

Saliva in Prosthodontic Therapy – All You Need To Know!

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ABSTRACT

Saliva, a versatile substance, serves many purposes in the oral environment. Saliva is of crucial importance both in edentulous and dentulous persons. In dentulous persons, it serves as a means of buffering the acids produced in plaque from food debris, supplying the inorganic ions required to remineralize incipient lesions and in diluting and washing away sugars from around the teeth. In edentulous patients, it is very important for the retention and comfort of the prosthesis. A comprehensive knowledge regarding saliva is essential for providing efficient prosthodontic treatment and after care.

INTRODUCTION

Neglected by dentists and ignored by physicians, saliva is the least known and the least appreciated of all the body fluids. Yet, this lowly secretion plays a vital role in the integrity of the oral tissues; in the selection, ingestion and preparation of the food for digestion and in our ability to communicate with one another ^[1].

Saliva has manifold functions in protecting the integrity of the oral mucosa; it participates in the clearing of the oral cavity of the food residues, debris and bacteria; it buffers, as far as possible, the deleterious effects of strong acids and bases; it provides the ions needed to remineralize the teeth; it has antibacterial, antifungal and antiviral capacity. Additionally, components of saliva facilitate the motor functions of chewing, swallowing and speaking as well as sensory and chemosensory functions in the oral cavity ^[2]. Saliva plays a central role in the maintenance of oral homeostasis. The importance of saliva is best demonstrated by patients in whom salivary volume is reduced significantly. The patients are at risk for serious oral complications like increase in oral infections such as candidiasis, burning mouth, abnormal taste sensations, caries and difficulty with speech.

Apart from this there exists a definite inter – relationship between saliva and various aspects of prosthodontic treatments. Most investigative effort in removable prosthodontics has been directed towards techniques and designs of denture construction that minimize movement of denture bases on their basal seats. While the mechanical factors in the denture construction have been well described, there has been little recognition of the inter relationship of the denture with salivary secretions and soft tissues in the treatment of edentulous patients ^[3].

Normally, dentures do not rest on bare mucous membranes but on an interposed salivary film. The functions of this film include the protection of the tissues from forces of the denture base and the lubrication and hydration of these tissues so that prosthesis can rest on this layer rather than directly on the oral tissues ^[2,4]. The importance of this film is evident from the multitude of problems associated with denture wear in the xerostomic patient. The prosthesis is but one component of the system, which consists of the denture base, the salivary layer and the oral tissues.

Adequate retention is a basic requirement for acceptance of complete dentures. The contribution of physical forces to the retention of a denture is heavily dependent upon the presence of a continuous thin film of saliva between denture and mucosa which wets both the surfaces [3,4,5].

This article describes the importance of saliva in the various stages of prosthodontic treatment which includes pre-treatment evaluation, during impression making, denture insertion and post – treatment evaluation.

DISCUSSION

Pre-Treatment Evaluation

All major salivary gland orifices should be examined for patency and the viscosity of saliva should be determined.

Saliva can be classified as [6]:

- Class I : Normal quantity and quality of saliva.
Cohesive and adhesive properties are ideal.
- Class II : Excessive saliva. Contains much mucous.
- Class III : Xerostomia. Remaining saliva is mucinous.

The flow rate and viscosity of saliva will affect the denture construction process and the quality of the final product itself. A flow of medium viscosity at normal resting salivary flow rate lubricates the mucosa and assists retention of complete dentures [7].

Many factors can affect the flow rate. Patients of denture wearing age take medications that can reduce salivary flow. Also patients who have received radiation therapy in the region of the salivary glands usually have glandular tissue destruction with resulting reduction in salivary flow. In the absence of a history of radiation or antisialagogue drugs to explain diminished flow, further investigation is warranted [7,8]. The glands themselves may be diseased or ducts can be blocked, although the latter would produce acute distress. Dryness of the mouth affects the retention of the dentures and increases the potential for soreness. Often the palatal glands are destroyed in patients who have worn a complete maxillary denture for many years. The cause is pressure atrophy resulting from lost residual alveolar ridge support of the denture.

An excess of saliva complicates denture construction, especially impression making. When new dentures are first inserted, it is common for the patient to experience a temporary increase in salivary flow [9].

The consistency of saliva can range from a thin, serous type to a thick, ropy consistency. It is best to work with a serous type. Thick saliva makes dentures more difficult to wear.

Impression Stage

The amount and consistency of saliva affects the impression making procedure.

Excessive salivation, particularly by the submandibular and sublingual glands, presents a problem in impression making. When this problem exists, appropriate drugs (e.g.–atropine sulfate) can be administered orally before making the impression [10].

Excessive secretions of mucous from the palatal glands may distort the impression material in the posterior two thirds of the palate.

