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The effect of saliva and oral environment on dental filling

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بسم الله الرحمن الرحيم

قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُولُو الأَلْبَابِ

الزمر:9

صدق الله العلي العظيم

Dedication

To the greatest person whose hands have crafted this research,

To the brilliant mind in which the genius of Aristotle and the wisdom of Ibn Khaldun converge,

To the star whose light cannot be extinguished, no matter how many stars fill the sky,

To the one whose words silence all pens and whose voice makes the world pause in awe—

I dedicate this work… to myself.

To me, and with pride.

The one of greatness, the master of words, the ruler of meaning, and the beauty of thought.

Who else deserves this dedication?

No one. And there never will be.

This achievement is for you—with all its pride, struggle, and triumph.

For you—because you have always been the true hero in a story only you truly understand.

Acknowledgment

I would like to express my deep appreciation and indebtedness

particularly to my supervisor

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for her invaluable guidance and experience. Her ideas and comments

greatly influenced my work and contributed to its quality and for her

support, kind efforts, time, advice and scientific opinions and I'm proud

to be one of his students.

All family and friends and others who in one way or another shared

their support , thank you GOD bless all.

Certification

I certify that the preparation of this project entitled:

The effect of diabetes on thyroid gland and the

subsequent effect on the oral cavity

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Was made under my supervision at Dentistry Department in partial

fulfillment of the Requirements for the Degree of Bachelor of Science

in dentistry.

Supervisor Name:

Date:

Abstract

Saliva and the oral microbiome play critical roles in the performance and longevity of dental restorative materials. Saliva's buffering capacity, pH regulation, and remineralization impact the durability and stability of materials. Variations in saliva composition among individuals can influence wear resistance and surface degradation of these materials. This review explores the intricate relationship between saliva, the oral microbiome, and restorative dental materials, emphasizing their mutual influences and the implications for dental practice. The oral microbiome, consisting of diverse microorganisms, further complicates this interaction. Bacterial adhesion, biofilm formation, and microbial metabolism significantly affect the integrity of restorative materials. For example, the degradation of composite resins by oral bacteria and their acidic byproducts can compromise the mechanical properties of these materials. Clinical manifestations of these interactions include deterioration of composite resin restorations, biofilm formation, and corrosion of amalgam restorations. Recognizing these manifestations is crucial for dentists to implement timely interventions and personalized management strategies. Regular monitoring and timely intervention, coupled with advancements in biomaterials, are key to enhancing the durability and effectiveness of restorative dental treatments.

List of Abbreviations

Ph	Potential of Hydrogen
(Na+)	Sodium ion
(K+)	Potassium ion
(Ca2+)	Calcium ion
(Cl-)	Chloride ion
(HCO3	Bicarbonate ion
AEP	. Auditory Evoked Potential
(Ca)	Calcium
(PO	Phosphate ion
(OH	Hydroxide ion
ABU	Asymptomatic Bacteriuria
MDP	Methylene Diphosphonate
RBC	Red Blood Cells

Chapter one

Introduction

Restorative materials used in dentistry have a role in repairing and enhancing the functionality and appearance of damaged teeth. However, it's essential to consider the nature of the environment, where saliva can significantly affect how these materials perform and last over time (1). This review delves into the relationship between saliva and restorative dental materials providing insights into how they influence each other. Saliva is a fluid with components that create a natural environment, for restorative materials once they are placed in the mouth (2) . Remineralize plays a role in maintaining oral balance. Additionally, it has an impact on the durability and stability of materials by affecting their surface properties both mechanically (3,4). Studies have shown that variations in composition between individuals can lead to interactions with dental materials ultimately influencing factors like wear resistance and surface degradation (5,6). The presence of a range of microorganisms in the microbiome further complicates the behavior of restorative materials within the mouth. Bacterial adhesion, biofilm formation and microbial metabolism collectively affect the integrity of materials (7,8). Composite resins used for restorations are particularly vulnerable to the influences of saliva composition and oral microbiome dynamics. Research indicates that salivary enzymes and esterase's can degrade the matrix in composites leading to changes in their mechanical properties (9,10). The connection between saliva and dental restorative materials also applies to amalgam restorations. Moreover, changes in pH and composition can impact the corrosion processes ultimately affecting the stability of dental amalgam restorations in the mouth. Recent advancements in biomaterials like glass and antibacterial composites aim to minimize the influence of saliva and oral bacteria on restorative materials. Bioactive glass has shown promise in promoting demineralization and hindering growth offering an avenue for developing more robust restorative materials. In summary, understanding how saliva interact with materials is a complex and ever-changing phenomenon. These interactions affect their properties, degradation processes and overall clinical performance. Gaining insight into these relationships is crucial for advancing the field of dentistry and guiding the development of materials capable of withstanding challenges in the oral environment (11).

