical excision remains the most effective approach for both diagnosis and treatment. Removing local irritants and ensuring clean surgical margins significantly reduces recurrence risk. For pregnancy related cases, long term follow up after hormonal stabilization is advisable (Vara et al., 2017; Seyedmajidi et al., 2015). As suggested by Sharma et al. (2019) and Martínez et al. (2023), coordinated follow up including periodontal care, control of systemic factors, and regular monitoring offers the best strategy to prevent recurrence.

In conclusion, this case highlights the complex interaction of hormonal, vascular, and medication related factors in the formation of pyogenic granuloma in postpartum patients receiving antihypertensive therapy. Thorough clinicopathological evaluation is essential to achieve accurate diagnosis and appropriate management.

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Chapter 5

DENTAL IMPLANT ABUTMENT TYPES

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An abutment is the component of an implant that retains or supports a prosthesis or an implant superstructure. The superstructure is defined as the metal framework that fits onto implant abutments or provides retention for removable prostheses, or as the main framework of a fixed prosthesis. Various options exist regarding the design and material of implant abutments (Misch, 2015). Implant abutments are extremely important in implant therapy in terms of both esthetics and function, and they directly affect the long-term prognosis of treatment. Dental implant abutments consist of three parts:

- **Prosthetic connection part:** The portion of the abutment that connects to the prosthesis.
- **Implant connection part:** The portion of the abutment that connects to the implant.
- **Transgingival part:** The portion of the abutment surrounded by gingival tissue above the implant prosthetic platform (Shafie, 2014).

The implant abutment material must be biocompatible and possess sufficient mechanical properties to meet esthetic, biological, and functional requirements (Kim & Shin, 2013).

With advancements in implant dentistry and esthetic dental applications, alternative materials for conventional implant abutments continue to be explored. Based on the retention of the superstructure or prosthesis, implant abutments are categorized into three main groups:

1. Abutments used for screw-retained restorations
2. Abutments used for cement-retained restorations
3. Abutments used as retainers in implant-supported removable prostheses

All three types can be further classified as angled or straight depending on the angulation between the abutment and the implant body. In cement-retained and screw-retained categories, abutments are available in various contours and heights, either as one-piece or two-piece designs (Misch, 2015). One-piece (solid) abutments are integrated with the abutment screw, whereas in two-piece abutments the screw is separate (Ahmad, 2012). In some implant systems, cemented or screwless abutments directly connected to the implant body are available (implant–abutment complexes) (Karunagaran et al., 2013). In two-piece implant systems, the implant portion designed for prosthetic retention is referred to as the crest module. The area where the abutment connects to the implant is called the platform, which resists occlusal forces (Misch, 2015).

Bidra and Rungruanganunt (2013) reported that various types of implant abutments can also be classified according to their use in the anterior region, based on restoration connection, material type, manufacturing technique, and color.

Another classification of implant abutments according to material type includes the most commonly used materials:

1. **Titanium**
   a) Machined
   b) Polished (non-machined)
   c) Laser-Lok
2. **Medical-grade stainless steel**
3. **Cast gold**
4. **Zirconia**
5. **Polyetheretherketone (PEEK)** (Shafie, 2014)

Implant abutments can also be classified based on duration of use:

Temporary Implant Abutments

a) Impression abutments

b) Healing abutments and cover screws

c) Metal and plastic temporary abutments

Definitive Implant Abutments

a) Standard prefabricated abutments – titanium (Ti), zirconia (Zr) (cement-retained)

b) Cast custom abutments – titanium (Ti), zirconia (Zr) (cement- or screw-retained)

c) Computer-aided custom abutments – titanium (Ti), zirconia (Zr), alumina (Al) (cement- or screw-retained) (Karunagaran et al., 2013)

Various implants, abutments, and restorations are manufactured with different designs and biomaterials to achieve optimal mechanical, biological, and esthetic outcomes. When selecting an abutment for the anterior region, factors such as the patient's smile line (low, medium, high, or gummy smile), peri-implant mucosa thickness (thin or thick), implant angulation, crown material, suitability of the restoration site, restoration type (cement- or screw-retained), clinician preference, and treatment cost should be considered (Bidra & Rungruanganunt, 2013).

Titanium Implant Abutments

Titanium (Ti) is a durable, strong, lightweight, and highly biocompatible element (Shafie, 2014). Implant abutments are commercially manufactured from grade I to grade IV commercially pure titanium or from grade V titanium alloy (Shafie, 2014; Yılmaz et al., 2015). Grade V titanium (Ti-6Al-4V) is an alloy containing approximately 6% aluminum, 4% vanadium, up to 0.25% iron, and up to 0.2% oxygen. Titanium alloys provide higher tensile and fracture strength compared to commercially pure titanium (Shafie, 2014).

Laser-Lok (BioHorizons) prefabricated titanium abutments, produced using laser surface texturing, contain 8–12 μm microchannels that promote connective tissue attachment, prevent apical migration of the junctional epithelium, and preserve existing bone levels. This enables a healing pattern similar to that of natural dentition, with connective tissue fibers attaching perpendicularly to the abutment surface in the transgingival region (Nevins et al., 2010; Geurs et al., 2011). Due to these advantages, their use is particularly recommended in the anterior region. No superiority has been identified between machined and polished titanium abutments in terms of soft tissue attachment levels (Zitzmann et al., 2002).

Clinical studies have demonstrated high success rates for titanium abutment-supported fixed implant restorations (Cooper, 2007; Kreissl et al., 2007). However, despite biomechanical stability, the metallic color of titanium abutments can compromise esthetics. Even when placed subgingivally, the matte gray color of titanium may result in an unnatural bluish appearance of the soft tissue, particularly when peri-implant gingival thickness is insufficient to block light reflection (Park et al., 2007). Therefore, titanium abutments may be inadequate in esthetically demanding areas (Martínez-Rus et al., 2012).

To address this issue, gold-colored titanium nitride (TiN)-coated titanium abutments and ceramic abutments made from alumina (Al_2O_3) or zirconium dioxide (ZrO_2) have been introduced (Foong et al., 2013). TiN coatings improve esthetics as well as physical and mechanical properties and are reported to be non-toxic, biologically inert, and corrosion-resistant. Additionally, TiN-coated abutments show reduced surface roughness and plaque accumulation after instrumentation compared to uncoated titanium abutments. However, Lim et al. (2012) reported potential allergic reactions associated with TiN coatings. Ceramic-based coatings have also been shown to significantly enhance the optical properties of titanium abutments (Pecnik et al., 2015a, 2015b).

Ceramic Implant Abutments

Ceramic abutments were developed to enable the use of all-ceramic systems in implant-supported fixed restorations and to achieve optimal

gingival adaptation and esthetics (Firidinoğlu et al., 2007). The main disadvantage of ceramic abutments is their brittleness and lower resistance to tensile forces compared to metal abutments. Fractures typically occur when tensile forces exceed the fracture toughness of the material (Elsayed et al., 2016). Nevertheless, ceramic abutments are recommended due to their superior optical properties, low corrosion potential, high biocompatibility, and low thermal conductivity (El S'adany et al., 2013). They are particularly advantageous in cases with thin and translucent gingiva and high smile lines. Unlike titanium abutments, ceramic abutments allow for supragingival crown margins, facilitating margin inspection, cementation, and removal of excess cement.

However, ceramic abutments are contraindicated in cases of excessive occlusal coverage, bruxism, parafunctional habits, abutment angulations exceeding 30°, and posterior regions (Firidinoğlu et al., 2007). While fractures in metallic abutments typically occur at the abutment screw, fractures in ceramic abutments involve the abutment itself and are not repairable. Additionally, ceramic abutments are more costly. Ceramic abutments can be fabricated as prefabricated units, laboratory-customized components, or CAD/CAM-produced restorations (Kohal et al., 2008). Materials used include high-strength ceramics such as alumina and yttrium-stabilized tetragonal zirconia polycrystals (Y-TZP) (Kohal et al., 2008).

Polimeric Implant Abutments

Polymeric implant abutments have gained increasing attention in implant dentistry as an alternative to conventional metallic and ceramic abutments, primarily due to their favorable biomechanical and biological properties. Among these materials, high-performance polymers such as polyetheretherketone (PEEK) and reinforced PEEK formulations are the most widely investigated. These polymers exhibit good biocompatibility, low allergenic potential, and resistance to corrosion, making them suitable for use in patients with metal sensitivities or esthetic concerns related to metallic abutments (Hahnel et al., 2014).

From a biomechanical perspective, polymeric abutments offer an elastic modulus closer to that of cortical bone compared with titanium or zirconia. This similarity may contribute to a more favorable stress distribution at the implant–abutment–bone interface by reducing the stress-shielding effect and potentially supporting peri-implant bone preservation. Although their fracture resistance is generally lower than that of metallic abutments, polymeric materials demonstrate sufficient mechanical performance for use in low-to-moderate load-bearing regions, particularly in the anterior area or as provisional components (Bechir et al., 2013; Vosshans et al., 2013).

Biologically, polymeric implant abutments have shown promising soft tissue responses. Several studies have reported comparable peri-implant mucosal health, inflammatory response, and bacterial adhesion when polymeric abutments are compared with titanium and zirconia abutments. The relatively smooth surface characteristics of polymers such as PEEK may limit plaque accumulation, while their chemical stability prevents ion release, further supporting favorable peri-implant tissue integration (Najeeb et al., 2016).

Clinically, polymeric implant abutments are commonly used as healing abutments, provisional abutments, and components of temporary or semi-definitive restorations. Advances in CAD/CAM technology have enabled precise fabrication of customized polymeric abutments with consistent material properties and improved fit. Despite these advantages, long-term clinical data remain limited, and polymeric abutments are generally recommended as alternatives or adjuncts rather than replacements for titanium in high load-bearing situations. Continued clinical studies are required to better define their long-term reliability and indications (Stawarczyk et al., 2015).

Prefabricated Implant Abutments

Prefabricated implant abutments are available in various forms, including multi-unit abutments used for two-stage screw-retained prostheses, cement-retained abutments shaped like prepared teeth, and overdenture abutments (Byrne, 2014). Prefabricated cement-retained implant abutments are produced in different sizes, shapes, and angulations, most commonly from titanium, base metals, or ceramics such as zirconia and alumina. These abutments can be modified either intraorally or in the laboratory, allowing the fabrication of temporary or definitive restorations on them (Byrne, 2014; Shafie, 2014).

Prefabricated implant abutments are cost-effective and enable clinicians to fabricate crowns and fixed partial dentures chairside using conventional prosthodontic techniques. Another advantage is that, when the implant is ideally positioned, minimal preparation is required, thereby avoiding weakening of the abutment material (Shafie, 2014).

Custom Implant Abutments

There are several methods for fabricating custom implant abutments:

1. Using preparable abutments (ceramic or titanium),

2. Utilizing CAD/CAM systems,

3. Copy-milling techniques (using scanners and computer-aided manufacturing), and

4. Casting with the lost-wax technique (Marchack et al., 2007).

Custom implant abutments became popular following the development of UCLA (University of California, Los Angeles) implant abutments (Shafie, 2014). Initially designed by Lewis et al. (1988), UCLA abutments are a type of abutment that can be screwed directly into the dental implant and used either as cement-retained or screw-retained restorations (Shafie, 2014). Custom UCLA implant abutments allow compensation for non-aligned implants by modifying the angulation, taper, finish line, and width of the abutment in accordance with the position and emergence profile of the final restoration. Typically, a plastic sleeve is cut and shaped with wax to the desired form and geometry, and the abutment is then cast, most commonly using a gold alloy (Ahmad, 2012; Shafie, 2014).

With the rapid development of CAD/CAM technology, CAD/CAM–fabricated custom abutments have been increasingly adopted in several dental implant systems. Compared with cast abutments, CAD/CAM abutments eliminate procedural complexity, reduce time loss associated with casting, and minimize potential fabrication errors. In contrast, CAD/CAM abutments demonstrate more precise fit and adaptation. Moreover, because CAD/CAM custom abutments are manufactured from a homogeneous bulk material under controlled conditions, they exhibit superior physical properties.

It has been reported that the reduced surface roughness of CAD/CAM–fabricated zirconium dioxide abutments enhances various cellular characteristics, including the viability and migration capacity of gingival fibroblasts and especially oral keratinocytes, as well as their adhesion capability (Pabst et al., 2016). Additional advantages of reduced surface roughness include decreased bacterial adhesion on zirconium dioxide abutments, resulting in reduced bacterial biofilm formation and consequently a lower risk of peri-implantitis and implant failure. The inherently low susceptibility of zirconium dioxide to bacterial adhesion further contributes to these favorable outcomes (Pabst et al., 2016).

Custom Titanium-Base (Hybrid) Implant Abutments and Abutment–Crown Complexes

While some custom abutments can be fabricated entirely from zirconium dioxide, others are produced as hybrid designs consisting of a zirconium dioxide superstructure bonded to a titanium base. Butz et al. (2005) reported that zirconium dioxide abutments reinforced with a titanium base exhibit fracture resistance values comparable to those of titanium abutments. The titanium base can be attached to zirconium dioxide either through frictional retention or adhesive systems (Lan et al., 2016; Guilherme et al., 2016). In such

designs, the titanium base bonded to the zirconium dioxide component comes into contact with the implant platform and abutment screw. The adhesive layer between the tooth-colored material and the abutment helps reduce the risk of damage to the implant platform during function and facilitates the formation of a stable zirconium dioxide–titanium–titanium interface.

The use of heat-pressed lithium disilicate bonded adhesively to a titanium base in tooth-colored implant abutment systems has been described, and more recently CAD/CAM lithium disilicate blocks have been developed to optimize laboratory procedures (Guilherme et al., 2016). Lithium disilicate–reinforced glass-ceramic implant abutments can be fabricated by bonding the abutment to a titanium base to support a glass-ceramic (lithium disilicate) crown, or they may be prepared as a one-piece abutment–crown complex containing an internal titanium base that is directly screwed into the implant. Additionally, some studies have evaluated the suitability of CAD/CAM resin-based composites as implant abutment and restorative materials, noting that their mechanical and esthetic behavior closely resembles that of dentin (Magne et al., 2011, 2013).

Temporary Implant Abutments

Various types of temporary implant abutments manufactured from titanium or resin are available. Some types of temporary implant abutments are screwed directly into the implant and allow the fabrication of a cement-retained provisional crown. Other designs feature a grooved surface to facilitate resin application and are connected to the implant by a central screw. In the anterior region, due to the position of the implant, the screw access hole is often located on the labial surface and therefore must be sealed with an appropriate restorative material (Byrne, 2014). As an alternative, temporary abutments made from PEEK material have also been introduced. These abutments are very easy to use chairside and, due to their white color, allow the fabrication of esthetic provisional restorations (Santing et al., 2012).

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Chapter 6

EPIDEMIOLOGY OF PERIODONTAL DISEASES

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Definition of Epidemiology and Objectives of Epidemiological Studies

Epidemiology is a scientific discipline that examines the distribution of diseases or health-related conditions within populations, investigates their causes, and evaluates the effects of these causes on such distributions. The findings obtained are applied to protect and promote public health and, consequently, are also utilized in clinical practice.