To counteract this problem

- the palate may be massaged to encourage the glands to empty
- the mouth may be irrigated with an astringent mouthwash just before inserting the impression material
- the palate may be wiped with gauze.
- warm gauze pads may be used to milk palatal glands, followed by cold pads to constrict gland opening.

In patients with xerostomia

- A very careful gentle approach is essential for patients with dry mouth as the mucosa and lips are easily traumatized.
- The lips should be coated with petroleum jelly to help with retraction and access to the oral cavity.
- The operator's gloved fingers should be wetted to prevent them from sticking to the soft tissues.
- A mirror should be used to facilitate insertion of the tray as it is less bulky than the fingers.

Silicone impression materials are the best tolerated and least traumatic to the mucosa. Zinc oxide eugenol paste will adhere to and burn the mouth and materials such as plaster of paris will adhere to the mucosa and abrade it.

Control of Saliva during Impression for Removable Partial Denture Using Irreversible Hydrocolloid

Excessive amounts of saliva can displace alginate impression material and contribute to an inaccurate impression. In most cases, saliva can be controlled by having the patient rinse the mouth with an astringent mouthwash and then with cold water. Subsequently, the patient's mouth should be packed with 4x4 inch gauze that has been folded to form an absorptive strip.

In the maxillary arch, one gauze strip should extend from the posterior portion of the right buccal vestibule to the posterior portion of the left buccal vestibule. The patient should be instructed to hold a second strip against the tissues of the palate. In the mandibular arch, one gauze strip should extend from the right buccal vestibule to the left buccal vestibule. A second gauze strip should be positioned in the lingual sulcus by having the patient raise the tongue, placing the gauze, and then having the patient relax the tongue. The gauze should be gently removed immediately before the impression is made.

Some patients secrete excessive amounts of thick mucinous saliva from the palatal salivary glands. This saliva displaces the alginate and results in inaccurate impressions. These patients should be instructed to rinse with an astringent mouthwash. If a mouthwash is not handy, the problem may be overcome by employing the "Tandem" impression technique, in which one impression is taken to "soak up" the bubbles and mucinous saliva, followed immediately by a second impression which will record the tissues in a relatively saliva-free state.

In turn, gauze sponges dampened in warm water should be used to place pressure over the posterior palate, causing the palatal glands to empty. Patients should then be directed to rinse mouth with ice water. At this point maxillary impressions can be made.

In rare instances, a patient will secrete so much saliva that it becomes extremely difficult to make accurate impressions. The use of an antisialagogue in combination with mouth rinses and gauze packs may be used to control salivary flow in such instances. A 15mg propantheline bromide tablet taken 30 minutes before the impression appointment may be indicated in certain instances. However, antisialagogues should not be prescribed in the presence of medical contraindications such as glaucoma, prostatic hypertrophy, or cardiac conditions in which any increase in heart rate is to be avoided.

Alginate has a tendency to stick to teeth if the teeth are too dry. Sticking of alginate to the teeth occurs when alginate radicals within the impression material form chemical bonds with hydroxyapatite crystals of the enamel ^[12]. As the impression is removed, tearing of the alginate occurs. This produces surface inaccuracies in the impression and the resultant cast.

Adequate moisture control should be accomplished by packing the mouth with gauze pads before making an impression. Gauze pads must be gently removed before the impression material is placed in the oral cavity. Drying with compressed air is contraindicated, because this minimizes the moisture content of tooth surfaces and contributes to sticking of alginate.

Cleaning the Alginate Impression

Failure to remove saliva from the impression will result in an inaccurate cast. Therefore saliva should be carefully removed from the impression surface before the associated cast is poured. Most patients have thin, serous saliva. This type of saliva can be removed by briefly holding the impression under a gentle stream of cool tap water. If running tap water is not effective, the saliva can be removed using a soft camel hair brush and a mild detergent.

On the other hand, some patients have thick, ropy saliva that is difficult to remove. Therefore it is recommended that a thin layer of dental stone be sprinkled on the surface of the impression. The stone adheres to the saliva and acts as a disclosing agent. When the impression is placed under running tap water, the saliva can be removed by light brushing with a wet camel hair brush. If saliva is retained on impression and cast is poured, this results in a cast with rough surfaces ^[12,13].

Control of Saliva during Impression for Fixed Partial Denture

When an impression is made or a restoration is cemented, great degree of dryness is required. It can be achieved by using a rubber dam, high-volume vacuum, saliva ejector, svedopter and anti-sialagogues.

Drugs used to control flow of saliva include Methantheline bromide (Banthine) and Propantheline bromide (Pro-Banthine). Usually one 50-mg tablet of Banthine or 15-mg tablet of Pro-Banthine taken 1 hour before appointment will provide necessary control. Another drug that has been shown to be effective as an anti-sialagogue is Clonidine hydrochloride.