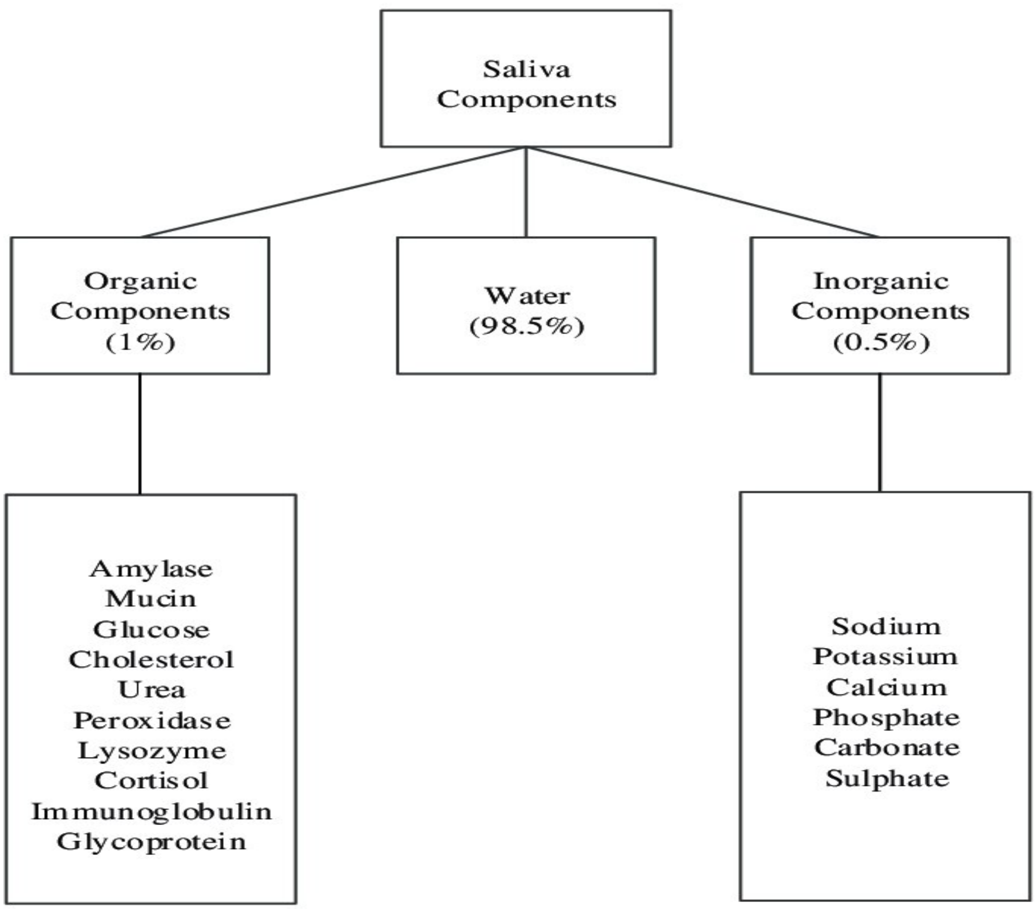
Chapter two

2.1 Saliva and oral health

Saliva plays a critical role in both oral and systemic health, acting as a fundamental component in maintaining oral hygiene, facilitating digestion, and serving as a diagnostic tool for various diseases. It is composed primarily of water, but it also contains important organic and inorganic molecules that contribute to its protective functions, including buffering acids, remineralizing tooth enamel, and providing an antimicrobial action (12) is a limpid, clear liquid with variable volume, density and composition that wets, moistens the mouth and forms a barrier against environmental and microbial insults. It supports the physiological and functional integrity of the whole “mouth” ecosystem: it contributes to maintain a functional oral local balance, provides calcium phosphate to maintain the mineralization of tooth enamel, maintains a beneficial commensal microbiome and defends the host against pathogenic microorganisms. The mouth is in constant relationship and adaptation with both the external environment and, as a junction and exchange point, with the respiratory, digestive and circulatory systems. Therefore, saliva has a great bio-functional importance by providing metabolic, digestive, immune and protective function (13) .

2.2 Composition of saliva:

Saliva is a secretion produced by exocrine gland called the salivary gland. The saliva producing glands include major glands i.e. parotid gland, submandibular gland and sublingual gland while others are also present called the minor salivary glands. It consists mainly of water along with salivary enzymes, some electrolytes, antibodies and other chemicals important for oral health (14) .