Epidemiological studies are conducted with the objectives of describing the natural course of diseases, determining their distribution within populations, preventing and controlling them, testing hypotheses through clinical applications, planning healthcare services, and evaluating their effectiveness. Within this framework, the necessity of interventions for diseases is identified; strategies for prevention and control, as well as diagnostic and therapeutic methods, are developed. Moreover, these methods are tested under scientifically controlled conditions, and their effectiveness is assessed. Data obtained regarding the distribution of treated and untreated diseases in the population, along with individuals' access to healthcare services, significantly contribute to the identification of service and workforce needs and to the shaping of health policies. (Gordis, 2009)

The examination of disease and health-related condition distributions constitutes *descriptive epidemiology*; the investigation of their causes is the focus of *analytic epidemiology*; and the determination of optimal diagnostic, therapeutic, and preventive approaches falls under *experimental epidemiology*. Ultimately, the outcomes of epidemiological studies contribute directly to the establishment of healthy individuals and healthy societies. The first step in epidemiological research is to determine disease prevalence, severity, and the demographic and socioeconomic characteristics of the affected population groups.

Prevalence = *(Number of diseased individuals / Total number of individuals)*	• It is defined as the proportion of individuals affected by the disease under investigation to the total population within a specific community and at a given point in time. • Factors influencing prevalence include variations in the duration of the disease, incidence rate, mortality rate, population migration, and advancements in diagnostic methods.
Incidence = *(Number of new cases / Number of individuals at risk)*	• Also defined as risk or cumulative incidence, it is calculated by dividing the number of new cases that occur within a specified time period by the number of individuals at risk in the population. • Prevalence and incidence data are fundamental epidemiological measures used to assess the frequency and rate of occurrence of a health problem within a population. These measures also play a crucial role in understanding the nature of the disease and its etiological factors. (Newman, Takei, & Carranza, 2002; Wilson & Kornman, 2004)

Potential Errors in Research

Ensuring accurate measurement is of critical importance in epidemiological research. Nevertheless, various types of errors may adversely affect the validity of a study.

1. **Random Error:** Random error refers to deviations of measurement results in a sample from the true values of the population due to chance. Such errors can be minimized by employing precise measurement techniques and increasing sample size.

2. **Sample Size Calculations:** The accuracy of a study increases when the groups being compared are relatively adequate in size. Determining sample size requires consideration of several factors, including the magnitude of the effect under investigation, the number of patients within the population, the expected outcome, the desired level of statistical significance, and the acceptable probability of missing the true effect.

3. **Systematic Error (Bias):** Systematic error occurs when measurements consistently deviate from the true values, leading to biased results. Major types of systematic error include:

    - Selection bias
    - Measurement or classification bias
    - Confounding: the presence of another factor influencing the risk apart from the factor under investigation
    - Issues related to test validity

4. **Ethical Considerations:** Biomedical ethical principles constitute the foundation of epidemiological research. All studies must be reviewed and approved by authorized ethics committees prior to implementation.

Study Validity

An epidemiological study is considered valid when random errors are absent and systematic errors are minimized to the greatest extent possible. (Beaglehole, Bonita & Kjellström, 1997)

Test Validity and Related Concepts

The validity of a test refers to its ability to accurately measure the condition it is intended to assess. Test sensitivity and specificity directly influence both its reliability and validity.

- Sensitivity is the probability that the test will yield a positive (+) result in individuals who actually have the disease.
- Specificity is the probability that the test will yield a negative (–) result in individuals who do not have the disease.
- Increasing sensitivity raises the false-positive rate and reduces specificity, whereas increasing specificity raises the false-negative rate and reduces sensitivity. Therefore, when evaluating the practical utility of tests, the positive predictive value (PPV) and negative predictive value (NPV) should also be considered.
- PPV represents the probability that an individual with a positive (+) test result truly has the disease.
- NPV represents the probability that an individual with a negative (–) test result is truly disease-free.

It should be noted that in clinical research, variations in disease prevalence may exert a greater influence on PPV and NPV than test sensitivity or specificity. For instance, a decrease in disease prevalence will lower the positive predictive value of the test. (Beaglehole, Bonita & Kjellström, 1997)

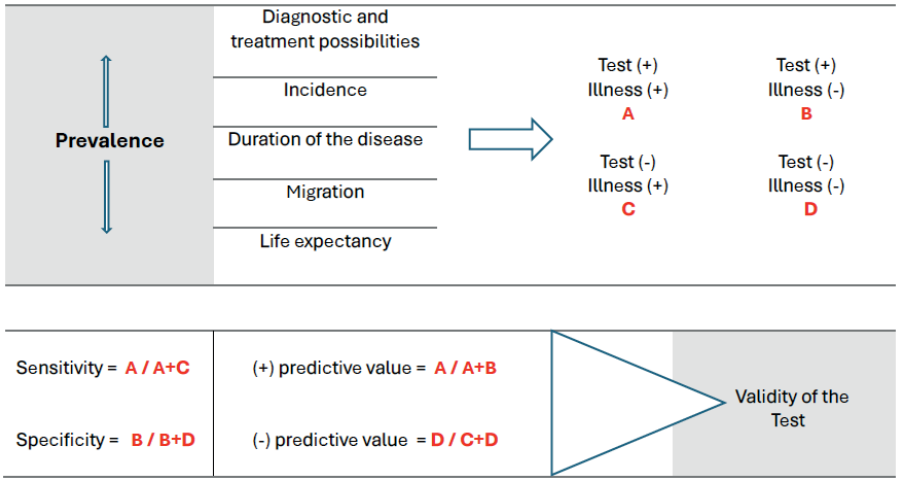

Table 1. *Validity of a Test*

Types of Studies

Health-related research can generally be classified into observational studies, experimental studies, and meta-analyses. The majority of studies conducted in the field of epidemiology are observational in nature. Within this category, the most frequently employed methods are cross-sectional studies, cohort studies, and case-control studies. Experimental studies, on the other hand, are primarily designed to evaluate the effectiveness of

preventive approaches and therapeutic interventions. (Newman, Takei & Carranza, 2002) Meta-analyses synthesize the findings of existing studies in a systematic manner, thereby allowing for a comprehensive evaluation and contributing substantially to the generation of generalizable conclusions. (Dawson & Trapp, 2001)

Cross-Sectional Studies

Cross-sectional studies are investigations in which the presence or absence of a disease, together with the characteristics of individuals within a population, are assessed simultaneously at a given point in time. In such studies, both exposure to a risk factor and the resulting health outcomes are measured concurrently. They are commonly employed for the following purposes:

- Determining the prevalence of a disease
- Comparing the characteristics of affected and unaffected individuals
- Developing hypotheses regarding the etiology of a disease

When repeated at regular intervals, cross-sectional studies contribute to monitoring disease progression and evaluating the effectiveness of preventive programs. Compared to long-term prospective studies, they offer advantages in terms of cost-effectiveness and feasibility. However, because the at-risk population is not followed over time, incidence cannot be calculated. As a result, it is difficult to establish causality from the associations observed in cross-sectional studies. (Newman, Takei & Carranza, 2002)

1. Cohort Studies

The primary aim of cohort studies is to determine whether a specific factor or characteristic is associated with the occurrence of a disease. At the outset of the study, all participants must be disease-free. For this reason, cohort studies are also referred to as prospective studies or incidence studies. Participants are classified into two groups based on their exposure status to the factor under investigation and are followed over a defined period to assess disease development. (Table 2)

This method enables the identification of new cases and the calculation of incidence rates. However, the requirement for long-term follow-up and the high cost of implementation are notable disadvantages. (Newman, Takei & Carranza, 2002) In cohort studies, the strength of the association between exposure and disease is typically evaluated using relative risk (RR) or odds ratio (OR), according to the following calculation formula:

$$OR = \frac{a/b}{c/d} = \frac{a \cdot d}{b \cdot c}$$

Figure 1. *(Gordis, 2009)*

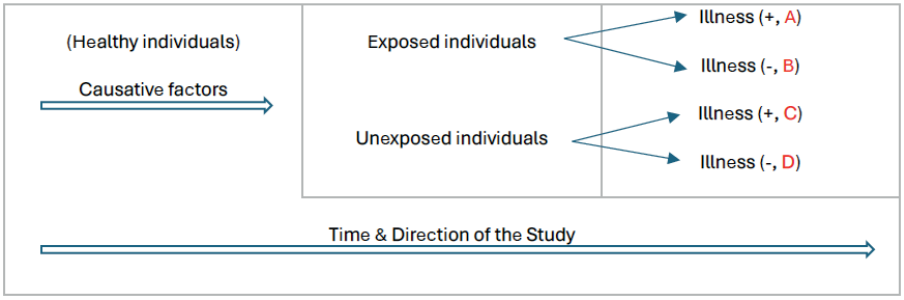

Table 2. *Cohort Study Design*

2. Case - Control Studies

Case - control studies are among the effective research methods used to examine the relationship between a specific factor and a disease, and they are generally conducted with a retrospective design. In this study type, individuals with the disease (case group) are compared with individuals without the disease (control group) in terms of exposure to a particular factor that is presumed to be associated with the disease. (Table 3)

When forming the groups, it is essential to ensure that cases and controls are as similar as possible with respect to demographic, environmental, and clinical characteristics. In case-control studies, the temporal relationship between exposure and disease onset cannot be fully established; moreover, disease prevalence or incidence cannot be directly determined using this design. (Dawson & Trapp, 2001)

In this design, relative risk (RR) cannot be directly calculated. However, in situations where the disease risk is low, the odds ratio (OR) can be used as an approximate indicator of relative risk. The OR is calculated using the following formula:

$$OR = \frac{a/c}{b/d} = \frac{a \cdot d}{b \cdot c}$$

Figure 2. *(Gordis, 2009)*

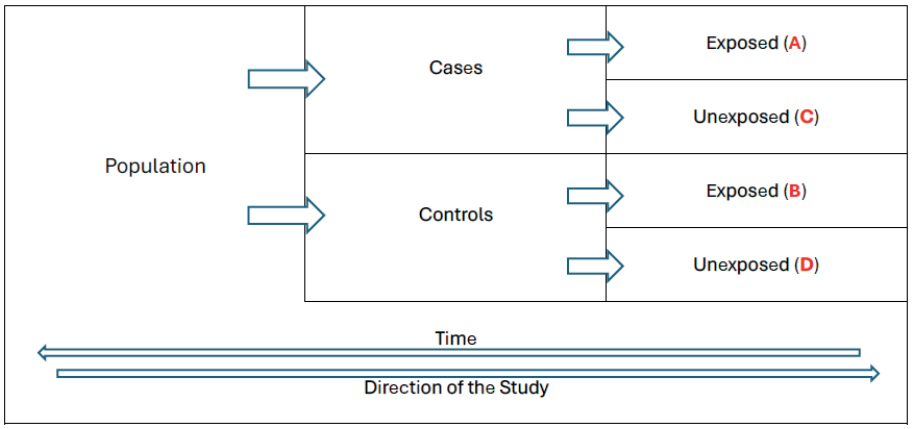

Table 3. *Case - control study design*

3. Randomized Controlled Trials (RCTs)

Randomized Controlled Trials (RCTs) are epidemiological research designs conducted to evaluate the effectiveness of a specific treatment method or intervention. These studies are based on the principle of randomly (through randomization) allocating participants into two or more groups, typically an intervention (treatment) group and a control group. (Table 4)

RCTs are regarded as the *gold standard* for determining the effectiveness of treatments, preventive strategies, and other health-related interventions in both clinical practice and public health. Randomization ensures that both known and unknown confounding variables are distributed equally across groups, thereby minimizing the risk of bias.

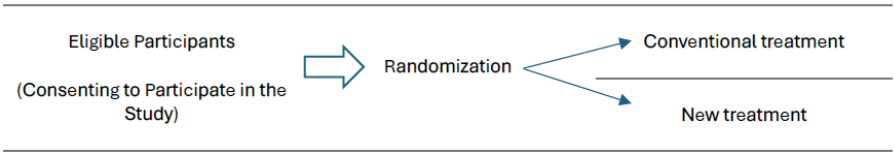

Table 4. *Randomized controlled study design*

Ethical Considerations in Randomized Controlled Trials

In Randomized Controlled Trials (RCTs), the potential ethical issues arising from random allocation constitute an important area of debate. One of the most frequently discussed topics, particularly in drug evaluation studies, is whether the use of placebo is ethically acceptable. Another critical issue concerns whether genuine and informed consent has been appropriately obtained from participants. (Gordis, 2009)

Indices Used in the Evaluation of Periodontal Conditions

Several factors complicate the epidemiological assessment of periodontal diseases:

1. **Chronic nature of periodontal diseases:** Their widespread occurrence in the population and the influence of socio-cultural risk factors associated with the disease make epidemiological investigation challenging.

2. **Increased life expectancy:** Early signs of the disease may appear in childhood and manifest at different stages throughout life. Lifestyle changes, migration, and intervening treatments often disrupt long-term data collection.

3. **Limitations of prevalence and severity data:** Prevalence alone is insufficient to fully demonstrate the impact of the disease on the population and its etiological factors. For this reason, indices have been developed to measure pathological changes at the individual level.

4. **Disease heterogeneity:** The etiological and clinical diversity of gingival and periodontal diseases complicates the assessment of fundamental differences at the population level.

5. **Lack of pathognomonic features:** Variability in the severity of periodontal signs prevents the general status of a population from being determined through a single pathological measure.

6. **Difficulties in determining disease activity:** There is no simple and reliable method available to identify the level of disease activity.