Denture Retention

Saliva is one of the principal components of denture retention. A sufficient layer of saliva is essential for complete denture retention. The contribution of physical forces to the retention of a denture is heavily dependent upon the presence of a continuous thin film of saliva between denture & mucosa, which wets both surfaces ^[13].

The various physical factors are:

- Adhesion
- Cohesion
- Interfacial surface tension
- Capillarity

Adhesion: Adhesion is the physical attraction of unlike molecules for each other.

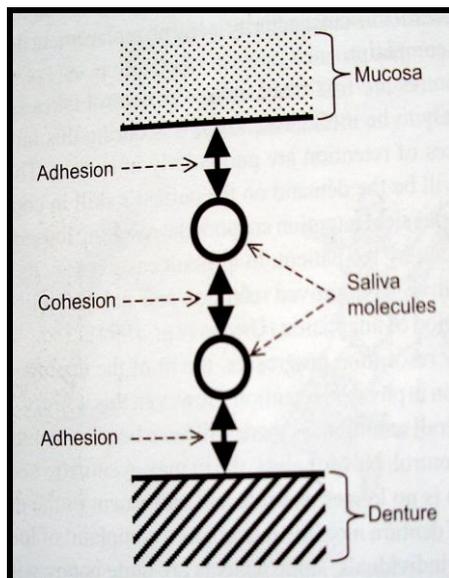
Adhesion of saliva to the mucous membrane and the denture base is achieved through ionic forces between charged salivary glycoproteins and surface epithelium or acrylic resin. Through its promoting contact of saliva to both oral tissue and denture base, adhesion works to enhance further the retentive force of interfacial surface tension.

The amount of retention provided by adhesion is proportionate to the area covered by the denture ^[14]. Mandibular dentures cover less surface area than maxillary prostheses and therefore are subject to a lower magnitude of adhesive retentive forces.

According to Bernard Levin- the most adhesive saliva is thin but containing some mucous component (This can be noticed by placing the index finger on the palatal side of recently removed maxillary denture and 'drawing up' a thin column of saliva). Thin and watery saliva is not as effective and can be identified by its inability to draw up a column of saliva. Thick and ropy saliva is very adhesive but tends to build up and becomes too thick in the palate area and pushes the denture away causing interference with overall adaptation.

Another version of adhesion is observed between denture bases and mucous membranes in xerostomic patient with sparse or absent saliva. The denture base material sticks to dry mucous membrane of basal seat and other oral surfaces like lips, cheek and tongue (Fig. 1). Such adhesion is not very effective for retaining dentures and predisposes to mucosal abrasion and ulceration due to lack of salivary lubrication.

Figure 1: The chain of intermolecular forces contributing to retention.



Cohesion: Cohesion is the physical attraction of like molecules for each other.

It is a retentive force because it occurs within the layer of fluid (saliva) that is present between the denture base and the mucosa and works to maintain the integrity of the interposed fluid. Normal saliva is not very cohesive so that most of the retentive force of the denture mucosa interface comes from adhesive and interfacial factors unless the interposed saliva can be modified (with the use of denture adhesive).

Thick, high-mucin saliva is more viscous than thin, watery saliva, yet thick secretions usually do not result in increased retention because watery, serous saliva can be interposed in a thinner film than the more cohesive mucinsecretions [15]. Stefan's law makes it clear that if all other factors are equal, then an increase in fluid viscosity cannot be accompanied by an equal increase in film thickness if displacement force is to be kept the same. Hence, in case of complete denture retention, the combined effect of adhesion, cohesion will provide retention due to forces developed with molecules of denture base materials, molecules of saliva and molecules of the mucous membrane.

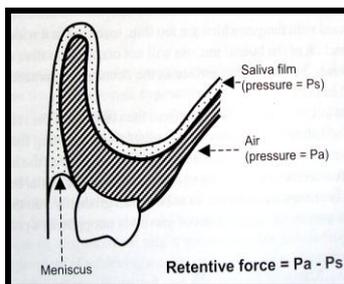
Interfacial Surface Tension

Surface tension is the result of cohesive forces acting at the surface of a fluid. Interfacial surface tension is the resistance to separation of two parallel surfaces that is imparted by a film of liquid between them. Interfacial surface tension is dependent on the ability of the fluid to 'wet' the rigid surrounding material. If the surrounding material has low surface tension, as oral mucosa does, fluid will maximize its contact with the material, thereby wetting it readily and spreading out in a thin film. If the material has high surface tension, fluid will minimize its contact with the material, resulting in the formation of beads on the material's surface [15,16]. All denture base materials have higher surface tension than oral mucosa, but once coated by salivary pellicle, their surface tension is reduced, which promotes maximizing the surface area between liquid and base. The thin saliva film between the denture base and the mucosa of the basal seat therefore furnishes a retentive force by the virtue of the tendency of the fluid to maximize its contact with both surfaces.