Figures (1) Component of humen saliva (15).

2.3 Functions of saliva in humans

Digestive functions Although amylase is a major component of the parotid secretion and is present at an appreciable level in the submandibular fluidas well ,its salivary role in the digestion of carbohydrates is really minimal .The only effective conversion of starch to maltose that occurs in the oral cavity is in food-retentive sites ,and this benefits primarily the plaque bacteria. Lubrication and demulcent properties From an evolutionary point of view, the oldest function of salivary glands is to supply lubrication molecules, to coat not only the food but the oral soft tissue as well. The lubrication film allows for ready phonation as well as food passage and provides for smooth tissue surfaces that exhibit minimal friction and are comfortable as well as functional. Soft Tissue Repair Licking one's wounds may be more than metaphor .The presence of nerve growth factor and epidermal growth factor in the submandibular saliva may accelerate wound-healing. A group of salivary proteins lysozyme, lactoferrin, and lactoper oxidase working in conjunction with other components of saliva can have an immediate effect on oral bacteria, interfering with their ability to multiply or killing them directly. Lysozyme can cause lysis of bacterial cells, especially Streptococcus mutans by interacting with anions of low charge density chaotropic ions (thiocyanate, perchlorate, iodide, bromide ,nitrate, chloride, and fluoride),and with bicarbonate. Maintenance of pH Saliva is effective in helping to maintain a relatively neutral pH in the oral cavity, in the bacterial plaque, and on swallowing, in the esophagus as well. In the oral cavity and the esophagus, the major regulation of pH, especially during eating or drinking, is the salivary bicarbonate, the level of which varies directly with flow rate.

In the bacterial plaque, where acid production is the natural sequela to bacterial metabolism of carbohydrates, saliva helps regulate pH in several ways. Bicarbonate, phosphate, and histidine-rich peptides act directly as buffers once they have diffused into the plaque. Urea from saliva is converted by bacterial urease to ammonia, which can neutralize the acid. Amino acids and peptides can be decarboxylated to form monoamines and polyamines, a process which consumes hydrogen ions. Arginine and arginine peptides can form ammonia as well as the polyamine, putrescine, and thus can be particularly effective in elevating plaque pH. Saliva and Periodontal Health Role of saliva in oral diseases is most apparent when salivary flow is markedly reduced. With respect to periodontal health, saliva plays a role in two ways. Excretory Functions Many drugs, as well as alcohol, are excreted into the saliva, which could theoretically serve as a route of elimination. However, since most of the saliva generated is swallowed rather than expectorated, it is a very inefficient disposal system, since the substances would be absorbed and recycled. Clearly this is a minor function. Water Balance Salivary glands are part of a control system for maintaining an appropriate level of hydration. Thirst and need for fluid intake are usually signaled by dry mouth. This sensation results from a diminution in resting secretion and activation of receptors in the oral cavity. The signals to salivary glands result from The composition, function, and role of saliva in maintaining oral health osmotic changes detected in hypothalamus or volemic changes operating through the renin-angiotensin system of the kidney. Thirst satiation and cessation of drinking are initiated by sensory messages passing into the brain from taste receptors in the mouth. Hormonal Function Several studies have shown that the polypeptide hormone known as an epidermal growth factor, is identical with human urogastrone. Nerve growth factor and transforming growth factor may be closely related as well. Human urogastrone, found in very high concentrations in urine,is readily measurable in the submandibular saliva. The major properties of urogastrone include gastric cytoprotection and inhibition of gastric acid secretion(16).