7. **Multifactorial etiology:** Although bacteria are the primary etiological agents, genetic, local, and systemic factors must also be taken into account in prevalence studies. (Gökalp & Doğan, 2006)

In the diagnosis of gingival and periodontal diseases, various indices are employed at both the individual and population levels to numerically express disease prevalence and severity. These indices are classified according to their ability to measure the degree of gingival inflammation, periodontal health, extent of tissue destruction, and the amount of calculus/deposits present. Moreover, in oral implantology, similar indices are also used to evaluate peri-implant health. (Tunalı, 1994)

Indices for Measuring the Degree of Inflammation in Gingival Tissues

Gingival Index (GI) (Löe & Silness, 1963)	**0**	*Presence of healthy gingiva*
	1	*Mild inflammation* *Slight change in color and mild edema* *Bleeding on probing (BOP) --*
	2	*Moderate inflammation* *Redness and edema* *Bleeding on probing (BOP) +*
	3	*Severe inflammation* *Pronounced redness and edema* *Ulcerations and tendency for spontaneous bleeding*
*** It is a widely used clinical index for assessing gingival inflammation. Tooth-specific gingival scores are obtained by summing the gingival index scores in each area and dividing by four, while patient-specific gingival scores are calculated by summing these values and dividing by the number of teeth. ***		

Modified Gingival Index (Lobene et al., 1986)	**0**	*Presence of healthy gingiva*
	1	*Mild inflammation* *Slight color change* *Mild edema*
	2	*Mild inflammation affecting the entire gingival unit*
	3	*Moderate inflammation* *Gingiva is shiny, red, and edematous* *Hypertrophy of the marginal or papillary gingival unit*
	4	*Severe inflammation* *Pronounced redness and edema of the gingiva* *Hypertrophy of the marginal or papillary gingival unit, spontaneous bleeding, and ulcerations*
*** It is an index used to assess gingival inflammation and bleeding without probing. Two marginal gingival sites and two papillary sites per tooth are evaluated. Tooth-specific scores are summed and divided by the number of teeth to obtain the patient-specific Modified Gingival Index score. ***		

Gingival Sulcus Bleeding Index (Mühlemann & Son, 1971)	**0**	*Visible change in the marginal and papillary gingival areas –* *Bleeding on probing (BOP) --*
	1	*Visible changes in the marginal and papillary gingival areas—* *Bleeding on probing (BOP) +*
	2	*Edema was observed in the marginal and papillary gingival areas --* *Slight color change* *Bleeding on probing (BOP) +*
	3	*Color change and edema of the gingiva* *Bleeding on probing (BOP) +*
	4	*Color change and pronounced edema of the gingiva* *Bleeding on probing (BOP) +*
	5	*Bleeding on probing (BOP) +* *Pronounced color change and edema* *Trend for spontaneous bleeding*
*** In this index, the marginal and papillary gingival areas are first visually examined, followed by probing of the sulcus. ***		

Gingival Bleeding Index

The Gingival Bleeding Index is a clinical assessment method that provides information about an individual's plaque control status. Following gentle probing within the gingival sulcus, the presence of bleeding is observed. A positive score is recorded if bleeding occurs within 10 seconds after probing. The results are expressed as a percentage, representing the proportion of sites exhibiting bleeding relative to the total number of teeth examined.

Gingival Bleeding Time Index (Nowicki, Vogel, Melcer & Deasy, 1981)	**0**	*Bleeding observed 15 seconds after the second stimulation --*
	1	*Bleeding occurring within 6 - 15 seconds after the second stimulation +*
	2	*Bleeding occurring within 11 - 15 seconds after the first stimulation or within 5 seconds after the second stimulation +*
	3	*Bleeding occurring within the first 10 seconds after the first stimulation +*
	4	*Spontaneous bleeding*
**** In this index, a periodontal probe is gently moved within the sulcus until slight resistance is felt, and bleeding after probing is assessed. If no bleeding occurs within 15 seconds, the procedure is repeated and an additional 15 seconds are observed. ****		

Periodontal Disease Index

This index is based on the assessment of the Ramfjord teeth (16, 21, 24, 44, 41, and 36), which are considered representative of the overall oral condition. If any of the Ramfjord teeth are missing, a functionally and morphologically equivalent tooth is selected as a replacement. If the gingival sulcus base is located apical to the cementoenamel junction, the gingival condition is not assessed, and scoring begins from 4. (Ramfjord, 1967)

Gingival Component	**1**	*İnflammation --*
	2	*Mild inflammation*
	3	*Pronounced redness, swelling, and tendency for bleeding* *Severe inflammation characterized by ulcerations*
Periodontal Component	**4**	*The base of the pocket is located apical to the cementoenamel junction (CEJ)* *Pocket depth < 3 mm*
	5	*The base of the periodontal pocket is located apical to the cementoenamel junction (CEJ)* *Pocket depth 3 - 6 mm*
	6	*The base of the pocket is located apical to the cementoenamel junction (CEJ)* *Pocket depth > 6mm*

Indices Measuring the Amount of Calculus/Deposits

Plaque Index (Silness & Löe, 1964)	**0**	*Dental plaque --*
	1	*Dental plaque in the form of a film adhering to the free gingival margin or the tooth-adjacent area +*
	2	*Visible accumulation of dental plaque in the gingival sulcus, along the gingival margin, and on adjacent tooth surfaces +*
	3	*Heavy accumulation of dental plaque in the gingival sulcus, along the gingival margin, and on adjacent tooth surfaces +*
**** It is an index used to assess dental plaque. Evaluation is performed by moving a periodontal probe within the sulcus and along the tooth surface. The use of disclosing solutions facilitates the assessment of dental plaque. ****		

Modified Quigley-Hein Plaque Index (Turesky, Gilmore & Glickman, 1970)	**0**	*Dental plaque --*
	1	*Islands of dental plaque on the tooth surface and along the gingival margin*
	2	*A thin, continuous dental plaque band ≤ 1 mm along the tooth surface and gingival margin*
	3	*Dental plaque accumulation extending > 1 mm from the gingival margin, covering less than one-third of the tooth surface*
	4	*Dental plaque accumulation extending > 1 mm from the gingival margin, covering less than two-thirds of the tooth surface*
	5	*Dental plaque accumulation on more than two-thirds of the tooth surface*

Simplified Oral Hygiene Index (OHI-S)

In this index, debris and calculus are assessed on the facial surfaces of teeth 16, 26, and 11, the lingual surfaces of teeth 46 and 36, and the facial surface of tooth 31. (Greene & Vermillion, 1964)

Evaluation of Debris	**0**	*Debris and discoloration --*
	1	*Less than one-third of the tooth surface with debris or staining in the absence of debris +*
	2	*Debris accumulation on one-third to two-thirds of the tooth surface*
	3	*Debris accumulation on more than two-thirds of the tooth surface +*

Evaluation of Calculus	**0**	*Dental calculus --*
	1	*Calculus accumulation on less than one-third of the tooth surface*
	2	*Accumulation of supragingival calculus on one-third to two-thirds of the tooth surface, or localized subgingival calculus at the cervical region of the tooth*
	3	*Accumulation of supragingival calculus on more than two-thirds of the tooth surface, or band-shaped subgingival calculus at the cervical region of the tooth*
**** Scores for each component are summed and divided by the number of tooth surfaces examined to obtain an individual score;* *0.0 – 1.2 :: Clinically good 1.3 – 3.0 :: Clinically fair 3.1 – 6.0 :: Clinically poor ****		

Calculus Index (Tunalı, 1994)	**0**	*Dental calculus --*
	1	*Small amount of supragingival calculus at the free gingival margin +*
	2	*Moderate amount of supra- and subgingival calculus, or subgingival calculus alone +*
	3	*Heavy accumulation of supra- and subgingival calculus*

Indices Used in Oral Implantology

Modified Plaque Index (Mombelli, van Oosten, Schurch & Lang, 1987)	**0**	*Plaque accumulation at the implant neck --*
	1	*Presence of plaque when a probe is passed along the smooth marginal surface of the implant*
	2	*Plaque visible to the naked eye*
	3	*Presence of abundant soft deposits*

Modified Gingival Crevicular Bleeding Index (Mombelli, van Oosten, Schurch & Lang, 1987)	**0**	*Bleeding on probing at the implant gingival margin --*
	1	*Presence of discrete bleeding sites*
	2	*Presence of a continuous bleeding ring*
	3	*Profuse bleeding*

Mobility Index (Mombelli, van Oosten, Schurch & Lang, 1987)	**0**	*Mobility in any direction when a force of 1 N is applied --*
	1	*Minimal mobility ≤ 0.5 mm*
	2	*İmplant appears mobile*

Evaluation of Periodontal Health

The primary objective of periodontal health screenings is not only to determine the current level and distribution of attachment within the oral cavity but also to identify the relationship between the presence and extent of attachment loss and potential contributing factors. To achieve this, clinical parameters considered indicators of active inflammation - such as bleeding on probing, periodontal pocket depth, level of attachment loss, gingival margin position, dental plaque accumulation, tooth mobility, and furcation defects in molar regions - should be recorded at the initial examination and re-evaluated at regular intervals depending on the severity of the periodontal condition. These clinical assessments are critical not only for diagnosing the presence and severity of disease and establishing an appropriate treatment plan but also for monitoring post-treatment healing and the progression of tissue destruction.

To facilitate periodontal health screening and integrate it into routine clinical practice, various screening systems have been developed for dental professionals. The Community Periodontal Index of Treatment Needs (CPITN), developed by the World Health Organization (WHO), focuses on evaluating treatment needs rather than the periodontal condition itself.

(Ainamo et al., 1982) In CPITN assessment, the teeth are divided into six sextants: anterior, right posterior, and left posterior in both the maxilla and mandible. Each sextant is examined using a specially designed periodontal probe with a ball tip. For a sextant to be evaluated, it must contain at least one tooth that does not have an extraction indication. Sextants with only a single tooth are combined with an adjacent sextant for assessment. The score of each sextant is determined by the worst-affected tooth within that region. In epidemiological surveys, for rapid evaluation, only teeth 1, 6, and 7 in each half-jaw are examined.

The Periodontal Screening and Recording (PSR) system, designed exclusively for adult patients, similarly divides the dentition into six regions for evaluation. (Corbet, 1998) However, neither the CPITN nor the PSR system differentiates whether individuals have previously undergone periodontal treatment.

Code	---------- Periodontal Status ----------	---------- Treatment ----------
0	*Healthy periodontium*	--
1	*Bleeding on probing (BOP) +*	*O.H.M.*
2	*Clinically visible supra- and subgingival calculus*	*O.H.M. + professional dental prophylaxis*
3	*Pathological pocket of 4 - 5 mm*	
4	*Pathological pocket ≥ 6 mm*	*O.H.M. + complex treatment including professional dental prophylaxis*

Table 5. *Community Periodontal Treatment Needs Index (CPITN) (Oral Hygiene Motivation: O.H.M.)*

Code	---------- Periodontal Status ----------	----Treatment ------
0	*Probe's colored band fully exposed* *No bleeding on probing --* *Presence of calculus or poorly contoured restoration --*	*Scaling, polishing, and restorative procedures*
1	*Probe's colored band fully exposed* *Bleeding on probing +* *Presence of calculus or poorly contoured restoration --*	
2	*Probe's colored band partially exposed* *Presence of supra- and/or subgingival calculus +* *Poorly contoured restoration +*	
3	*Probe's colored band partially exposed* *Designation as CODE 1 or CODE 2*	*Comprehensive periodontal assessment and specialist consultation*
4	*Probe's colored band completely within the tissue*	
(*)	*Furcation defect* *Mobility* *Soft tissue defect* *Gingival recession reaching the probe's colored band*	

Table 6. *Periodontal Screening and Recording (PSR)*

Risk Factors in Periodontal Disease

Determining the etiology of diseases is crucial not only for developing preventive strategies but also for ensuring the accurate and effective treatment of diseases. Characteristics that increase an individual's likelihood of developing a disease are defined as risk factors. (Beck & Koch, 1995) In epidemiological studies, Hill's criteria for causal association are frequently used as a reference for identifying risk factors: (Muller, 2005)

- **Strength of association:** The degree of association between a disease and a factor, typically expressed as relative risk (RR).
- **Consistency:** The reproducibility of findings across different times, locations, research conditions, and investigators.
- **Specificity:** Whether the disease occurs as a result of exposure to a particular factor alone.
- **Temporality:** The presence of the risk factor prior to the onset of the disease.
- **Biological gradient:** Evidence of a dose-response relationship between the factor and the disease.
- **Plausibility:** The biological rationale supporting a causal relationship.
- **Coherence:** Consistency of the causal association with existing knowledge and literature.
- **Experiment:** The observed effect on disease when the risk factor is removed or its influence is reduced.
- **Analogy:** The causal association is consistent with previously established similar relationships.

Risk factors may be effective over a specific time period and can be episodic or continuous in nature. The elimination or reduction of a risk factor should decrease an individual's likelihood of developing the disease. However, if the individual has already developed the disease, removing the risk factor does not guarantee recovery. (Beck & Koch, 1995)

For a factor to be defined as a risk factor, exposure must precede the onset of the disease. In the literature, alternative terms related to risk factors are also used. For example, predisposing characteristics may sometimes replace the term non-modifiable risk factors. A risk indicator refers to a potential risk factor identified in cross-sectional studies but not yet confirmed by longitudinal studies, whereas a risk marker is associated with an increased risk of disease in both cross-sectional and longitudinal studies but does not cause the disease. (Newman, Takei, Klokkevold & Carranza, 2012)

Risk factors that increase the prevalence and severity of periodontal disease can be classified into two main groups: non-modifiable risk factors and environmental, acquired, or behavioral risk factors. (Table 7)

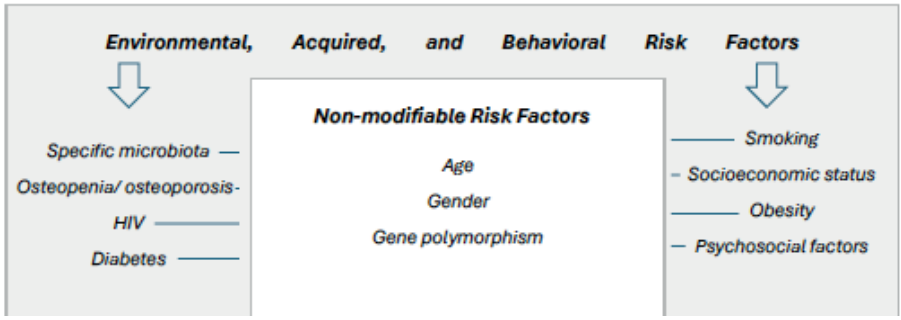

Table 7. *Risk factors for periodontal disease*

Non - Modifiable Risk Factors

Age: Currently, it is believed that prolonged exposure to risk factors with advancing age contributes to increased prevalence of periodontal disease and attachment loss in elderly individuals. (Papapanou et al., 1991) Additionally, chronic systemic conditions and medications commonly used by older adults are considered contributing risk factors for periodontal disease. (Wilson & Kornman, 2004) However, age-related changes in immune defense appear to be more limited than previously assumed. (McArthur, 1998) Assessment of systemic inflammatory response has shown increased C-reactive protein (CRP) levels in elderly individuals with active periodontitis. (Swoboda et al., 2008) Age-related nutritional changes may also serve as potential risk factors for periodontal disease progression; for example, low serum folate levels in older adults have been associated with greater severity of periodontitis. (Yu, Kuo & Lai, 2007) Poor plaque control and lack of effective periodontal treatment can accelerate disease progression with advancing age. (Papapanou et al., 1989) Nevertheless, elderly individuals with regular dental care and minimal attachment loss can also be encountered.