Interfacial surface tension may not play as important a role in retaining the mandibular denture as it does for the maxillary one, because in many patients, there is sufficient saliva to keep the external borders of the mandibular denture awash in saliva, thereby eliminating the effect of interfacial surface tension. This is not so in the maxilla.

Also, in case of saliva, the cohesive forces result in the formation of a concave meniscus at the surface of the saliva in the border region of the denture. When a fluid film is bounded by a concave meniscus the pressure within the fluid is less than that of the surrounding medium; thus a pressure differential will exist between saliva film and air and thereby aids in the retention of the denture [12,16,17] (Fig. 2).

Figure 2: Retention due to pressure differential between the saliva film and air



The size of this pressure differential is inversely related to the diameter of the meniscus i.e., the closer the fit of the denture to the tissues the stronger the retentive forces attributable to surface tension.

Capillarity

When the adaptation of the denture base to the mucosa on which it rests is sufficiently close, the space filled with a thin film of saliva acts like a capillary tube in that the liquid seeks to increase its contact with both the denture and the mucosal surface.

When the denture is adjusted on the tissue surface, a space of about 0.1mm is created between the denture and the mucous membrane. In this way, the condition for the capillary attraction to come into action is developed. The more narrow the space, the greater the attraction. When good wetting of the walls of the space occurs, the attraction inside the liquid is lowered because of capillary attraction. In case of the mucous membrane, saliva and the denture base, the denture is attracted to the mucous membrane by a force whose magnitude responds to the difference of attraction of the exterior atmosphere and the saliva under the denture. Thus capillary attraction may be the force which results in denture retention [17,18,19].

Capillary attraction in a capillary tube or space ceases to be effective if the tube is submerged under the surface of the same liquid. A similar situation occurs in the lower complete dentures. The basal seat tissues of the lower jaw are wetted in saliva far more intensively than the basal seat tissues of the upper jaw. Therefore, the capillary attraction in the lower complete dentures functions only very little and for a short period of time in many instances as saliva accumulates.

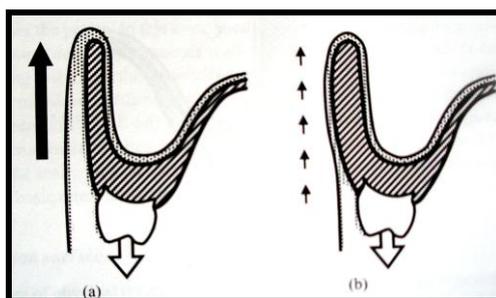
Viscosity of saliva:

Saliva, a relatively viscous liquid, is present in the space between the denture base and the mucous membrane. The viscosity depends on the proportion of secretion of the serous and mucous glands. The movement of a viscous liquid can be imagined as a successive shifting of infinitesimal layers. During this shifting, friction develops which tends to impede the shifting. At a sufficiently small distance between the denture and the mucous membrane, the layer of saliva is parallel to both walls and the resistance of this layer is indirectly proportional to the distance. Dislodgement of denture is rendered possible in the initial phase only but the fact that the quantity of saliva between the mucous membrane and the denture base increases by a certain volume from the surroundings and from palatal glands [20,21].

Viscosity of saliva, then, is not a direct source of the force which retains the denture. However, viscosity of saliva helps prevent the dislodgement of denture, especially in the initial phase and so it becomes an important factor in denture retention.

As denture is pulled away from the tissues, saliva is drawn into the space being created beneath the denture. A retentive force is generated by a resistance to this flow of saliva, resulting from the viscous properties of saliva and the dimensions of the channel through which it flows (Fig.3).

Figure 3: Relationship between the width of the buccal channel and resistance to flow of saliva



- a) Wide channel, rapid flow, poor retention.
- b) Narrow channel, slow flow, good retention.

Very viscous saliva is associated with relatively poor retention, because excessive viscosity of saliva leads to thick and discontinuous film between denture and mucosa. Air flows more readily than saliva. This offers very little resistance to denture displacement.

The denture flange is rigid while the soft tissues of the cheeks or lips are movable. If the denture is displaced, the pressure within the saliva film drops and mucosa is drawn tightly against the denture surface. The channel between the two becomes narrow leading to increased resistance to the flow of saliva. This aids in increased retention [20,22].

Interfacial Viscous Tension

According to Boucher, interfacial viscous tension refers to the force holding two parallel plates together that is due to the viscosity of the interposed liquid. According to Stefan's law, for two parallel circular plates of radius 'r' that is separated by a Newtonian (incompressible) liquid of viscosity 'k' and thickness 'h', the force 'F' necessary to pull the plates apart at the velocity 'V' will be [21,23,24]

$$F = (3/2) \pi k r^4 / h^3$$

i.e., viscous force increases proportionally to increase in the viscosity of saliva.