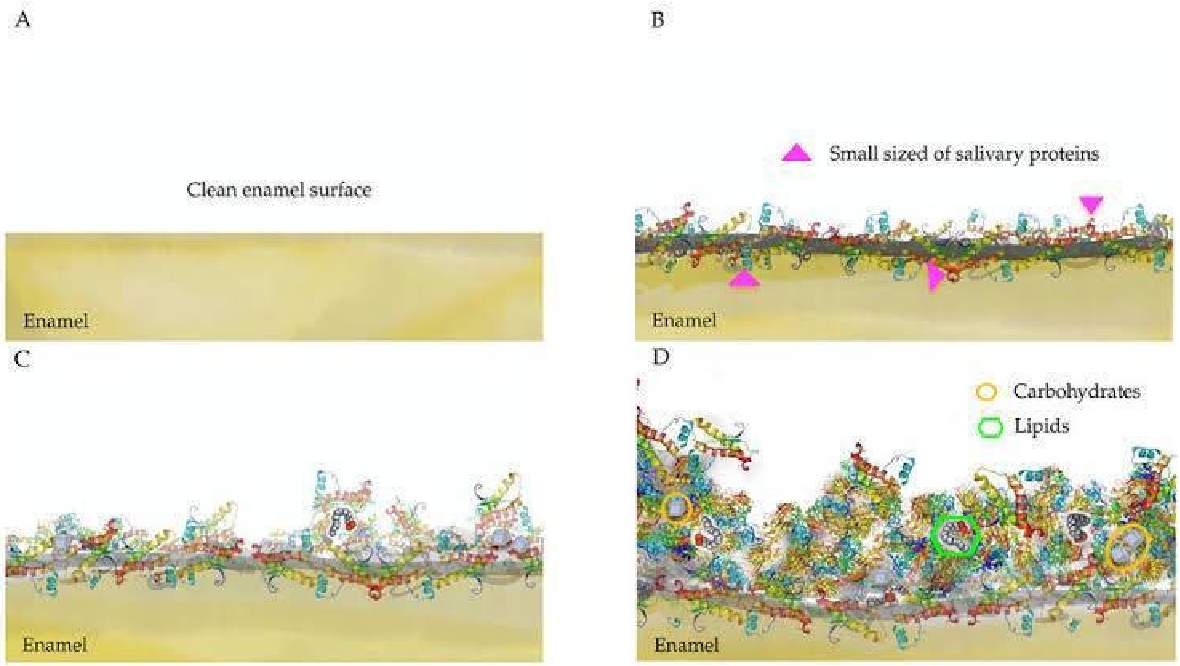
2.4 Enamel pellicle formation

Acquired enamel pellicle (AEP) is a thin layer of protein which covers all the surfaces having enamel. It also covers the layers of dentine and cementum of tooth when enamel is lost to protect the teeth from wearing.

It was first thought that all the proteins of this layer are salivary in origin but after extensive research it has been found that AEP is composed of more than 130 proteins out of which 14.4% are originated from the salivary glands.

Depending on the susceptibility of the surfaces towards aberrations, the thickness of AEP varies from 0.3 to 1.1 micrometer at different locations in the mouth. As soon as the AEP wears off, enamel is reformed in seconds when saliva is exposed to the surface. This property of saliva to reform so quickly on wearer surfaces makes it the most efficient renewable lubricant of mouth The AEP is reported to lower the friction coefficient by 20-fold between opposing teeth. Thus, we can say that AEP provides protection to enamel by aberrations caused by foreign objects i.e. food and toothbrush as well as by attrition that is caused by contact between opposing teeth.

The enamel is composed of calcium and phosphorus in the form of crystalline structure formed exactly of (Ca)10 (PO4)6 (OH)2. Saliva have both Ca and P ions in supersaturated form. In the absence of AEP, there could be deposition of Ca and P making crystals causing the teeth to be enlarged with the passage of time. The presence of AEP not only stop the crystallization but due to its permeable nature, it let Ca and P ion to permeate to the enamel for re-mineralization(17).



Figures (2) Acquired salivary pellicle and oral (18).

2.5 hyposalivation

Decreased salivary flow or hyposalivation is a common problem in older people Hypo-salivation may result in xerostomia, the subjective feeling of dry mouth, but xerostomia may be experienced in cases with normal salivary gland function. The overall estimated preva- lence of dry mouth (xerostomia or hyposalivation) was 22.0% and the prevalence was higher in the elderly population . Although the production of saliva and its composition are largely age-independent in healthy people, a large number of medications can affect salivary flow . Thus, elders may be more prone to hyposalivation. Moreover, higher prevalence of hyposalivation was reported in elders with edentulism or with fewer teeth . However, not many studies examined both xerostomia and hyposalivation, and measured both unstimulated and stimulated salivary flow rates in the same population, especially in dentate elders. The decrease in saliva flow could disrupt several oral functions. When salivary flow is significantly reduced, the oral microbiome is altered . Defects in oral clearance, low salivary pH and changes in salivary compositions lead to microbial dysbio-

sis and increase the risks of oral diseases, including gingivitis, dental caries and fungal infections Candidais a commensal microorganism in the oral cavity. However, when host immune system is compromised or there are local predisposing conditions, these fungi can cause oral and systemic infection (candidiasis) Reduced salivary flow could lead to increased Candidaaccumulation, which could elevate the risk of oral candidiasis(19)A wide range of systemic diseases and conditions are capable of affecting salivary secretion, such as diabetes , Sjögren’s syndrome (SS) , hypertension, hypo- thyroidism, as well as clinical conditions that require the administration of anticholinergic drugs . These drugs cause a reversible effect on the salivary glands by com- peting with muscarinic receptors in the salivary glands As examples, drugs of recurrent use with antihista-mine, antidepressant, antihypertensive, antiparkinsonian, and anxiolytic effects are anticholinergic agents most commonly associated with adverse effects on the salivary glands (20).