Gender: Males exhibit a higher risk of developing periodontal disease compared to females, even when factors such as oral hygiene practices and smoking are controlled. Following infection or trauma, males show higher levels of interleukin IL-1B and tumor necrosis factor (TNF-α) than females, paralleling sex-related differences in periodontitis. Gene regulation responsive to sex hormones may contribute to these gender differences in susceptibility (Shiau & Reynolds, 2010). Moreover, in males with periodontitis, nitric oxide levels have been correlated with CRP and serum lipid levels, suggesting a potential link between periodontal disease, sex, and increased cardiovascular risk. (Andrukhov et al., 2013)

Ethnicity and Genetic Polymorphisms: Periodontitis prevalence is higher in certain ethnic groups. These differences may result from socioeconomic status, occupation, education, access to healthcare, and cultural or environmental factors. (Hobdell et al., 2003) Some studies, however, have found that these variables do not significantly affect prevalence or severity of periodontal disease. (Craig et al., 2003) Genetically, specific genotypes may vary among ethnic groups; for instance, the IL-1 genotype has a lower prevalence in Chinese and Thai populations compared to European populations (Anusaksathien et al., 2003). The role of single nucleotide polymorphisms in influencing the periodontitis phenotype remains incompletely understood. (Borrell & Papapanou, 2005) Various studies have reported associations of IL-1B, IL-1RN, VDR, and TLR4 polymorphisms with aggressive periodontitis, and IL-1B, IL-1RN, IL-6, IL-10, VDR, CD14, TLR4, and matrix metalloproteinase-1 polymorphisms with susceptibility to chronic periodontitis. (Laine et al., 2012) Epigenetics, in the context of gene-environment-disease interactions, is an emerging field, wherein lifestyle and microbial exposure can influence an individual's genome and cellular phenotype. (Hirst & Marra, 2009)

Environmental, Acquired, and Behavioral Risk Factors

Socioeconomic Status: Low income and education levels, limited dental awareness, and inadequate access to preventive healthcare are associated with increased incidence of periodontal disease and dental caries. (Hobdell et al., 2003)

Specific Microbiota: Periodontitis is an infectious disease predominantly caused by Gram-negative bacteria. The composition of dental plaque is more important than its quantity in the pathogenesis of periodontal disease; however, factors promoting plaque accumulation should also be considered in treatment outcomes. Severe periodontal destruction can occur even with minimal plaque accumulation. Key etiologic agents include *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, and *Tannerella forsythia*, while other potential pathogens include *Campylobacter rectus*, *Eubacterium nodatum*, *Fusobacterium nucleatum*, *Prevotella intermedia*, *Peptostreptococcus micros*, *Streptococcus intermedius*, and *Treponema denticola*. (Borrell & Papapanou, 2005; Rylev & Kilian, 2008)

Smoking: Smoking has been positively associated with both the prevalence and severity of periodontal disease. Smokers have a 2.5 - 7-fold higher risk of periodontitis compared to non-smokers. (Salvi, 1997) A strong correlation exists between the number of cigarettes smoked and periodontal pocket depth. (Alpagot et al., 1996) Smoking reduces vascularity, impairs inflammatory response and wound healing, and limits response to periodontal therapy in active smokers. (Rezavandi et al., 2002; Borrell & Papapanou, 2005)

Diabetes: Diabetes is a major risk factor for increased susceptibility to periodontal disease. Diabetic individuals demonstrate higher prevalence and severity of periodontitis. (Newman, Takei & Carranza, 2002; Fıratlı, 1997) Metabolic control is critical in maintaining periodontal health; well-controlled diabetics show similar treatment outcomes to healthy individuals, whereas poorly controlled diabetics exhibit limited clinical improvement. (Tervonen et al., 1997; Stewart et al., 2001)

Obesity: Characterized by excessive and abnormal fat accumulation, obesity is associated with increased serum acute-phase proteins, pro-inflammatory cytokines, and leukocyte levels, leading to a subclinical inflammatory response. (Boesing et al., 2009) The association between obesity and periodontal disease has been linked to hyperinflammatory status, impaired lipid metabolism, and insulin resistance, with several studies reporting a positive correlation. (Borrell & Papapanou, 2005; Morita et al., 2011)

Osteopenia/Osteoporosis: Postmenopausal women with low bone mineral density have been reported to exhibit increased clinical attachment loss and gingival recession, although some studies do not support these findings. (Lunström et al., 2001; Öztürk et al., 2012)

HIV Infection: HIV and AIDS can increase the risk of periodontal disease, though long-term studies are limited. In HIV-positive individuals, CD4(+) cell counts below 200/mm^3 have been associated with more severe periodontal destruction. Highly active antiretroviral therapy (HAART) controlling immunosuppression can mitigate the severity of periodontal findings. (Riley, London & Burmeister, 1992; Borrell & Papapanou, 2005; Hofer et al., 2002)

Psychosocial Factors: The mechanisms by which psychosocial stress affects periodontal health are not fully elucidated. Stress may increase susceptibility to infection through behavioral changes or impaired immune response. (Borrell & Papapanou, 2005; Genco et al., 1998) Financial and psychological stress have been reported to elevate periodontal disease risk, although some studies found no significant association. (Genco et al., 1999; Aleksejuniene, 2002)

Epidemiology of Gingivitis

Gingivitis is simply defined as inflammation of the gingiva (Newman, Takei & Carranza, 2002) and, from a clinical perspective, requires assessment of gingival color, contour, consistency, position, bleeding, and pain. (Newman, Takei & Carranza, 2002) Gingivitis is closely associated with inadequate plaque control. Studies indicate that maintaining oral hygiene does not produce substantial changes in gingivitis prevalence among young and middle-aged individuals.

Age, smoking, and genetic factors play significant roles in gingivitis development. With advancing age, a more pronounced inflammatory response to plaque is observed compared to younger individuals. (Fransson et al., 1999) The IL-1(+) genotype has been reported to increase the risk of gingival bleeding independently of smoking. (Lang et al., 2000) In a U.S. screening study, gingival bleeding prevalence was highest (63%) in the 13–17 age group, decreased between ages 35 - 44, increased again between 45 - 54, and remained stable in older age groups. (Newman, Takei & Carranza, 2002) Additionally, in areas without attachment loss, bleeding on probing prevalence decreased from 54% to 47%.

Adolescents exhibit higher gingivitis prevalence than prepubertal children and adults. While increased sex hormones during this period may influence gingivitis frequency, plaque control remains the more decisive factor. Similarly, pregnancy and oral contraceptive use have been associated with increased gingivitis prevalence. (Newman, Takei & Carranza, 2002) National U.S. surveys conducted between 1960-62 and 1985-86 demonstrated higher gingivitis and gingival bleeding prevalence in males compared to females, with young males exhibiting more affected sites. (Newman, Takei & Carranza, 2002)

Epidemiology of Periodontitis

Periodontitis is an inflammatory disease characterized by progressive loss of alveolar bone and periodontal ligament, accompanied by increased probing depth, gingival recession, or both, and is caused by specific microorganisms or microbial consortia. (Newman, Takei & Carranza, 2002) It is classified into three main forms: chronic periodontitis, aggressive periodontitis, and periodontitis associated with systemic diseases. (Armitage, 1999)

Epidemiology of Chronic Periodontitis

Chronic periodontitis is the most common form of the disease. (Fleming, 1999) Although primarily detected in adults, it can also be observed in childhood. (Newman, Takei & Carranza, 2012) In the U.S., between 1988 and 1994, attachment loss prevalence in individuals aged 30 years and older was 99% at a 1 mm threshold and 7% at a 7 mm threshold. Both attachment loss and pathological pocket depth were higher in males than females. Age-related increases in attachment loss prevalence were associated with cumulative loss and gingival recession, while pocket depth appeared age-independent. (Albandar et al., 1999)

In Turkey, CPITN data indicated that 22.5% of individuals aged 35 - 44 had 4 - 5 mm attachment loss, and 9% had ≥6 mm loss (Gökalp & Doğan, 2006). Comparable prevalence of pockets ≥4 mm in the same age group in other

countries were: China 14%, Zimbabwe and Australia 23–24%, Hungary 27%, U.S. 12%, and Germany–Canada 73–74%. (Dye, 2012) Chronic periodontitis is generally mild to moderate in severity, affecting 13–57% of populations, whereas more severe forms affect 10–25% of susceptible individuals. (Rylev & Kilian, 2008)

Epidemiology of Aggressive Periodontitis

Aggressive periodontitis differs from chronic periodontitis by rapid progression, familial history, low plaque and calculus accumulation, presence of specific microorganisms, and functional defects in defense cells. It can be localized or generalized. (Tonetti & Mombelli, 1999) Prevalence of localized aggressive periodontitis is below 1% in several countries. (Papapanou, 1996)

In the UK, a five-year study of individuals aged 14 - 19 showed that the proportion with >1 mm attachment loss increased from 3% to 77%, and >2 mm loss increased from 0% to 14% (Clerehugh et al., 1990). In Norway, 2767 14-year-olds were examined and 215 were re-evaluated after 8 years; individuals with initial bone loss in one or more sites had a prevalence of 3.5% at baseline, which doubled at follow-up. The proportion with loss in three or more sites increased from 2.5% to 33.3%. (Aass et al., 1994)

Aggressive periodontitis has been reported to show ethnic differences, with higher prevalence in Mediterranean and West African adolescents. In the U.S., localized aggressive periodontitis prevalence was 2.05% among African Americans and 0.14% among whites, while generalized aggressive periodontitis prevalence was 0.59% and 0.33%, respectively. (Löe, 1991)

Periodontal Disease as a Risk Factor for Systemic Conditions

It has been proposed that localized chronic infections can influence systemic health, with periodontal disease serving as a local model for such studies. (Amar & Han, 2003) Low-grade chronic inflammation may contribute to the development of a systemic inflammatory phenotype. In individuals with periodontitis, systemic inflammatory markers such as C-reactive protein (CRP), interleukin-6 (IL-6), haptoglobin, and fibrinogen are elevated. (Loos, 2005) Periodontal disease has been evaluated as a potential risk factor for increased morbidity and mortality in systemic conditions including cardiovascular diseases, pregnancy-related complications, and diabetes. (Loos, 2006) (Table 8)

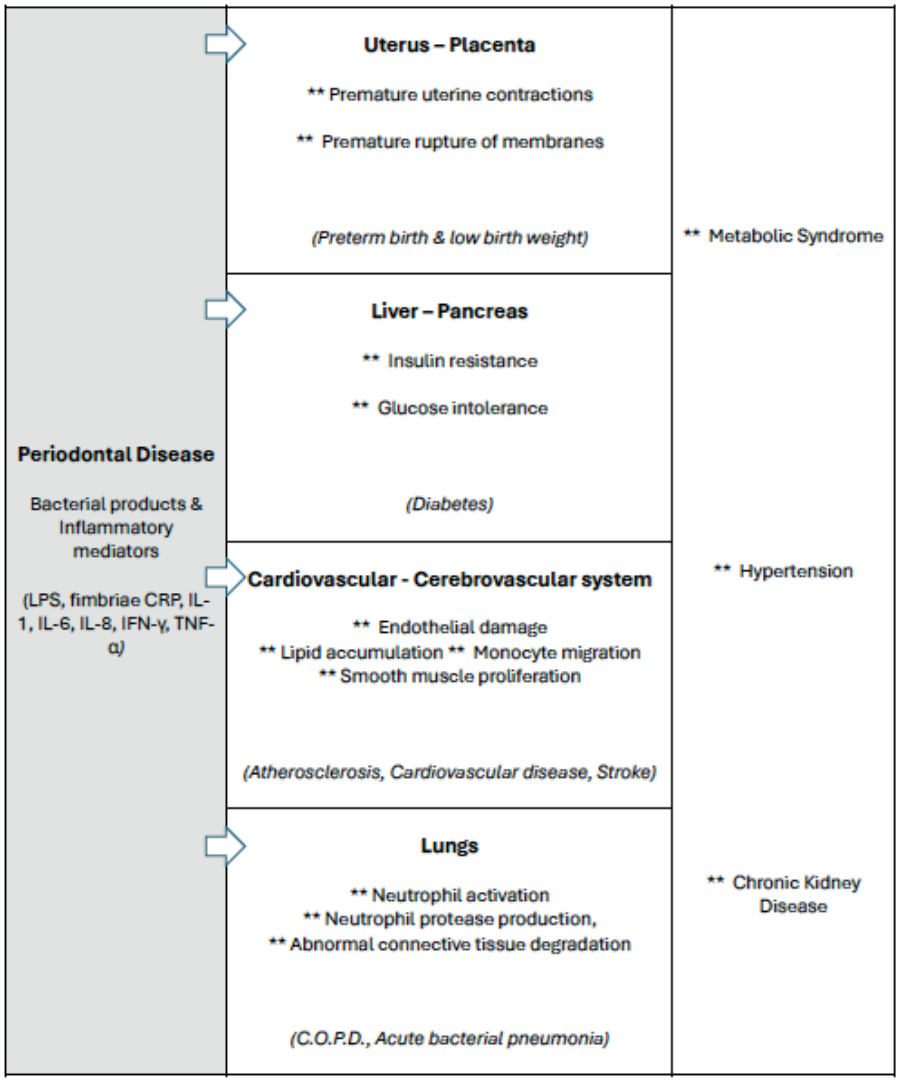

Table 8. *Periodontal disease as a risk factor in the development of systemic diseases (Chronic Obstructive Pulmonary Disease: C.O.P.D.)*

Preterm Birth and Low Birth Weight (LBW)

Preterm birth (gestational age <37 weeks) and/or low birth weight (<2500 g) are leading causes of neonatal mortality and morbidity. (Khader & Ta'ani, 2005) Associated risk factors include advanced or young maternal age, low socioeconomic status, inadequate prenatal care, substance abuse, alcohol and tobacco use, hypertension, diabetes, and multiple pregnancies. (Agueda et al., 2008) Nevertheless, LBW may still occur even when these risk factors are controlled.

Subclinical genitourinary and periodontal infections are believed to adversely affect pregnancy outcomes. (Marakoğlu et al., 2008) During pregnancy, subclinical infections can alter the Th1/Th2 lymphocyte ratio, and these cytokine changes have been linked to complications such as preterm birth and preeclampsia. Serum levels of IL-1β, IL-1β/IL-10 ratio, vascular endothelial growth factor, and its receptor 2 were found to be higher in periodontitis-affected mothers delivering preterm or low birth weight infants. (Sert et al., 2011) Improving periodontal health before or during pregnancy may reduce maternal and perinatal morbidity and mortality. (Marakoğlu et al., 2008)

Chronic Obstructive Pulmonary Disease (COPD)

COPD is a major global health concern, characterized by progressive and irreversible airway obstruction. (Calverley & Walker, 2003; Taylor, 2010) Poor oral hygiene and dental plaque are considered contributing factors to respiratory infections. (Scannapieco, 1999) The aspiration of oral pathogens and the effects of periodontal disease - associated enzymes and cytokines on the respiratory epithelium play significant roles in infection pathogenesis.

Individuals with chronic respiratory diseases have been reported to exhibit poorer oral hygiene compared to healthy controls. Systematic reviews support the association between poor oral hygiene and pneumonia. (Azarpazhooh & Leake, 2006) In intensive care settings, antiseptic mouth rinses or oral antibiotics can reduce pneumonia incidence. (DeRiso et al., 1996) Alveolar bone loss, gingival bleeding, and tooth loss are associated with COPD severity, with average attachment loss <3 mm considered an independent risk factor. (Scannapieco, 2001; Si et al., 2012)

Diabetes Mellitus and Periodontal Disease

Periodontal disease is considered a complication of diabetes. (Löe, 1993) Diabetic individuals exhibit increased prevalence, extent, and severity of periodontal disease. (Mealey & Rethman, 2003) Advanced glycation end-products, oxidative stress, matrix metalloproteinase activity, and impaired endothelial function contribute to periodontal destruction.