Denture Insertion and After Phase

New dentures are often interpreted as foreign objects by the oral system. This leads to stimulation of salivary glands to produce saliva. On excessive salivation patient may complain of floating dentures. But this decreases over the weeks after denture insertion [25,26].

Also it is generally recognized that dentures have some effect on taste sensation. But the exact nature of sensory alteration and the role of saliva are not well understood.

If good denture hygiene is not maintained, in the long run, saliva modulates the colonization of micro organisms in the pellicle leading to plaque formation which in turn leads to denture stomatitis.

Taste

Apart from alteration in sensory mechanisms, other factors which have been explored in relationship to effect on taste sensation are age and saliva. Recent controlled studies show only a small decrease in ability to taste salt and bitter and no significant impairment of taste function to sweet and sour with human aging [25,27]. Since a substance or tastants must be present at the taste receptor in a solution, the role of saliva in taste function may be that of a tastants solute. Many xerostomic patients exhibit altered taste abilities. However, irradiated patients and Sjogren's syndrome patients have been shown to have damage to the taste cells. Short term decreases in salivary flow in humans following drug administration has not been found to alter taste acuity.

Salivary composition may also be related to taste acuity. Sodium levels in saliva have been positively correlated with salt taste threshold levels although levels of salivary glucose apparently have no effect on sweet taste threshold. Henkin et al[28] demonstrated that a patient population with idiopathic hypogeusia (decreased taste acuity) was deficient in zinc concentrations in parotid saliva, which could be restored with dietary zinc supplements.

In summary, no single factor, whether prosthesis use or salivary quantity or composition, has been correlated with altered taste perception. It is more likely that dentures may mediate some change in salivary characteristics that may subsequently alter the perception of taste.

Pellicle as a Mediator of Plaque Formation

When denture prosthesis is placed in the oral cavity, a layer of saliva is rapidly adsorbed to the surface. This is termed the acquired denture pellicle (ADP). The presence of ADP is described in ultrastructural studies as a thin (2 to 4 µm) electron dense layer that may appear organized as a striated lamellar palisade [30]. Microorganisms are then observed in contact with this pellicle layer instead of becoming attached directly to the denture surface. Pellicle deposition has shown to be specific for both the adsorbent surface and the composition of saliva in contact with the surface. ADP has been shown to differ in composition between the tissue and polished surfaces of complete dentures. Therefore, it may be expected that microbial adherence is specific for the individual denture surface [30,31].

The ability of bacteria to survive and grow in an ecosystem in the oral cavity is dependent on their ability to selectively adhere to hard and soft tissue surfaces. Microbial adherence has been shown to involve nonspecific ionic or hydrophobic interactions with the surface layer and specific interactions with salivary glycoproteins. Selective binding of microorganisms to salivary components may act as a mechanism of adherence when these components are part of an adsorbed surface layer.

The minor salivary glands of the palatal mucosa must be considered a major source of ADP on the tissue side of the maxillary denture. This is due not only to their close opposition to the denture base, but also to the isolating effect of the maxillary palatal surface, which is designed to create a border seal [28,32]. Although the intraoral environment is often considered a homogenous composition of all salivary secretions, marked environmental differences exist between sites within the oral cavity because of differences in the accessibility of uniform salivary flow. Changes in salivary contact with surfaces may alter subsequent microbial colonization [33,34].

Denture Plaque, Denture Stomatitis and the Adhesion of *Candida albicans* to Inert Materials

Biofilm forms on hard non-shedding surfaces in the oral cavity. These surfaces include, in addition to tooth enamel, restoratives, implants, crowns and bridges, dentures (full & partial) and accompanying tissue conditioners, obturators and other maxillofacial prostheses. These appliances encompass a wide range of materials including metals, plastics and silicones and their chemical composition and physical properties will affect the formation of biofilm on their surfaces.

Denture Plaque

There is a general agreement that denture plaque is broadly similar to dental plaque in composition particularly that from occlusal surfaces, both niches that offer a relatively protected environment. Facultative anaerobic Gram-positive cocci, particularly streptococci which comprise 40-50% of the total cultivable population and Gram-positive rods predominate in denture plaque from healthy subjects. Gram-negative rods and yeasts appear to be relatively scarce. Yeasts have been found to comprise only 0 - 0.45% of the total cultivable population. Few obligate anaerobes have also been described. Similarities between denture plaque flora and that of gingival crevice have been noted and saccharolytic bacteroides and fusobacteria in healthy denture plaque identified [31,35,36].

The plaque microflora varies between sites in the mouth. On the denture, differences between the buccal flange, the smooth denture tooth surface, the denture 'tooth gum interface' and the denture fitting surface have been identified. Yeasts were present on external surfaces less often than on the fitting surfaces. The environment enclosed by the fitting surface is more stagnant and this

would facilitate plaque accumulation and hence enhance the yeast cells' chances of being retained; it also has a more acidogenic plaque population than those of the more exposed denture surfaces [28,37].