Figures (3) Xerostomia (21)

Chapter three

3.1 The effect of saliva on dental restoration materials

The impact of saliva and the oral microbiome on materials has a profound effect on the success and longevity of dental treatmen. One significant manifestation is seen in the deterioration of composite resin restorations (22, 23). Despite their use for purposes and versatility composite resins are vulnerable to the enzymatic activity present in saliva. Salivary enzymes and esterases can compromise the matrix of composites leading to a decrease in properties and potentially affecting the overall integrity of the restoration. Clinically this may result in changes to restoration texture, surface roughness or even partial loss of the restoration over time. Another crucial clinical observation is related to biofilm formation on materials. The oral microbiome consists of microorganisms that contribute to the formation of biofilms on material surfaces. If not properly managed this microbial colonization can lead to complications such, as caries (tooth decay) and inflammation of the gums (inflammation). Signs, like changes in color or texture on the surface of a restoration can suggest the existence of biofilm and activity.

The vulnerability of amalgam to corrosion is a reflection of how the oral microbiome and restorative materials interact. Bacterial byproducts, which are acidic in nature can cause the deterioration of amalgam over time. Dentists may notice changes in the appearance and texture of amalgam restorations indicating that corrosion has occurred. Addressing these issues may involve replacing deteriorating restorations and considering materials that're less susceptible to microbial induced corrosion.

Glass ionomer cements, known for their ability to release fluoride can be influenced by variations in saliva flow rates and composition. The therapeutic benefits of release depend on how the material interacts with saliva. In cases where there are compromised saliva flow rates or differences in composition the expected advantages of release may be affected. Dental professionals may observe differences in how these restorations prevent cavities emphasizing the importance of considering individual patient factors when planning treatment. Advancements in biomaterials like glass and antibacterial composites introduce new possibilities for clinical outcomes. By utilizing glass, which has potential for promoting remineralization and inhibiting growth, improved clinical results can be achieved. Dentists might notice a decrease in cavities or enhanced durability of restorations that use bioactive glass, which is a positive outcome, in the clinical setting (24) .

3.2 The effect of saliva on composite restoration

Although many different restorative materials are available today, resin composites are still considered the first choice by dental practitioners due to their superior properties.In addition to improved esthetics, various resin composites that are biocompatible and easy to apply, with high polishability and mechanical durability, have been developed (25) .

The bond strength between the restorative material and dentin plays an important role in the successfulness of a restoration. Tensile bond strength is influenced by many factors, including physical and mechanical properties of the restorative material, the intra-oral environment and occlusal stresses. In clinical condition, fluid contamination is one of the intra-oral environmental factor. Psychological reasons. Contamination can affect the quality of the bond, leading to microleakage at the interface. As a result of microleakage, loss of the restorations, staining, recurrent caries, postoperative sensitivity, and discoloration may occur.