Periodontitis increases inflammatory and platelet mediator levels, contributing to insulin resistance. In periodontitis-affected diabetic patients, elevated serum inflammatory mediators complicate metabolic control. (Nassar, Kantarcı & van Dyke, 2007) Well-controlled diabetic patients respond to periodontal therapy similarly to healthy individuals, whereas poorly controlled patients exhibit limited improvements. (Tervonen & Karjalainen, 1997) Mechanical periodontal therapy and/or systemic antibiotics can positively influence glycemic control (Kıran et al., 2005), supporting a

bidirectional relationship between diabetes and periodontal disease. (Kuo, Polson & Kang, 2008)

Chronic Kidney Disease (CKD)

CKD is associated with cardiovascular diseases, end-stage renal failure, and premature mortality. Risk factors include; age >60 years, hypertension, diabetes, obesity, macroalbuminuria, smoking, elevated CRP, hyperlipidemia, sex, ethnicity, low income, and limited access to education/health services. (Feldman et al., 2003) In end-stage CKD patients, periodontitis severity correlates with age, smoking, diabetes, reduced serum albumin, increased BUN, and CRP (Chen et al., 2006). Individuals with periodontitis have a fourfold higher risk of CKD. (Fisher et al., 2008) Subgingival scaling and periodontal flap therapy have been reported to reduce CKD risk.

Cardiovascular Diseases (CVD)

CVDs, including congestive heart failure, arrhythmias, coronary artery disease, and stroke, account for approximately 29% of deaths. (Ross, 1999) Periodontitis may contribute to atherogenesis and endothelial dysfunction through transient bacteremia, endotoxemia, and increased production of pro-inflammatory cytokines (TNF-α, IL-1β, IL-6, PGE2, CRP). (Robbesyn et al., 2004; Kleeman, 2008) Despite genetic factors, smoking, diabetes, and stress, periodontal treatment can improve endothelial function and reduce CVD risk. (Tonetti et al., 2007; Bokhari et al., 2012)

Hypertension

Hypertension is a chronic vascular disease resulting from genetic, physiological, environmental, and psychological interactions. Low-grade chronic systemic inflammation may serve as an independent risk factor for hypertension. The relationship between periodontitis and hypertension is mediated through inflammatory markers such as CRP and IL-6, as well as endothelial dysfunction. (Boos & Lip, 2006; Vidal et al., 2011)

Hyperlipidemia

Hyperlipidemia is characterized by elevated plasma lipid levels, including cholesterol and triglycerides. (Bhatnagar, Soran & Durrington, 2008) Pro-inflammatory cytokines (TNF-α, IL-1β) influence lipid metabolism, increasing LDL, decreasing HDL, and promoting hypertriglyceridemia. (Chu et al., 1999; Robbesyn, Salvayre & Negre-Salvayre, 2004) Periodontal disease is positively associated with plasma lipid levels. Periodontal therapy can improve lipid parameters and inflammatory responses, thereby supporting metabolic control. (Awartani & Adassi, 2010; Fentoğlu et al., 2012)

Metabolic Syndrome (MetS)

MetS is an endocrinopathy characterized by abdominal obesity, insulin resistance, glucose intolerance, dyslipidemia, hypertension, and coronary artery disease. (Dandona et al., 2005) Individuals with MetS have increased risk of periodontal disease, and this risk rises with the number of metabolic components. (Morita et al., 2009; Han et al., 2010) Periodontal therapy reduces serum CRP, leukocyte, and triglyceride levels, while increasing HDL, providing cardioprotective effects. (Acharya et al., 2010)

Potential Future Research

Prevention is a primary objective in chronic diseases, preceding treatment. Prevention programs should be well-organized, goal-oriented, implemented, evaluated, and continuously improved based on public health systems. (Gjermo, 2005) Increasing oral health awareness in the population is crucial, as even small improvements in hygiene can significantly impact periodontal health data. Prevention programs and campaigns target a limited number of causative factors, but collectively can reduce disease prevalence.

Over the past 50 years, prevention programs and campaigns in developed countries have contributed to improvements in gingivitis and mild-to-moderate periodontitis data. (Gjermo, 2005) However, in developing countries and some developed regions, oral health often lacks sufficient priority, and effective periodontal care programs remain limited. (Kandelman et al., 2012) A lack of clear population-level periodontal data complicates understanding the effects of risk factors. Large-scale epidemiological studies evaluating both attachment loss and pocket depth provide more accurate data. The relationship between periodontitis and systemic diseases, as well as the clarification of associated risk factors, can be established through well-designed observational studies. (Dye, 2012)

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Chapter 7

ORAL SQUAMOUS PAPILLOMA: CASE REPORT

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Introduction

Oral squamous papilloma (OSP) is a benign epithelial growth that develops from the stratified squamous lining of the oral mucosa and is characterized by small, finger like surface projections (Carneiro et al., 2009; Bao et al., 2012). Clinically, it usually appears as a small sessile or pedunculated mass often less than 1 cm pinkish to white in color and slowly enlarging (Abbey, Page & Sawyer, 1980; Sahoo et al., 2020). The lesion often has a cauliflower like surface and is generally asymptomatic.

Microscopically, OSP shows papillary projections formed by acanthotic squamous epithelium supported by thin fibrovascular cores (Betz, 2019). Surface hyperkeratosis or parakeratosis may be present, and koilocytosis can sometimes be seen in the upper spinous layers. These features help differentiate OSP from other papillary lesions including verruca vulgaris, condyloma acuminatum, and multifocal epithelial hyperplasia which may present with similar clinical appearances (Carneiro et al., 2009).

Low risk human papillomavirus (HPV) types are known to play a key role in the development of OSP. In most cases, HPV-6 and HPV-11 are detected (Betz, 2019; Kaminagakura et al., 2012). Because the E6 and E7 proteins of these low risk subtypes have minimal impact on tumor suppressor pathways such as p53 and pRb, the malignant potential of OSP remains extremely low (Benyo et al., 2021). However, HPV DNA is not always detectable, so identifying the virus is not required for diagnosis (Bao et al., 2012).

Histopathological examination remains the primary diagnostic method. Molecular tests such as PCR or in situ hybridization may assist in selected cases. Nevertheless, p16 immunostaining commonly used for high risk HPV lesions has limited usefulness for OSP because low risk HPV types typically do not produce strong p16 expression (Kaminagakura et al., 2012).

Epidemiological data show that OSP has preferred intraoral sites. It occurs most frequently on the dorsal tongue, the junction of the hard and soft palate, the uvula, and the labial mucosa (Abbey et al., 1980; Bao et al., 2012). Repetitive trauma or chronic irritation in these areas may cause microinjury to the epithelium, making viral entry more likely.

In the general population, oral HPV infections are relatively uncommon. Meta analyses estimate that overall oral HPV prevalence is around 7–8% for all types, with high risk HPV-16 showing a prevalence close to 1% (Tam et al., 2018; Di Spirito et al., 2023). The predominance of low risk HPV types in the oral cavity supports their role in the development of OSP.

Clinically, many OSP lesions are discovered incidentally during routine examination. Local irritants such as prosthetic trauma, tooth contacts, or habitual cheek and tongue biting—may draw attention to the lesion (Carneiro et al., 2009). When explaining the diagnosis, it is important to emphasize the benign nature of OSP, its well circumscribed borders, and the absence of invasive features.

The treatment of choice is simple surgical excision. Removing the entire lesion provides both tissue for diagnosis and complete resolution. Current studies show that conventional excision, CO_2 laser, and Er,Cr:YSGG laser approaches all have similar outcomes, with recurrence being rare (Toledano-Serrabona et al., 2019). Overall, OSP carries an excellent prognosis when excised with adequate margins.

Case Report

A 58 year old man presented with a papillomatous lesion on the palatal mucosa of the maxilla that had been present for nearly four to five years. He mentioned having a similar growth in the same region about twenty years earlier, which had regressed on its own and caused no problems for many years. The patient reported no systemic illnesses and no history of alcohol use. He stated that the lesion had slowly increased in size over recent years but had never caused pain, bleeding, or any functional discomfort.

Intraoral examination showed a well defined, pedunculated mass with a pinkish white color and a cauliflower like surface on the palatal mucosa. On palpation, the lesion felt soft and elastic, was easily movable, and was not tender (Figure 1). Radiographic assessment revealed no associated pathological changes (Figure 2). Based on its clinical appearance, the lesion was considered benign, and complete excision was planned for diagnostic and therapeutic purposes.

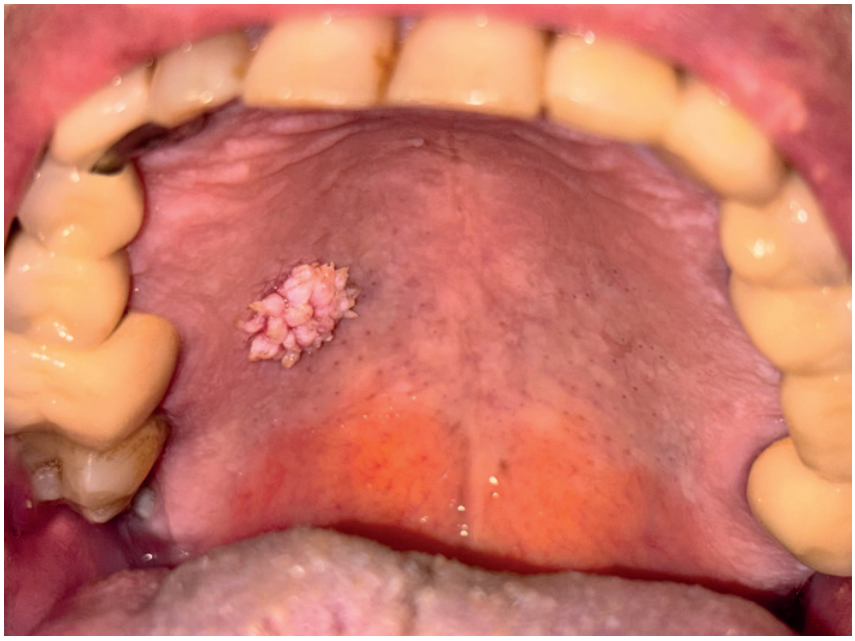

Figure 1. *Intraoral view of the patient*

The surgical procedure was conducted under local anesthesia. The lesion was distinctly delineated from the adjacent tissues and excised in its entirety from the base (Figure 2). Primary closure of the surgical site was achieved, and postoperative management included analgesic therapy and antiseptic mouth rinses.

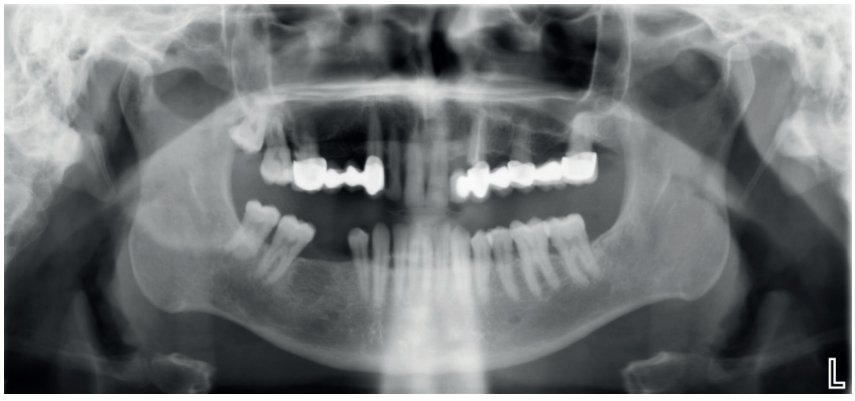

Figure 2. *Orthopantomographic radiograph of the patient*

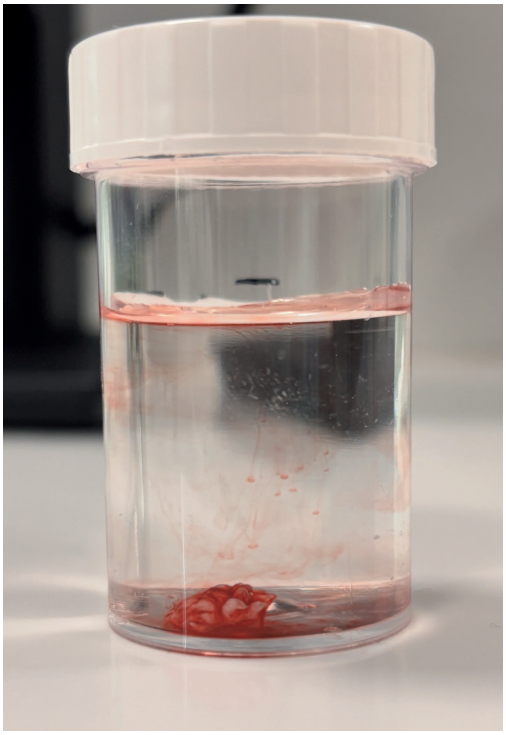

Figure 3. *Excised pathological specimen from the patient*

On gross examination, the specimen consisted of a pedunculated lesion measuring about 0.9 × 0.5 × 0.3 cm, showing several small, finger like projections on its surface.

Microscopically, the surface epithelium formed clear papillomatous extensions, with areas of irregular acanthosis and pronounced hyperparakeratosis. Between the papillary projections, thin fibrovascular cores were present, containing multiple small blood vessels.

The stratified squamous epithelium showed koilocytotic changes in the superficial layers. Importantly, the basal and parabasal layers displayed no signs of atypia or invasive behavior. The underlying stroma showed only minimal inflammatory cell infiltration.

Overall, these histological features matched the typical structural pattern of oral squamous papilloma (OSP). When combined with the clinical findings, the diagnosis of OSP was confirmed. Postoperative healing was smooth, and no recurrence or early complications were noted during follow up.