Denture Plaque Formation

Plaque formation is usually preceded by the adsorption of a pellicle onto the naked substratum. The composition of the pellicle on denture acrylic as compared with tooth enamel may vary due to the differing chemical nature of the substratum and the possible presence of serum exudates from tissue which might be damaged by an ill-fitting denture. Pioneer species are Gram-positive rods and cocci, particularly streptococci, whose dextran provides an anchor for secondary colonizers.

Accumulation proceeds primarily by the multiplication of adherent bacteria and deposition of others and tends to be more rapid/successful in protected areas of the surface. Within 24 – 48 hours, the plaque is several micrometers thick and the microflora is predominantly Gram – positive. Staphylococci, particularly *Staphylococcus aureus*, are often isolated from the denture. Other unexpected bacteria which have been cultured from dentures, such as *Streptococcus pneumoniae*, *Haemophilus influenzae* and *Neisseria meningitidis* are deemed to be transient. Enterobacteriaceae may be present as a result of a lack of denture hygiene and/or the immunosuppressed state of an elderly wearer [38,39]. The denture may spend time out of the mouth, in a less than hygienic environment and can easily become contaminated with microorganisms foreign to the oral environment.

Denture Stomatitis: A Plaque Mediated Disease

A complete or partial denture surface in contact with the palatal mucosa can provide an environment highly susceptible to plaque mediated disease called denture induced stomatitis (DIS). The term describes a bright red inflammation in the oral mucosa in contact with the fitting surface of a denture usually the maxilla.

Denture stomatitis is usually graded clinically in 3 types^[40]

Type 1 – localized inflammation or pinpoint hyperemia

Type 2 – diffuse erythema

Type 3 – inflammatory papillary hyperplasia.

The area of the most extensive inflammation is usually clearly delineated by the denture fitting surface. Types 2 and 3 have been associated with infection by *Candida albicans*. Patients are often not bothered by, or even aware of the condition, the initial alert being associated with more overt infection such as angular cheilitis, glossitis or rarely oral thrush.

Trauma to the underlying tissues by a poorly fitting prosthesis with occlusal disharmony is one contributing factor in denture stomatitis. Occlusal adjustment or refitting of the dentures can result in complete resolution of denture stomatitis. Although allergic response to the denture base material has been suggested as an etiology, no instance of true allergic sensitization has been reported [41].

Infection of the palatal mucosa by *Candida albicans* as a cause of DIS was first demonstrated by Lyon and Chick. Cultures from direct smears of the palatal mucosa of patients with DIS demonstrated significantly higher percentages positive for *Candida* species compared with those from patients with a healthy palatal mucosa. In addition, the quantity and location of fungal colonization could be directly correlated to the degree of palatal inflammation. Further evidence of the involvement of *Candida albicans* in denture stomatitis is the effectiveness of short term topical treatment with antifungal oral rinses, such as nystatin and amphotericin B [41,42].

A more consistent association is the microbial infective origin of denture stomatitis by denture plaque. Patients with DIS have significantly higher plaque and yeast counts than control patients. In both groups however yeasts constitute less than 1% of total bacterial counts although patients with DIS have both a relative and absolute increase in the number of yeast cells. Studies correlating plaque levels and *Candida* counts with tissue erythema suggest a positive but independent relationship [41,42,43]. These studies implicate yeast antigens and toxins of denture plaque as significant factors in the initiation and maintenance of DIS [41,43].

Adhesion of *Candida* to Inert Surfaces

Candida albicans is imperfect dimorphic yeast. It is a common commensal of mucosal surfaces, particularly the gut and is an opportunistic pathogen. In adhesion work, the most common method entails the incubation of standardized yeast cell (blastospore) suspensions with substratum, after which the number of adherent cells are assessed. Factors affecting adhesion have been explored and a range of standard factors are widely accepted, such as live cells adhere in higher numbers than dead cells, indicating an active process; germ tubes are more adherent than blastospores, providing an association of dimorphism with virulence; the presence of saliva or *Streptococcus salivarius* on the substratum decrease adhesion.

Growth of *Candida albicans* in carbohydrate stimulates the production of a 'fibrilofloccular layer'. This extracellular polymeric material was proposed to be mannoprotein.

Adhesion to naked surfaces has been described as 'non-specific' since there are no biological interactions occurring between cell and substratum. Physico-chemical features associated with adhesion, such as hydrophobicity, have been described [44,45]. *Candida tropicalis* strains are usually more hydrophobic than *Candida albicans* and the adhesion of the two species to naked substrata is comparable although *Candida tropicalis* is far less pathogenic. However, in vivo, all interacting surfaces will be surrounded by a conditioning film, thus specificity returns, and the attributes of *Candida albicans* presumably cause the organism to regain its advantage.