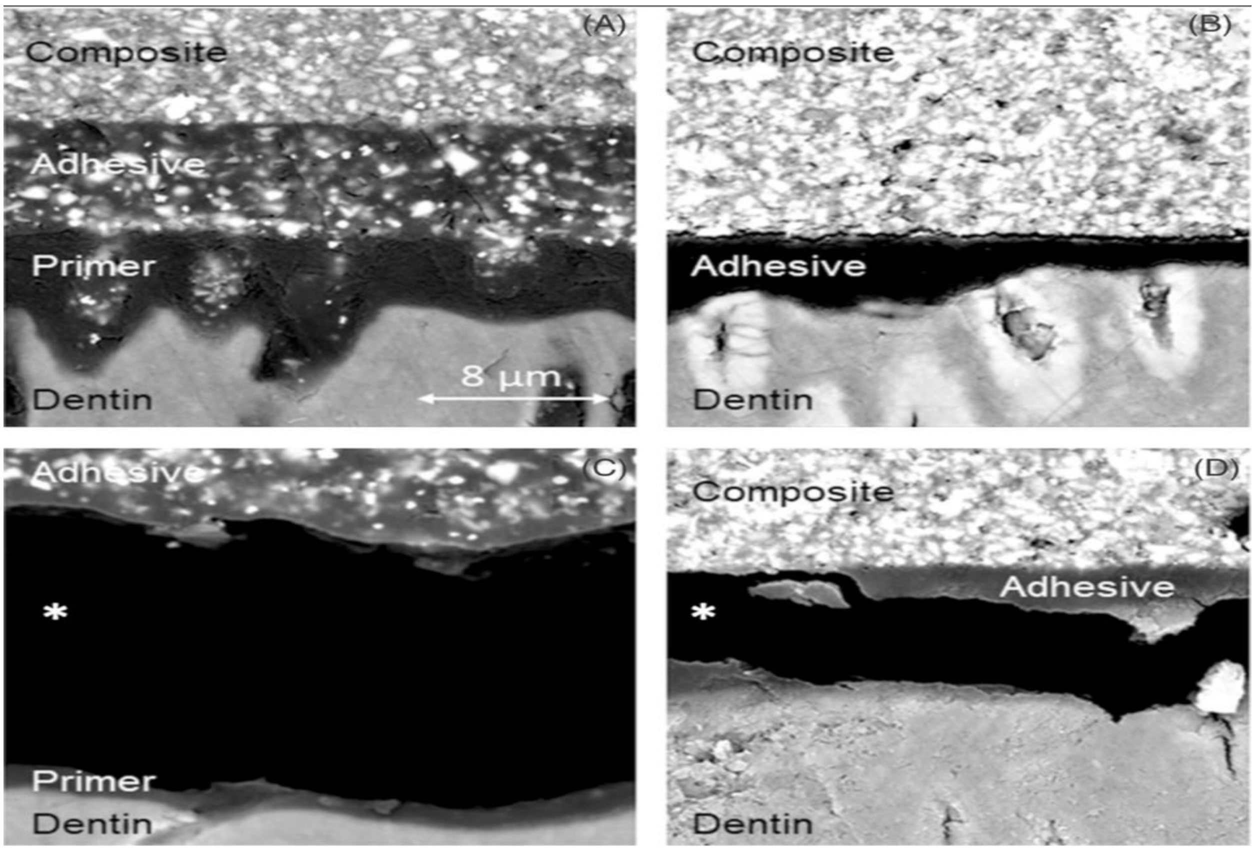
Saliva is an exocrine fluid that consists of 99% water, plus electrolytes, immunoglobulins, polypeptides, and oligopeptides that are important for oral hygiene. Glycoprotein of saliva decreases the efficacy of interaction between the composite resin and the tooth . Saliva has a low surface energy which weakens the adhesive materials (26) .

3.3 The influence of contamination and decontamination with saliva on adhesive system

The options available for restorative dentistry have been essentially changed with the concept of adhesion between the tooth and resin-based restorative. Since the introduction of adhesives for dentin bonding in the 1980s, numerous adhesive products and procedures have been introduced.

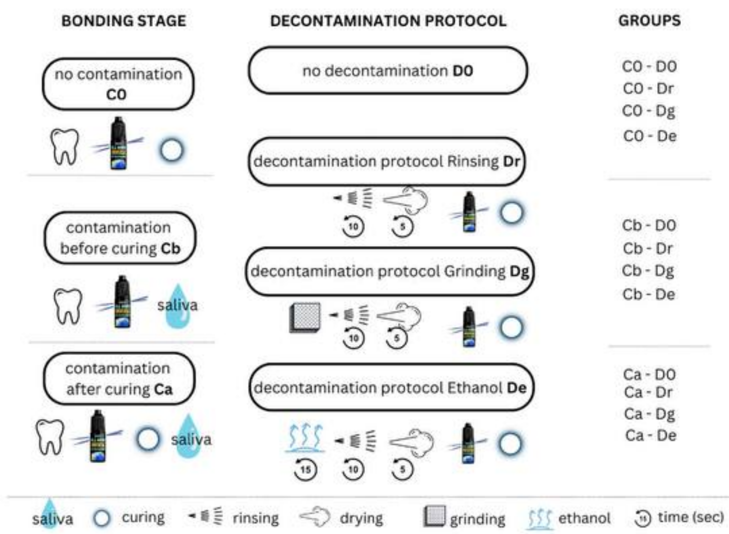
Dental adhesives today can be divided in two main groups according to the adhesion strategy used: etch-and-rinse adhesive systems and self-etch adhesive systems. The etch-and-rinse adhesive system can be further subdivided into three-step adhesive approaches and two-step adhesive approaches. The self-etch adhesive system includes two-step adhesive approaches and single-step adhesive approaches. The etch-and-rinse three-step approach involves three basic steps with successive applications of acid etchant (30-40% phosphoric acid), primer and adhesive, while the self-etch approach involves a self-etching primer and adhesive. Both strategies are represented by numerous products on the market.