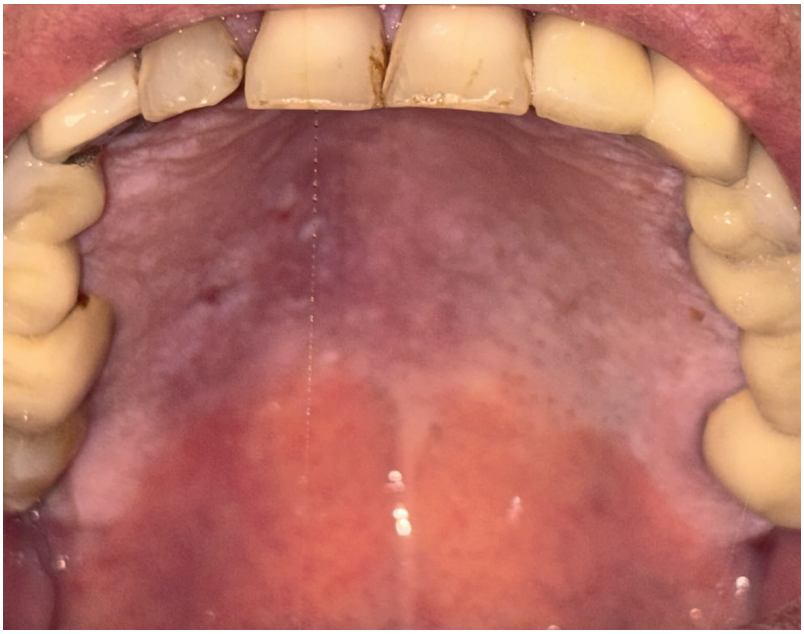

Figure 4. *Postoperative intraoral appearance of the patient at six month follow up The clinical and histopathological findings were in complete accordance with the typical OSP cases described in the literature (Abbey et al., 1980; Carneiro et al., 2009; Betz, 2019).*

Discussion and Conclusion

Oral squamous papilloma (OSP) is among the most common benign epithelial lesions of the oral cavity and is defined histologically by papillary squamous projections supported by thin fibrovascular cores (Betz, 2019). Clinically, OSP tends to be a small, slow growing, and well circumscribed mass that is usually asymptomatic. It most frequently appears on areas of the mouth that are more exposed to repeated irritation such as the dorsal tongue, the junction of the soft and hard palate, the uvula, and the labial mucosa (Abbey et al., 1980; Carneiro et al., 2009).

The development of OSP is strongly associated with low risk Human Papillomavirus (HPV) infections, particularly HPV types 6 and 11 (Betz, 2019). After viral entry, the E6 and E7 proteins from these HPV types interact with p53 and pRb, but their effects are limited compared with high risk strains. As a result, OSP retains a benign biological behavior, with an extremely low likelihood of malignant transformation (Betz, 2019; Carneiro et al., 2009). This is an important distinction separating OSP from other HPV related lesions in the oral mucosa.

On microscopic evaluation, OSP usually shows elongated finger like papillary projections, marked acanthosis, hyperkeratosis, and superficial koilocytotic changes. The basal layer remains orderly, without signs of atypia or invasion one of the most reliable indicators of its benign nature (Carneiro et al., 2009). In the present case, these classical histopathological findings allowed a straightforward diagnosis.

From a clinical standpoint, OSP lesions are often picked up incidentally during routine dental checks. Chronic irritation from habits, dental appliances, or local trauma may contribute either to their formation or to late recurrences (Abbey et al., 1980). In this patient, the recurrence of a similar lesion at the same site years later raises the possibility of latent HPV infection or reactivation triggered by local trauma. Previous studies have documented that OSP can reappear after long intervals, possibly due to the persistence of viral DNA within deeper epithelial layers (Toledano-Serrabona et al., 2019).

Surgical excision remains the preferred treatment because it provides both diagnostic tissue and complete removal. Unlike laser or cryotherapy, conventional excision avoids thermal artifacts, making histopathological interpretation more reliable (Betz, 2019). Recurrence reported in the literature typically ranges from 4% to 6%, and incomplete removal is often cited as the main risk factor (Toledano-Serrabona et al., 2019). In the present case, the absence of recurrence during follow up is consistent with these findings and reflects the effectiveness of complete excision.

Overall, oral squamous papilloma is a benign epithelial lesion with distinct histological features, a low recurrence rate, and an excellent prognosis. Diagnosis is best established by correlating clinical characteristics with histopathological evaluation. Although OSP is associated with HPV infection, the predominance of low risk types ensures a minimal risk of malignant progression. This case is notable in demonstrating that even recurrent lesions in the same location can maintain a benign course. Early detection, complete surgical removal, and regular follow up remain the key steps for optimal management. Future molecular studies may help clarify mechanisms of viral persistence and improve our understanding of OSP pathogenesis.

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Chapter 8

BIOCERAMIC MATERIALS IN ENDODONTICS

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1. Introduction

Materials used in endodontic treatment play a critical role in preventing recontamination of the root canal system by microorganisms and in establishing a healing environment that is compatible with surrounding tissues. Within this context, bioceramic materials have gained increasing attention over the past few decades due to their favorable biological and physicochemical properties, offering notable advantages over conventional endodontic materials. Bioceramics are inorganic ceramic compounds specifically designed to be compatible with human tissues and typically consist of components such as hydroxyapatite, calcium phosphates, calcium silicates, bioactive glass, and related structures.

The introduction of bioceramic materials into endodontics dates back to the 1990s with the development of mineral trioxide aggregate (MTA). Since then, these materials have rapidly become an integral part of clinical practice, particularly in applications such as root-end filling, perforation repair, and vital pulp therapies. The emergence of bioceramics has expanded the concept of endodontic treatment beyond mere mechanical sealing, emphasizing instead their ability to interact biologically with surrounding tissues and to support reparative processes.

Among bioceramics, calcium silicate–based formulations have achieved widespread clinical acceptance. These materials are characterized by their ability to create an alkaline environment and to promote the formation of hydroxyapatite-like structures, which collectively contribute to favorable tissue responses and improved sealing at the material–tissue interface. Bioceramic sealers and putty-type formulations, in particular, demonstrate the capacity to set adequately even in the presence of moisture, thereby enabling their use at various stages of endodontic treatment.

When compared with traditional endodontic materials, bioceramics have been reported to exhibit superior performance in terms of biocompatibility, bioactivity, and chemical stability. These characteristics may facilitate more favorable interactions with periapical tissues, potentially reducing the risk of inflammation and promoting tissue repair. Nevertheless, the current literature also highlights the need for well-designed, long-term controlled clinical studies to better elucidate the clinical performance of bioceramic materials, especially with regard to differences in efficacy and durability among various formulations (Dong & Xu, 2023; Raghavendra, Jadhav, Gathani, & Kotadia, 2017).

Overall, bioceramic materials are increasingly regarded not merely as filling or repair materials, but as innovative, tissue-compatible systems capable of supporting biological processes in endodontic therapy. A more

comprehensive understanding of their properties and clinical outcomes is expected to play a key role in shaping future treatment protocols in endodontics.

2. Fundamental Properties of Bioceramic Materials Used in Endodontics

The clinical performance of bioceramic materials used in endodontics is largely dependent on their chemical composition and the interactions established with surrounding tissues during the setting process. The majority of contemporary bioceramic materials are based on calcium silicate formulations, which are designed to simultaneously provide adequate physical strength and biological activity. The primary objective of these materials is to achieve long-term sealing of the root canal system while creating a biologically favorable microenvironment for periapical tissues (Dawood, Parashos, Wong, Reynolds, & Manton, 2017).

2.1. Chemical Composition and Setting Mechanism

Calcium silicate–based bioceramics are primarily composed of tricalcium silicate and dicalcium silicate, together with inert radiopacifying agents such as zirconium oxide or tantalum oxide. Upon contact with water or tissue fluids, these materials undergo a hydration reaction that results in the formation of calcium silicate hydrate gel and calcium hydroxide. The release of calcium hydroxide creates an alkaline environment in the surrounding tissues, which contributes to antibacterial activity while simultaneously facilitating the activation of biological signaling pathways involved in hard tissue formation (Camilleri & Gandolfi, 2010).

A distinctive feature of the setting mechanism of bioceramic materials is that their hardening is not compromised by the presence of moisture; on the contrary, moisture is essential for the progression of the setting reaction. This characteristic represents a significant clinical advantage, particularly in situations where complete desiccation of the root canal system is difficult to achieve. Furthermore, the continuation of the hydration process over time promotes the formation of apatite-like deposits on the material surface, a phenomenon that underlies the bioactive nature of calcium silicate–based bioceramics (Prati & Gandolfi, 2015).

2.2. Physical and Chemical Properties

The physical properties of bioceramic materials have a direct impact on their performance in endodontic applications. Flowability and film thickness are particularly critical when these materials are used as root canal sealers, as they influence adaptation to the dentinal walls and the prevention of microleakage. Previous studies have demonstrated that bioceramic sealers,

owing to their low film thickness and appropriate flow characteristics, are capable of penetrating dentinal tubules, a feature that may contribute to improved sealing ability (Zhang, Li, & Peng, 2009).

Dimensional stability represents another key parameter affecting the long-term success of bioceramic materials. Their tendency to exhibit minimal expansion during setting may enhance adaptation to the root canal walls and compensate for minor interfacial gaps. In this respect, bioceramics are often considered advantageous when compared with conventional resin-based sealers, which are susceptible to polymerization shrinkage during setting (Viapiana, Flumignan, Guerreiro-Tanomaru, Camilleri, & Tanomaru-Filho, 2014).

Radiopacity is an essential requirement for endodontic materials to allow radiographic assessment after placement. In bioceramic formulations, radiopacity is typically achieved through the incorporation of metal oxides. Contemporary bioceramic materials have been reported to provide radiopacity levels that comply with ISO standards. Nevertheless, the biological inertness and long-term stability of the radiopacifying agents used remain subjects of ongoing investigation in the literature (Camilleri, 2013).

Overall, the chemical and physical characteristics of bioceramic materials used in endodontics extend their role beyond that of passive filling agents, positioning them instead as active materials capable of influencing biological processes. However, the extent to which these properties translate into favorable clinical outcomes is dependent on multiple factors, including material formulation, application technique, and the specific clinical indication.

3. Biological Properties and Tissue Interaction

The clinical success of bioceramic materials used in endodontics is not determined solely by their physical and chemical characteristics, but is also closely related to the biological interactions they establish with surrounding tissues. Rather than functioning as passive filling agents, these materials are increasingly regarded as biologically active systems capable of modulating cellular responses and influencing tissue healing processes. In particular, calcium silicate–based bioceramics interact dynamically with periapical tissues through their ion release profiles and surface characteristics, thereby contributing to a biologically favorable healing environment (Prati & Gandolfi, 2015).

3.1. Biocompatibility and Cellular Response

Biocompatibility represents a fundamental requirement for endodontic materials and refers to the ability of a material to function without inducing

toxic or excessive inflammatory responses in the surrounding tissues. Evidence from both in vitro and in vivo studies on contemporary bioceramic materials indicates that these materials are generally compatible with high levels of cell viability when tested on periodontal ligament fibroblasts, osteoblast-like cells, and dental pulp–derived cells. This favorable cellular response is thought to be associated with the controlled release of calcium ions and the establishment of an alkaline pH environment during the setting process (Dawood, Parashos, Wong, Reynolds, & Manton, 2017).

The alkaline environment created by bioceramic materials may provide an initial antibacterial effect while simultaneously contributing, over the longer term, to a microenvironment that supports cellular proliferation and differentiation. Nevertheless, biocompatibility may vary depending on factors such as material formulation, setting dynamics, and local environmental conditions. Consequently, the biological effects of bioceramic materials should not be assessed based on a single parameter, but rather through a comprehensive evaluation that accounts for multiple interacting variables (Niu et al., 2014).

3.2. Bioactivity and Hard Tissue Formation

One of the most distinctive biological characteristics of bioceramic materials is their bioactive nature. Bioactivity refers to the ability of a material to form an apatite-like layer on its surface upon contact with tissue fluids, thereby establishing a chemical bond with hard tissues. In calcium silicate–based bioceramics, this process occurs as a result of interactions between calcium ions released during the hydration reaction and phosphate ions present in the surrounding environment (Prati & Gandolfi, 2015).

The formation of this apatite-like layer not only enhances sealing at the material–dentin interface, but also plays a supportive role in tissue repair by stimulating osteogenic and odontogenic cellular responses. Clinical observations such as the development of hard tissue barriers in apical regions and the healing of periapical lesions have been associated with the bioactive properties of bioceramic materials. However, the literature indicates that the degree of bioactivity may vary considerably among different bioceramic products, and such variability has the potential to influence clinical outcomes (Niu et al., 2014).

3.3. Antibacterial Effects and Inflammatory Response

A substantial proportion of endodontic failures is associated with residual or recurrent microbial contamination within the root canal system. The antibacterial activity of bioceramic materials is largely attributed to the alkaline environment generated during and after the setting process. This

elevated pH has been shown to exert an inhibitory effect, particularly against obligate anaerobic microorganisms. However, it has also been reported that the antibacterial efficacy of bioceramics may decrease over time and that, under clinical conditions, this effect alone may not be sufficient to ensure complete microbial control (Dawood et al., 2017).

With regard to the inflammatory response, bioceramic materials have been reported to induce minimal inflammation in periapical tissues, with this response tending to transition toward regenerative processes over time. This behavior is commonly explained by the chemical stability of the material and its biologically compatible ion release profile. Nevertheless, especially in cases of material extrusion beyond the apical foramen, the biological response may vary depending on the amount of material extruded and the type of tissue involved, and these factors should be carefully considered in clinical practice (Prati & Gandolfi, 2015).

Overall, bioceramic materials exhibit a biologically active, tissue-friendly, and healing-supportive profile in endodontic applications. Despite these favorable characteristics, the existing body of evidence is largely derived from short- to mid-term observations, and there remains a need for high-quality studies with long-term follow-up to more clearly define their clinical outcomes.

4. Clinical Applications of Bioceramic Materials in Endodontics

Bioceramic materials are used across a wide range of stages in endodontic treatment, and their clinical applications are largely determined by their biocompatibility, moisture tolerance, and bioactive properties. In clinical practice, the rationale for selecting bioceramics extends beyond their ability to provide mechanical sealing, encompassing their capacity to promote a more predictable biologically driven healing response in the surrounding tissues. These characteristics are particularly relevant in clinical scenarios where contact with periapical tissues is unavoidable.

Nevertheless, the biological rationale underlying the use of bioceramic materials varies among different clinical indications, as does the level of evidence supporting each application. Recognition of these differences is essential for rational material selection and evidence-based clinical decision-making (Prati & Gandolfi, 2015). In this context, the principal clinical applications of bioceramic materials in endodontics, together with their biological rationale and reported findings in the literature, are summarized in Table 1.