Surface Topography and Cell Retention

Most studies on the in vitro adhesion of *Candida albicans* to inert surfaces take great care to ensure that the substrata are comparably smooth, to facilitate reproducibility [46,47]. In vivo, the upper fitting surface of the denture is far from smooth; in vitro a small increase in surface roughness of a poly methyl methacrylate substratum resulted in significantly higher numbers of *Candida albicans* being retained on the surface. Both the type and degree of roughness influenced adhesion. It may be that ultimately the formation of a mature biofilm is unaffected by substratum roughness, but colonization of surfaces by organisms other than pioneers is facilitated if viable cells are trapped in surface defects. This retention would be particularly useful for large cells such as *Candida*, for which active adhesion on a smooth surface is variable and which a pioneer species is probably not usually. Thus in addition to attempting to create low adherent surfaces by chemical modification or by using copolymers with drug delivery systems, merely casting materials against smoothest appropriate surface, will increase smoothness and reduce microbial retention on the surface. The use of a smoother surface will therefore reduce fouling and enhance cleansability [47,48] (Fig 5).

Figure 4: Drop in pressure of the saliva film beneath the denture causing the impaction of the buccal mucosa and greatly increased retention.

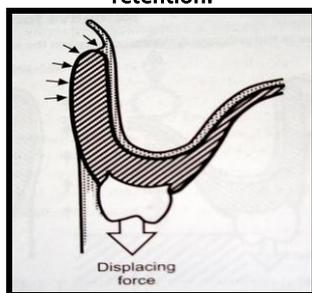
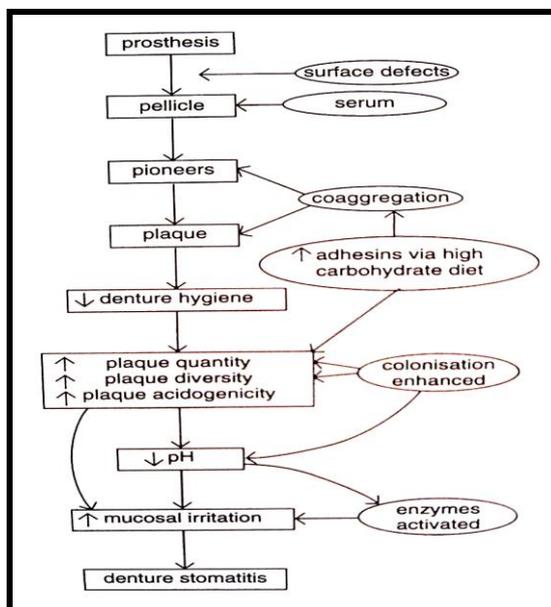


Figure 5: Flow chart depicting the development of denture plaque and possible progression to denture stomatitis. Factors conducive to *Candida* colonization are shown on the right hand side of the chart.



Candida in Biofilm on Other Biomaterials

Dentures are most commonly constructed of polymethylmethacrylate, which most authors believe resist penetration by the biofilm on its surface.

In maxillofacial prostheses, silicones are used heavily, with different structural parts being exposed to different environments. Contamination may lead to aesthetic spoilage as well as providing a focus of infection. Denture soft linings/tissue conditioners are used to improve the fit and comfort, being softer than denture acrylic. The surface is more prone to penetration by microorganisms and the surface texture and chemistry hamper effective mechanical cleaning. Silicone rubbers are particularly prone to colonization. Candida involvement in biofilm on silicone voice prostheses and gastrostomy tubes have also been described.

Thus in the oral environment and in other parts of the body, biofilms accumulate on a variety of inert foreign surfaces which have a relatively extended stay particularly those surfaces which are more penetrable. The microbiology of such films has been investigated little but Candida has been isolated frequently and has been associated with infection. It may be that these films are different from those formed on denture acrylic and that the surface texture of the materials used facilitates Candida colonization far more than does the denture material and/or the yeast could be a secondary invader. Denture fabricated from metal are less common but are much less frequently associated with denture stomatitis. This may be due to different properties of the substratum and to the different prosthesis design ^[48].

Microbial Colonization – Dental Titanium Implants

Dental titanium implants are commonly used as substitutes for lost teeth. Titanium seems not to have a significant antibacterial effect on microorganisms in vivo and does not offer different bacterial binding properties compared to other materials. The success of dental implants is related to their rapid colonization by low virulent streptococci and Actinomyces that prevent pathogenic microorganisms becoming established. Similarly as on the tooth surface plaque on dental implants undergoes changes resulting in a more gram negative and anaerobic flora contemporary with the development of inflammatory reactions in the gingiva. The mechanism underlying implant failure is not known, but the microflora in the peri-implantitis with the loss of supporting bone is strikingly similar to that of the tooth with periodontal disease ^[49].