It is well established that bonding between a polymer-based restorative material and dentin is based on physico-chemical interaction. Generally, the adhesives are complex mixtures of different promotors, usually substances that have amphiphilic properties . The bonding quality depends on the surface properties of the substrate and the chemical, physical, and handling properties of the adhesive. An intimate contact between the substrate and the adhesive is decisive for a strong bond. The dentin substrate represents a challenging surface, being moist and prone to contamination with blood, gingival fluids or saliva, and accidental contamination of the prepared surfaces is a real risk in the clinical setting (27) .



Figures (4) Scanning electron micrographs (back-scatter mode) (10,000X) of the dentin adhesive/composite interface. (A) Control group of the total-etch approach. (B) Control group of the self-etch approach. (C) Saliva contaminated and air dried after primer application (group 4). (D) Saliva contaminated before adhesive application and air dried (group 6). *The degradation of theadhesive layer (28) .

Saliva contamination is one of the most serious challenges facing any dental operator during restorative procedures. In addition to its water content, saliva contains macromolecule proteins and glycoproteins, alongside particles like calcium, sodium, and amino acids . Both constituents of saliva can adversely affect bond strength. Literature has extensively reviewed the effect of saliva contamination on adhesive restorations. The adverse effects of this persistent clinical challenge includes microleakage at the tooth-restoration interface with subsequent postoperative sensitivity, discoloration and recurrent caries (29) As a general rule for good adhesion, intimate contact between the adhesive and the adherent is required (30). Dentin bonding is considered more difficult than that of enamel, as the water content is higher, which can prevent proper wetting by the hydrophobic dental adhesives (31). Contaminants like saliva, blood and gingival fluid are still considered major risk factors that could further negatively affect the bonding quality to dental substrates (32). Universal adhesives became more commonly used by dental clinicians due to their versatility and ease of use. All-Bond Universal (ABU) is a popular adhesive containing 10-MDP, crucial for durability of dentin bond strength of universal adhesives(33). ABU was used in self-etch mode as previous studies showed no significant difference between bond strength values when used in self-etch and etch-and-rinse modes and it was also recorded that self-etch mode improved bond durability after water storage (34).Saliva contamination before curing of the adhesive may have led to retention of additional water molecules within the adhesive layer decreasing the degree of monomer conversion resulting in weak adhesive and reduced bond strength (35). On the other hand, when saliva contamination occurred after curing of the adhesive, the adherence of salivary proteins to the oxygen inhibited layer of the adhesive could prevent the proper tallying and copolymerization of the following resin layer and thus similarly decreasing the bond strength (33). Hence, for decontamination, rinsing, grinding with SiC grit 600, were used to attempt to mechanically remove the saliva contaminated surface and regain the bond strength. Alternatively, ethanol as a proven organic solvent may be able to dissolve the salivary glycoproteins from the contaminated surface, as well as excess moisture (36). just water rinsing, simple drying and reapplication of the bonding agent was enough to achieve good bond strength after salivary contamination. They also suggested that the acidic monomer component of self-etch adhesives may be able to degrade and denature the salivary proteins thus overcoming the effect of salivary contamination and providing good bonding. The acidity of universal adhesives is determined according to the concentration of 10-MDP functional monomer . Therefore, the results of our study (37). may be attributed to the MDP- containing universal ABU that may have overcome the barrier effect of salivary glycoproteins, increasing the stability of the adhesive, reducing its hydrolytic degradation and forming strong and stable ionic bonds with hydroxyapatite crystals. All Bond Universal is also known for its low water content that contributes to more moisture resistance (38). The contamination agents used were blood, saliva, and hemostatic agents. A great variety of protocols were used to contaminate the dentin surface, and the contamination process occurred in several steps of the bonding process, including before and after the etching process, after the primer application and after the adhesive application. Also, several decontamination procedures were tested, including reapplication of the etching material, rinsing with water, chlorhexidine or sodium hypochlorite and reapplication of the adhesive system(39).



Figures (5) Saliva contamination at different bonding stages and decontamination protocols (40) .

3.4 The influence of saliva ph on surface roughness and discolouration of Dental filling restoration

Esthetic appearance becomes the main demand for adult as well as children. A variety of tooth colored restorative materials is now used in pediatric dentistry as composite resin and compomers for their esthetic appearance. Since oral cavity is a dynamic environment due to presence of saliva, microflora and food, the esthetic restorative materials are always susceptible to changes in surface roughness.