Table 1. Clinical Applications of Bioceramic Materials in Endodontics

Clinical indication	Biological rationale	Evidence from the literature
Root canal obturation as a sealer (bioceramic sealer + gutta-percha/single-cone technique)	Hydraulic calcium silicate–based sealers create a biologically favorable microenvironment through moisture tolerance, calcium ion (Ca^{2+}) release, and alkaline pH. Their tendency to promote mineralization or apatite-like deposition at the dentin interface may provide a biological contribution to sealing.	Current evidence indicates that bioceramic sealers exhibit a favorable profile in terms of biocompatibility and bioactivity; however, parameters such as obturation quality and porosity remain strongly influenced by technical factors and case-related variables rather than the sealer alone (Khalil, Naaman, & Camilleri, 2016).
Perforation repair (furcation/ lateral perforations)	In perforation sites, the material is in direct contact with periodontal and periapical tissues; therefore, high biocompatibility and bioactivity are considered critical for limiting inflammatory response and supporting hard tissue repair.	Comprehensive clinical overviews report that MTA and other bioactive cements can provide predictable outcomes in perforation repair, while emphasizing that clinical success depends as much on contamination control and application technique as on the material itself (Torabinejad, Parirokh, & Dummer, 2018).
Apexification / apical barrier formation (apical plug in immature teeth)	The goal is to establish an artificial apical barrier; the ability of hydraulic cements to set in the presence of moisture and to release ions that support hard tissue formation may biologically facilitate apical closure.	Overviews indicate that the apical barrier technique using MTA or other bioactive cements is widely accepted and clinically applicable; however, heterogeneity in protocols and follow-up periods highlights the need for long-term comparative evidence (Torabinejad et al., 2018).
Root-end filling (apical surgery/ retrograde filling)	During surgical procedures, the material directly contacts periapical tissues; low cytotoxicity, adequate marginal adaptation, and bioactivity are regarded as key factors supporting periapical healing.	Reviews summarizing clinical applications and complications report that bioactive cements have been used as root-end filling materials for many years, with successful outcomes when appropriate surgical technique and isolation are achieved (Torabinejad et al., 2018).
Vital pulp therapy (direct/ indirect pulp capping, pulpotomy)	When in contact with pulp tissue, biocompatibility, controlled inflammatory response, and a bioactive ionic environment capable of supporting reparative dentin or hard tissue bridge formation are essential.	Recent overviews focusing on vital pulp therapy indicate that MTA and other bioactive cements are widely used in VPT, and that clinical success is closely related to proper case selection, hemostasis, contamination control, and coronal sealing (Parirokh, Torabinejad, & Dummer, 2018).
Regenerative endodontic procedures (REP) – coronal barrier/ cervical sealing	In REP, a biocompatible coronal barrier and effective sealing are essential to prevent reinfection and to maintain a stable environment for regenerative processes; tissue tolerance of bioactive cements is considered advantageous in this context.	Clinical reviews emphasize that selection of the coronal barrier material is a critical step in REP protocols; bioactive cements are frequently preferred, although variability in protocols limits full standardization of the available evidence (Torabinejad et al., 2018).
Repair of defects associated with internal resorption and perforation	In complex defects, the material should adapt to irregular cavities, set in moist conditions, and remain compatible with surrounding tissues; bioactivity may enhance the biological aspect of tissue repair.	Clinically oriented reviews describe bioactive cements as "repair materials" with a broad range of indications, while highlighting the need to manage technique-sensitive challenges and the risk of material extrusion on a case-by-case basis (Torabinejad et al., 2018).

4.1. Use as a Root Canal Sealer

Bioceramic sealers have been developed as alternatives to conventional sealers for root canal obturation and have gained widespread use, particularly in combination with single-cone techniques. The tendency of these materials to interact chemically with dentinal walls, together with their minimal dimensional change during the setting process, may contribute to improved apical and lateral sealing. From a clinical perspective, cases in which bioceramic sealers are used have been reported to exhibit favorable tolerance by periapical tissues, with no adverse effects on the healing process (Khalil, Naaman, & Camilleri, 2016).

In addition, the ability of bioceramic sealers to penetrate more deeply into the root canal system is thought to indirectly contribute to a reduction in microbial load. However, it should be emphasized that this potential advantage is not independent of other critical factors, such as the effectiveness of the irrigation protocol and the quality of canal shaping.

4.2. Perforation Repair and Root-End Filling

The use of bioceramic materials for perforation repair and as root-end filling materials represents one of the clinical contexts in which their biological properties are most clearly manifested. In such applications, direct contact between the material and periapical as well as periodontal tissues is inevitable. The high level of biocompatibility exhibited by bioceramics, together with their capacity to limit excessive inflammatory responses, constitutes a primary rationale for their clinical use in these scenarios (Camilleri, Atmeh, Li, & Meschi, 2022).

In particular, in root-end filling procedures, bioceramic materials have been reported to create a biologically favorable environment that supports hard tissue formation in the apical region, thereby contributing positively to periapical healing. Nevertheless, it should be acknowledged that clinical success in these applications is not solely dependent on material selection, but is also strongly influenced by surgical technique and appropriate case selection.

4.3. Apexification and Apical Barrier Applications

In teeth with open apices, bioceramic materials are frequently used to establish an apical barrier. In such applications, the ability of bioceramics to form a stable structure after setting and to support tissue compatibility in the apical region is considered a significant clinical advantage. The literature indicates that apical barriers created using bioceramic materials are generally well tolerated by periapical tissues, with inflammatory responses tending to diminish over time (Torabinejad, Parirokh, & Dummer, 2018).

However, in these cases, factors such as apical extrusion of the material and the amount applied may have a decisive influence on the periapical response and therefore require careful clinical management. Consequently, the biological advantages of bioceramic materials alone do not guarantee clinical success unless they are supported by appropriate clinical protocols and meticulous application techniques.

4.4. Use in Vital Pulp Therapy

Bioceramic materials have also gained prominence in vital pulp therapy owing to their favorable biological properties. In procedures such as direct and indirect pulp capping as well as pulpotomy, bioceramics have been shown to induce limited inflammatory responses upon contact with pulpal tissue and to support the formation of a dentin bridge. In this context, ion release from the material and its surface bioactivity play a critical role in directing pulpal healing processes (Parirokh, Torabinejad, & Dummer, 2018).

The favorable outcomes reported in vital pulp therapy further suggest that the indirect interaction of bioceramic materials with periapical tissues is biologically well balanced. Nevertheless, long-term clinical data remain limited, and there is a continuing need for controlled studies comparing different bioceramic formulations to more clearly define their relative effectiveness and durability in vital pulp applications.

5. Comparative Evaluation with Conventional Materials

The introduction of bioceramic materials into clinical endodontic practice has prompted a reassessment of the biological and physical limitations associated with conventional root canal filling materials and sealers that have been used for decades. In this context, bioceramics should be evaluated not only in terms of the advantages they offer—particularly when compared with zinc oxide–eugenol–based and resin-based sealers—but also with respect to their inherent limitations. A meaningful comparative assessment should therefore extend beyond parameters such as sealing ability or mechanical performance, and instead be framed within the broader context of the biological interactions established between these materials and the surrounding tissues.

5.1. Comparison in Terms of Biological Response

Zinc oxide–eugenol–based materials, despite their long-standing and widespread clinical use, are considered biologically limited due to their potential to elicit irritant effects on periapical tissues. The eugenol component has frequently been reported to exhibit cytotoxic effects at the cellular level and to prolong inflammatory responses. Resin-based sealers, while offering improved physical stability, have also shown controversial biocompatibility

outcomes, largely attributed to the release of unpolymerized monomers during and after the polymerization process (Prati & Gandolfi, 2015).

In contrast, bioceramic sealers tend to exhibit a more balanced biological interaction with surrounding tissues following setting, contributing to the establishment of a microenvironment that supports cellular viability. This difference is commonly associated with the ion release profile and bioactive surface characteristics of bioceramic materials, which may promote a more predictable healing response, particularly in periapical tissues (Niu et al., 2014).

5.2. Physical Properties and Dimensional Stability

One of the main advantages of conventional resin-based sealers is their clinically manageable setting times and high initial flowability. However, polymerization shrinkage represents a potential drawback with respect to long-term dimensional stability. In zinc oxide–eugenol–based materials, solubility and gradual material loss over time may increase the risk of microleakage.

Bioceramic sealers differ from these materials by exhibiting minimal expansion during the setting process and maintaining stability in the presence of moisture. This characteristic may contribute to improved adaptation, particularly in the apical region of the root canal system. Nevertheless, the relatively longer setting times of bioceramic materials and the limited control over this process under clinical conditions may present application-related challenges in certain cases (Khalil, Naaman, & Camilleri, 2016).

5.3. Sealing Ability and Clinical Performance

Sealing ability represents a fundamental criterion for the success of all endodontic materials. Resin-based sealers are capable of providing effective initial sealing through micromechanical bonding to dentin; however, the long-term stability of this bond is highly dependent on factors such as intracanal moisture conditions and technique sensitivity. In zinc oxide–eugenol–based sealers, sealing effectiveness relies predominantly on mechanical adaptation to the canal walls.

In contrast, the sealing ability of bioceramic sealers is not solely attributed to mechanical adaptation, but is also associated with the formation of apatite-like structures on the material surface. This phenomenon suggests that chemical interactions developing over time at the material–dentin interface may contribute to improved sealing. Nevertheless, as the majority of available evidence is derived from in vitro studies, a cautious interpretation is warranted regarding the extent to which these advantages translate into predictable clinical outcomes (Prati & Gandolfi, 2015).

5.4. Clinical Handling and Limitations

Conventional endodontic materials benefit from decades of clinical experience and a substantial body of evidence, which contributes to their overall predictability in daily practice. In contrast, bioceramic materials present certain clinical limitations, including challenges associated with retreatment procedures, prolonged setting times, and higher costs. These factors suggest that bioceramics should not be regarded as direct replacements for conventional materials, but rather as complementary options that may offer advantages in specific clinical scenarios.

Overall, when evaluated comparatively, bioceramic materials demonstrate a more favorable biological profile than conventional sealers. Nevertheless, additional evidence is still required to clarify their long-term clinical success and cost-effectiveness, underscoring the need for further well-designed clinical investigations.

6. Clinical Limitations and Controversial Issues

Despite the biological advantages offered by bioceramic materials in endodontics, their clinical use is associated with certain limitations and controversial aspects. These limitations are largely related to the physicochemical properties of the materials, clinical handling conditions, and the current lack of robust long-term clinical data. Consequently, when evaluating the role of bioceramic materials in endodontic therapy, it is essential to consider not only their potential benefits but also application-specific risks and existing uncertainties.

6.1. Retreatment Challenges

The tendency of bioceramic sealers to interact chemically with dentin, together with their high bond strength after setting, may lead to clinical challenges during retreatment procedures. In particular, bioceramic sealers that penetrate deeply into the dentinal walls have been reported to be difficult to remove completely using conventional mechanical and chemical techniques. This issue has generated ongoing debate regarding the effectiveness of canal cleaning following retreatment (Hess, Solomon, Spears, & He, 2011).

The clinical relevance of retreatment difficulty becomes especially significant not only in cases of material failure, but also in situations where prognosis is uncertain or where the likelihood of future re-intervention is increased. Accordingly, the use of bioceramic sealers necessitates careful case selection and consideration of long-term follow-up requirements.

6.2. Setting Time and Clinical Control

The setting process of bioceramic materials is influenced by several factors, including environmental moisture, canal anatomy, and material thickness. In the clinical setting, the inability to fully control these variables may result in variability and unpredictability in setting time. In particular, delayed setting of premixed bioceramic sealers may pose a risk in situations such as early restorative procedures or post placement (Al-Haddad, Kutty, Kasim, & Ab Aziz, 2017).

In this context, although the "moisture tolerance" of bioceramic materials is often presented as a clinical advantage, it should be recognized that excessive moisture or residual irrigants may adversely affect material properties. The literature further emphasizes that significant differences in setting behavior exist among various bioceramic formulations, underscoring the importance of material-specific considerations in clinical practice.

6.3. Discoloration Potential

One of the controversial aspects associated with bioceramic materials is the risk of discoloration, particularly in esthetically critical regions. It has been reported that certain radiopacifying agents incorporated into some bioceramic formulations may lead to color changes in dental hard tissues over time. This issue is of particular clinical relevance in anterior teeth and in procedures such as vital pulp therapy or applications performed close to the coronal aspect of the tooth (Marciano et al., 2014).

Although modifications in material composition have been introduced in newer generations of bioceramics with the aim of reducing discoloration risk, the long-term clinical effectiveness of these improvements has yet to be clearly established.

6.4. Limitations of Clinical Evidence

A review of the literature on bioceramic materials indicates that a substantial proportion of the available evidence is derived from in vitro studies and short-term clinical observations. The limited number of long-term randomized controlled clinical trials necessitates a cautious interpretation of the true clinical effectiveness and cost-effectiveness of bioceramic materials (Sfeir et al., 2021).

This situation suggests that broad generalizations regarding the complete replacement of conventional materials by bioceramics may be premature. From an academic perspective, it is essential to clearly acknowledge not only the advantages of bioceramic materials in clinical practice, but also the existing gaps in the evidence base.

7. Current Evidence and Future Perspectives

The role of bioceramic materials in endodontics has been increasingly evaluated in a more systematic manner in recent years, supported by a growing number of review articles and clinical investigations. Nevertheless, an examination of the current body of evidence reveals a persistent gap between findings that support the biological and physicochemical advantages of bioceramics and the availability of robust long-term clinical outcomes. Consequently, the appraisal of current evidence is essential not only for defining the present clinical role of bioceramic materials, but also for guiding future research directions in this field.

7.1. Findings from Systematic Reviews and Meta-Analyses

Systematic reviews published in recent years have generally reached a consensus that calcium silicate–based bioceramic materials exhibit a more favorable profile in terms of biocompatibility and bioactivity when compared with conventional endodontic materials. These reviews report that bioceramics support cellular viability, limit inflammatory responses, and promote a healing process that is compatible with periapical tissues (Niu et al., 2014; Sfeir et al., 2021).

However, meta-analytical evaluations have struggled to demonstrate a statistically significant and consistent superiority of bioceramic materials over conventional alternatives with respect to clinical success rates. This limitation is primarily attributed to methodological heterogeneity among studies, the inclusion of different bioceramic formulations within single analytical groups, and relatively short follow-up periods. Consequently, while current meta-analyses support the potential advantages of bioceramic materials, they also emphasize the need for caution when drawing definitive clinical conclusions (Sfeir et al., 2021).

7.2. Current Status of Long-Term Clinical Studies

Long-term clinical data on bioceramic materials remain limited. The majority of available clinical studies are characterized by short- to medium-term follow-up periods and tend to focus on specific clinical indications. As a result, critical parameters such as the long-term sealing performance of bioceramics, the sustainability of periapical healing, and the need for retreatment have not yet been adequately evaluated (Lim, Jung, Shin, Cho, & Song, 2020).

The lack of long-term randomized controlled trials restricts the recommendation of bioceramic materials as standard alternatives to conventional endodontic materials. Nevertheless, the existing clinical evidence suggests that, with appropriate case selection and adherence to correct application

protocols, bioceramic materials can provide safe and predictable clinical outcomes. Future research should therefore prioritize study designs that include extended follow-up periods and direct comparisons among different bioceramic materials, which are essential for strengthening the overall level of evidence.

7.3. Potential of Bioceramics in Regenerative Endodontics

The potential application of bioceramic materials in regenerative endodontics represents one of the most compelling areas of current research. The ability of bioceramics to create a microenvironment that supports cellular differentiation through controlled ion release offers a theoretical advantage for regenerative processes. In particular, the stimulatory effects of calcium ions on odontogenic and osteogenic cellular responses suggest that bioceramic materials may serve as biologically supportive components within regenerative treatment protocols (Torabinejad, Parirokh, & Dummer, 2018).

Nevertheless, the role of bioceramic materials in regenerative endodontics has not yet been clearly defined within a standardized clinical framework. As the existing evidence is predominantly derived from experimental studies, more comprehensive clinical data are required before bioceramics can be considered standard materials in regenerative therapies. In this context, bioceramic materials are more realistically viewed not as standalone solutions, but as adjunctive components that support biologically based regenerative approaches.