Microbiology at Healthy Oral Implants Sites

The primary colonizers on oral implants are Streptococcus and Actinomyces species bound through receptors mediated by salivary glycoproteins in the oral biofilm.

Successfully osseointegrated implants are characterized by little plaque and no marginal inflammation. Plaque microbial composition at well maintained implant sites shows many similarities with that of the tooth at gingival health ^[50,51]. The subgingival plaque of stable osseointegrated implants is dominated by coccoid cells and predominantly gram positive organisms. Streptococcus sanguis, Streptococcus oralis, Streptococcus mitis, Actinomyces naeslundii, Veillonella parvula and Fusobacterium nucleatum are dominating species while black pigmented gram negative rods, Prevotella and Campylobacter are present at less than 1% of the total. Despite the fact that plaque development on implants and on teeth shows a microbiologically similar pattern, there might be differences in the very early phases of microbial establishment. Several factors can be involved in bacterial establishment to foreign materials e.g.: material toxicity, the surface biofilm and material roughness.

Material Toxicity

The antibacterial effect of dental restorative materials, especially metals is well known. The antibacterial effect of titanium is however somewhat controversial. While some studies ^[50,52,53] have shown no influence of titanium on various oral gram positive and gram negative species in vitro, others have found some antibacterial activity. Titanium has also been suggested to have antimicrobial and anti-inflammatory effects due to the formation of peroxides at the titanium surface in vitro. It is not known whether this phenomenon is of biological significance.

Although many metals and alloys exert a toxic effect in vitro, microbial plaque is formed on such dental materials in vivo. Plaque formation on titanium, amalgam and hydroxyapatite followed the same pattern in terms of rate and composition during the first 72 hours of installation in the human mouth. This insignificant effect of the underlying material was explained by a hampered release of metal ions from the surface by the formation of a protecting pellicle mainly originating from saliva. However, close to the gingival margin organic components from serum and gingival exudates may also participate ^[52,54].

Bacterial Adherence

Adherence of oral bacteria to tooth surfaces and restoratives is generally mediated by unspecific binding through hydrophobicity and electrostatic forces and/or by specific binding to surface pellicle receptors. Since the latter might be dependent on compositional alterations due to the underlying material, this may change the specificity of the bacterial binding. While a material dependency on the direct binding of microorganisms to the naked surface has been shown this binding is considerably reduced and the material dependency is almost abolished when the surface is covered by a pellicle. Although, there is very little evidence of specific protein pellicle formation on different dental materials, studies indicate that pellicle composition between individuals might be different and thus may promote in various degrees adhesion of *S.sanguis* and *Actinomyces viscosus*.

Experimental plaque formation on titanium, amalgam and hydroxyapatite in vivo showed striking similarities in bacterial composition even after 10min and strongly resembled the composition of early plaque composition on a tooth surface [52,55].

Microbiology at Failing Implants

Despite the high success rate of dental implants failures do exist and a significant number of implants are lost due to peri-implantitis [56,57]. Tissue breakdown can be even more substantial around implants compared to the natural tooth and there is a high failure rate in patients with persisting own teeth and in those with previous history of periodontitis. A combination of a periodontitis associated microflora and a susceptible host may thus predispose towards implant failure. Implant failure are characterized by a complex peri-implant microbiota resembling that of adult periodontitis [58]. Thus the subgingival flora of failing implants is dominated by *Prevotella* and *Porphyromonas* species, spirochetes, fusobacteria and campylobacter, while *Streptococci* and *Actinomyces* although present are proportionally lower in number than in healthy situations. An increased proportion of putative periodontal pathogens has been documented at implant sites of dentate patients as compared to edentulous, suggesting that the periodontal pocket may serve as a reservoir for bacterial colonization of titanium implants [59,60].

Osseointegrated titanium implants installed in the oral cavity are exposed to the saliva and its microflora and are immediately colonized by non-virulent oral bacteria. If plaque is allowed to accumulate, this leads to inflammatory reactions in the adjacent tissues. Peri-implantitis increases the risk of more virulent microorganisms becoming established and thereby the risk of failing implants.

CONCLUSION

A wealth of evidence suggests that saliva plays a profound role in the maintenance of oral health in the prosthetic patients. Indeed the presence of a thin salivary layer is essential to the comfort of the mucosa beneath a denture base and to denture retention. Saliva also plays a pivotal role in the initiation and maintenance of plaque mediated disease, denture induced stomatitis, found in significant numbers of complete and partial denture wearers. Additionally, saliva is involved in calculus deposition and stain formation on the denture surface and has a role in the mechanism of taste sensation, speech and swallowing.

Research in salivary physiology and chemistry is just beginning with the recognition of the significance of saliva to oral and dental health. Much work remains to provide better therapies to patients suffering from salivary gland dysfunction beyond the simple prescription of artificial saliva.

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