Many factors affect saliva pH as diseases, medications, food and drinks. The change in saliva pH can adversely affect the tooth structure and the esthetic restorative materials .Surface roughness is an essential factor of the restorative material surface.

The material should have smooth surface without porosity as rough surface causes plaque accumulation leading to gingival irritation. Rough surface also diminishes the restoration gloss resulting in more discoloration .Surface roughness can be a result of disintegration of restorative materials when exposed by chemicals or acids retained in the oral cavity. Erosive potential of acidic solution is associated with its pH, titratable acidity and buffering capacity. Rough surface leads to many problems as discoloration, plaque retention and gingival irritation (41).

Over time, RBC restorations in the oral cavity are exposed to various factors such as the forces generated during chewing and the moisture introduced by saliva, as well as chemical compounds present in food and beverages, and thermal effects due to the varying temperatures of the food ingested. RBC materials are susceptible to changes caused by chemicals found in food and beverages, leading to alterations in surface structure and physical properties. Consequently, increased surface roughness can occur over time, resulting in the loss of material's aesthetic qualities and aging.The increase in surface roughness resulting from chemical degradation can lead to issues such as discoloration of restorations, increased plaque accumulation, irritation of soft tissues, and the development of recurrent caries. Although improvements have been achieved in the materials used for dental restorations in modern dental practice, the longevity of dental composites in the oral environment remains a concern for clinicians. Dental composites can undergo changes over time in the oral cavity, such as discoloration, water absorption, dissolution, microleakage, increased roughness, and wear. Such changes are influenced by the type and ratio of fillers, as well as the content and monomers that make up the resin matrix. Deterioration and discoloration of the composite restorations over time still represent their major disadvantages. Especially in today's world, where patients have higher aesthetic expectations, discoloration is one of the main factors affecting the replacement of composite restorations. The color stability of composite resins depends on various factors such as the resin matrix structure, water absorption, filler particle structure and size, and the matrix-filler relationship. Degradation occurring at the filler particle- resin matrix interface and increased surface roughness due to mechanical and chemical deterioration can enhance discoloration (42) .

Chapter four

4.1 Recommendations

1. Improved Oral Health Screening:

Clinicians should be well aware of patients' salivary status, measuring salivary pH and the presence of enzymes. This information can help determine the appropriate materials for treatment.

2. Oral Care Education:

It is important to educate patients on how to care for dental fillings and emphasize the importance of regular checkups to ensure the absence of problems such as caries or biofilm formation.

3. Individual Material Selection:

It is recommended that restorative materials be selected based on the individual patient's condition, including any pre-existing health conditions or saliva production problems that may affect the performance of the fillings.

4. Continuing Research and Development:

The medical and research community must continue to explore the impact of the oral environment on dental materials and develop new materials that can overcome the challenges associated with saliva and the microbiome.

4.2 Conclusions

1. The Complex Interaction Between Saliva and Restorative Materials:

Saliva significantly influences the performance of restorative materials, as its composition and properties can enhance or diminish their effectiveness. Studies have shown that saliva components, such as enzymes and proteins, can cause corrosion of materials used, such as composite resins and amalgams, ultimately degrading the effectiveness of fillings.

2. The Importance of the Oral Microbiome:

Restorative materials face additional challenges due to oral microbes, which can lead to the formation of biofilms. These films can affect the quality of the bond between dental materials and enamel, increasing the risk of caries and periodontal disease.

3. Changes in Surface Properties:

Surface roughness is an important factor affecting the performance of restorative materials. Changes in saliva pH can lead to increased surface roughness of fillings, which promotes plaque accumulation and negatively impacts esthetics.

4. Innovations in Dental Materials:

Modern materials such as bioglass and antibacterial resins offer new opportunities to improve the clinical performance of restorative materials. These innovations aim to reduce the harmful effects of the oral environment, leading to better patient outcomes. The impact of saliva and the oral environment on restorative materials in dentistry is a complex topic that requires a comprehensive understanding. It is important to recognize that each patient has unique oral characteristics that influence treatment outcomes. Therefore, the success of dental materials depends in part on how they interact with the different oral environments. Therefore, ensuring oral health and developing innovative solutions for restorative materials remains an urgent necessity to ensure the sustainability of results and quality of life for patients.

Research in this area is ongoing, and the findings could contribute to improving clinical practices and developing dental materials that promote oral health and reduce caries and periodontal disease.

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