8. Conclusion

8.1. Clinical and Academic Implications

When the current literature is evaluated in conjunction with clinical observations, bioceramic materials may be considered to represent a significant paradigm shift in endodontics. These materials reflect an approach that extends beyond the provision of mechanical sealing within the root canal system, aiming instead to support a biologically compatible and predictable healing process in the surrounding tissues. In particular, the biocompatibility, bioactivity, and moisture tolerance of calcium silicate–based bioceramics provide meaningful advantages in selected clinical indications.

Nevertheless, it is evident that the clinical success of bioceramic materials cannot be attributed solely to their intrinsic material properties. Factors such as application technique, case selection, irrigation protocols, and restorative strategies play a decisive role in determining whether the potential advantages of bioceramics are translated into favorable clinical outcomes. From an academic perspective, bioceramic materials have also prompted renewed

discussion regarding the biological foundations of endodontic treatment, giving rise to a research field that places material–tissue interaction at its core.

Accordingly, bioceramic materials should not be positioned as direct and unconditional alternatives to conventional materials, but rather as biologically advantageous options that should be selected rationally for specific clinical scenarios. This approach supports the maintenance of realistic expectations in clinical practice while also enabling academic discussions to progress within a more balanced and evidence-based framework.

8.2. Future Research Directions

Future research on bioceramic materials should primarily address the existing gaps in the current evidence base. Well-designed randomized controlled clinical trials with long-term follow-up periods are essential for more clearly defining the clinical performance of bioceramics. In particular, studies that directly compare different bioceramic formulations would provide valuable scientific support for material selection in clinical practice.

In addition, a more detailed investigation of the biological mechanisms underlying the effects of bioceramic materials at the molecular and cellular levels would enhance understanding of their potential role in regenerative endodontics. Research focusing on the control of ion release profiles, surface modifications, and the development of next-generation bioceramics capable of eliciting targeted biological responses represents a promising direction for future studies.

Finally, the establishment of standardized clinical protocols for the use of bioceramic materials, along with their regular evidence-based updating, is of considerable importance for ensuring consistency in clinical practice and improving the comparability of academic research. Efforts in this direction will contribute to defining the role of bioceramic materials in endodontics within a clearer and more sustainable clinical and scientific framework.

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Chapter 9

POLYETHERETHERKETONE (PEEK) POLYMERIC MATERIAL AND ITS USE AS AN IMPLANT ABUTMENT

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Polyetheretherketone (PEEK) is a synthetic, tooth-colored, aromatic, polymeric high-performance biomaterial that has been used in orthopedics for many years (Toth et al., 2006; Kurtz & Devine, 2007; Pokorny et al., 2010). The polymer is formed through the polymerization of ether-ether-ketone monomer units via a step-growth dialkylation reaction of bisphenolates. The general synthesis route of PEEK involves the reaction between 4,4′-difluorobenzophenone and the disodium salt of hydroquinone in a polar solvent such as diphenyl sulfone at approximately 300 °C. PEEK is a semi-crystalline material with a melting temperature of 335 °C, and its structure can be modified through chemical processes such as the incorporation of functional monomers (prepolymerization) or post-polymerization modifications including sulfonation, amination, and nitration (Fig.1) (Najeeb et al., 2016).

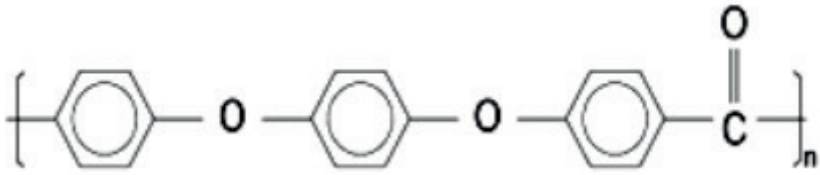

Figure 1

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Properties that make PEEK an attractive material in dentistry:

1. Excellent thermomechanical properties

2. Chemical stability

3. Biological inertness (biocompatibility)

4. Adequate mechanical strength

5. White color

6. Sufficient stiffness

7. Good fatigue resistance

8. Ability to absorb occlusal forces

9. Sterilizability without alteration of mechanical properties or biocompatibility

10. Compatibility with computed tomography, magnetic resonance imaging, and X-ray imaging without producing artifacts

11. Natural color providing good esthetics

12. Prevention of ion exchange, offering metal-free solutions in the oral environment

13. Various technical advantages such as ease of chairside adjustment and application (Ha et al., 1997; Katzer et al., 2002; Shafie, 2014; Siewert & Parra, 2013).

The mechanical properties of PEEK can be enhanced by incorporating compatible reinforcing agents such as ceramic, glass, and carbon fibers. PEEK-based dental polymers have opened a new field by enabling the fabrication of metal-free and ceramic-free crowns, bridges, and implants (Hunter et al., 1995).

Since 1998, PEEK has been recommended as a polymeric implant material for long-term implantation, particularly in trauma and orthopedic applications, due to its elastic modulus being very close to that of cortical bone (Table 1), making it a potential alternative to metal implants (Kurtz & Devine, 2007; Najeeb et al., 2016; Schwitalla et al., 2015).

Table 1. Tensile strength and elastic moduli of PEEK, CFR-PEEK, PMMA, and mineralized human tissues

Material	**Tensile strength** (MPa)	**Elastic modulus** (GPa)
PEEK	80	3-4
CFR-PEEK	120	18
Cortical bone	104-121	14
PMMA	48-76	3-5
Dentin	104	15
Enamel	47.5	40-83
Titanium	954-976	102-110

PEEK, polietereterketon; CFR-PEEK, karbon fiberle güçlendirilmiş polietereterketon; PMMA, polimetilmetakrilat

In the field of dentistry, the use of PEEK has been steadily increasing in situations where alloplastic, non-biological materials (such as metals and ceramics) have traditionally been widely used. This trend is partly due to the development of hypersensitivity reactions to certain components of dental composites, as well as reports that even titanium—a metal with well-documented biocompatibility—may trigger inflammatory reactions in some cases. In addition, an increasing number of patients prefer metal-free restorations because of the risk of oral galvanic current formation (Schwitalla et al., 2015).

Considering its adequate biocompatibility, PEEK can be used for the fabrication of implant healing screws and abutments (Hahnel et al., 2014; Koutouzis et al., 2011). In a randomized controlled clinical study conducted by Koutouzis et al. (2011), no significant differences were found between PEEK and titanium abutments in terms of peri-implant soft tissue inflammation or bone resorption. Furthermore, Hahnel et al. (2014) compared microbial adhesion on PEEK surfaces with zirconium dioxide (ZrO_2), titanium (Ti), and polymethyl methacrylate (PMMA), and reported that the amount of microbial biofilm accumulated on PEEK was comparable to or lower than that on the other materials. The authors attributed this finding to the similarity between the elastic moduli of bone and PEEK, which may reduce the stress-shielding effect—defined as the reduction in bone density and mechanical strength caused by load transfer through an implant—and thereby promote bone remodeling. Consequently, PEEK has emerged as a viable alternative to titanium for abutment fabrication (Hunter et al., 1995; Hahnel et al., 2014).

PEEK can be processed using various techniques. One method involves pressing the material in a dental laboratory using a dedicated vacuum press system, commonly referred to as the "For 2 Press System." For this purpose, PEEK is available in both industrially pre-pressed pellet form and granular form. In addition to the material itself and the pressing unit, a flask and a pressing plunger are required. A wax pattern of the desired framework is invested in the flask using a special investment material. Approximately 20 minutes later, the flask and pressing plunger are preheated in a furnace at temperatures between 630 °C and 850 °C for a duration recommended by the manufacturer. The flask is then cooled to 400 °C to reach the melting temperature of the PEEK polymer. Granular PEEK material is placed into the sprue channel of the flask and maintained at this temperature for 20 minutes. Subsequently, the molten polymer is transferred using the pressing plunger, and the loaded flask is placed into the vacuum pressing device. The vacuum pressing process starts automatically once the device is closed. After vacuum pressing, the flask continues the pressing cycle for approximately 35 minutes and is then cooled to room temperature. The resulting framework is separated and finished using carbide burs (Bechir et al., 2013; Vosshans et al., 2013).

Another option is the milling of PEEK blocks manufactured under standardized parameters (pressure, temperature, and time) using CAD/CAM technology (Stawarczyk et al., 2015). PEEK is one of the most commonly used CAD/CAM polymers, along with PMMA and composite resins. Due to its notable mechanical properties, its use in fixed prostheses may be considered depending on the magnitude of functional loads in the applied region. Variations in the composition of CAD/CAM polymers aim to improve mechanical properties by influencing water absorption and dimensional stability (Liebermann et al., 2016).

Based on their generally favorable mechanical and physical properties, and despite the lack of long-term clinical studies, polymeric materials such as PEEK, reinforced PEEK, polyetheretherketone/polyetherketoneketone (PEEK/PEKK), and polyetherketoneketone have been considered suitable for use in dental implants, temporary abutments, fixed prostheses, implant-supported bars, and even prosthetic superstructures such as clasps in removable partial dentures (Stawarczyk et al., 2015). In addition, the similarity of PEEK's stress values to those of bone, enamel, and dentin is an important factor in prosthetic restorations, alongside its mechanical properties (Najeeb et al., 2016).

Modified (reinforced) PEEK (BioHPP; Bredent GmbH, Senden, Germany) is a high-performance polymer containing approximately 20% ceramic fillers, offering high biocompatibility, favorable mechanical properties, high thermal resistance, and chemical stability (Table 2). It is available in CAD/CAM, prefabricated, and conventionally pressable forms. With an elastic modulus of approximately 4 GPa, which is close to that of bone, it transmits minimal force to the supporting abutment tooth. Moreover, the white color of BioHPP provides a distinct esthetic advantage.

This polymer offers several advantages, including:

1. Reduction of allergic reactions

2. Excellent polishability

3. Low plaque accumulation

4. Good wear resistance

5. Improved visualization of the peri-implant region due to its radiolucency (Zoidis et al., 2015; Zoidis & Papathanasiou, 2016; Zoidis, 2017; Al-Rabab'ah et al., 2017).

Table 2. Characteristic physical properties of BioHPP

Mechanical Properties (DIN EN ISO 10477)	
Elastic modulus	4.000 Mpa
Flexural strength	> 150 MPa
Water absorption	6.5 µg/mm^3
Solubility in water	<0.03 µg/mm^3
Other Properties	
Melting temperature	340 °C civarında
Bond strength	> 25 MPa
Density	1.3 to 1.5 cm^3
Hardness (HV)	110 HV 5/20

Indications for the BioHPP polymers:

1. Three-unit bridges with a single pontic and four-unit bridges with two pontics

2. Telescopic crowns and endocrowns

3. Fabrication of customized/prefabricated and temporary implant abutments and abutment–crown complexes

4. Superstructures for bar-supported prostheses

5. Frameworks for implant-supported hybrid prostheses

6. Frameworks for removable partial dentures (Zoidis, 2017).

Contraindications:

1. Implant body fabrication

2. Root canal posts

3. Fixed partial dentures longer than two pontics (Siewert & Parra, 2013).

BioHPP can be manufactured using CAD/CAM technology or by conventional pressing techniques. Its favorable bonding strength with composite resins and resin cements has been reported to facilitate its use in adhesive resin-bonded bridges. Resin-bonded fixed partial dentures with BioHPP frameworks veneered with composite resin not only facilitate the fabrication of metal-free restorations in the esthetic zone but also provide superior esthetic outcomes compared with metal-supported resin-bonded bridges (Zoidis & Papathanasiou, 2016).

In a study by Liebermann et al. (2016), various CAD/CAM polymers—including a hybrid material (Vita Enamic), a nanohybrid composite (Lava Ultimate), PEEK (Dentokeep, 20% ceramic-filled), and PMMA-based materials—were subjected to different aging protocols, and their solubility, water absorption, and hardness were compared. The authors reported that PEEK exhibited higher hardness values than PMMA-based materials. Moreover, due to its low solubility and water absorption, PEEK can be used for extended periods in the oral environment. Given its superior mechanical properties compared with PMMA, PEEK is considered a suitable material for CAD/CAM fabrication of both fixed and removable prostheses.

In a clinical case report by Zoidis et al. (2015), a patient's existing distal-extension removable partial denture with a Cr–Co framework was replaced with a new distal-extension prosthesis fabricated from heat-polymerized PMMA resin supported by a BioHPP framework, due to complaints of metallic taste, excessive weight, and unfavorable positioning of metal clasps. At the one-year follow-up, advantages such as light weight and favorable color were noted, and no fractures or changes in clasp retention were observed in the BioHPP framework. Apart from a slight reduction in surface gloss, no differences were detected compared with the initial condition. Under current clinical conditions, BioHPP has been concluded to be a viable alternative framework material to conventional Cr–Co alloys for removable partial dentures, particularly in patients with metallic taste sensitivity or allergies.

Rosentritt et al. (2015) evaluated fracture resistance after in vitro aging and investigated the suitability of customized zirconium dioxide (ZrO_2) and PEEK abutments with titanium bases for use in the anterior region. Both titanium-based zirconia and PEEK abutments were reported to have high potential; however, their success was noted to depend on improvements in screw retention and the quality of adhesion. Nevertheless, their use in the anterior region was considered appropriate.

It has been reported that the stress-breaking properties of PEEK reduce the elastic modulus around the pulp, thereby protecting the tooth and root structure. From this perspective, modified PEEK may be considered an alternative framework material for endocrown restorations used in the treatment of endodontically treated teeth (Zoidis et al., 2016). Owing to this property, it effectively absorbs occlusal forces and exhibits wear behavior similar to that of natural teeth. When used as a crown restoration material on zirconia implants in the posterior region, it may optimize and maintain osseointegration over time. Furthermore, it represents an excellent alternative for patients with allergies or hypersensitivity to metal alloys (Parmigiani-Izquierdo et al., 2017).

The SKY implant system (Bredent, Germany) has introduced a BioHPP hybrid abutment with a titanium base. This polymeric hybrid abutment has been reported to be non-traumatic to the gingival tissues and suitable for both temporary and permanent use, effectively shortening treatment time and improving clinical efficiency. Compared with titanium and zirconium dioxide, its ability to absorb masticatory forces allows for immediate placement during implant surgery and fabrication of a temporary prosthesis, with transition to the definitive prosthesis possible within a few weeks. Superstructures can be fabricated using both conventional and digital workflows, and the material is highly compatible with digital production, including intraoral scanning of the abutment for manufacturing.

The role of PEEK in dental implantology is gaining importance, particularly for patients with metal allergies, high esthetic demands, or specific clinical requirements. Although titanium remains the gold standard, surface modification techniques and the ease of CAD/CAM fabrication support the potential for broader future use of PEEK. Given the current lack of long-term clinical data, the need for further controlled clinical studies should be emphasized.

PEEK is a promising material in dental implantology and restorative dentistry. Its superior biocompatibility, esthetic advantages, and elastic modulus compatible with bone may provide significant clinical benefits when applied appropriately. Nevertheless, surface treatments aimed at optimizing osseointegration and the evaluation of long-term outcomes should remain the focus of the future research.

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