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Epidemiology and Etiology of Denture Stomatitis

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Abstract

Denture stomatitis, a common disorder affecting denture wearers, is characterized as inflammation and erythema of the oral mucosal areas covered by the denture. Despite its commonality, the etiology of denture stomatitis is not completely understood. A search of the literature was conducted in the PubMed electronic database (through November 2009) to identify relevant articles for inclusion in a review updating information on the epidemiology and etiology of denture stomatitis and the potential role of denture materials in this disorder. Epidemiological studies report prevalence of denture stomatitis among denture wearers to range from 15% to over 70%. Studies have been conducted among various population samples, and this appears to influence prevalence rates. In general, where reported, incidence of denture stomatitis is higher among elderly denture users and among women. Etiological factors include poor denture hygiene, continual and nighttime wearing of removable dentures, accumulation of denture plaque, and bacterial and yeast contamination of denture surface. In addition, poor-fitting dentures can increase mucosal trauma. All of these factors appear to increase the ability of *Candida albicans* to colonize both the denture and oral mucosal surfaces, where it acts as an opportunistic pathogen. Antifungal treatment can eradicate *C. albicans* contamination and relieve stomatitis symptoms, but unless dentures are decontaminated and their cleanliness maintained, stomatitis will recur when antifungal therapy is discontinued. New developments related to denture materials are focusing on means to reduce development of adherent biofilms. These may have value in reducing bacterial and yeast colonization, and could lead to reductions in denture stomatitis with appropriate denture hygiene.

Denture stomatitis is a very common disorder affecting denture wearers. It is characterized as inflammation and erythema of the oral mucosal areas covered by the denture.[1-3] Several studies suggest that up to two-thirds or more of individuals who wear removable complete dentures can suffer from denture stomatitis.[3-6] Despite its frequency, denture stomatitis is most often asymptomatic; only a minority of sufferers experience pain, itching, or burning sensation, and the disorder is primarily diagnosed during examination as presence of inflammation or swelling of mucosal tissues covered by the denture.[2,7]

Despite its commonality, the etiology of denture stomatitis is poorly understood. Associations of denture stomatitis have been reported with mucosal trauma due to poor denture fit, increasing age of the denture user, increased age of dentures, bacterial and fungal (primarily *Candida)* infection, and poor denture hygiene;[1,4,5,8] however, no clear cause-and-effect relationships have been demonstrated for most associated etiologic factors. Indeed, the current thinking is that the etiology of denture stomatitis is multifactorial. In many incidences it likely includes a pathogenic response to *Candida* infection, and primarily infection with *C. albicans*.[5-7]

While access to dental care is improving, and persons are retaining their natural dentition for longer periods of their lives, the occurrence of edentulousness remains significant, especially among the elderly. The need for long-term use of dentures will remain for the foreseeable future, and as a consequence, a sizable at-risk population for denture stomatitis will remain.[9] This review provides an update on the epidemiology and etiology of denture stomatitis and the potential role of denture materials in this disorder. As denture matrices differ in the ability of oral bacteria and yeast to form biofilms and colonize them, they may reflect greater or lesser susceptibility for occurrence of denture stomatitis.

Methods

Articles were identified by a search of the PubMed electronic literature database. Articles listed in the PubMed database through November 2009 are included. Search terms included "denture stomatitis" and "denture sore mouth" associated with terms related to epidemiology, etiology, and treatment. The search was limited to studies in humans and those published in English.

Titles and abstracts of identified articles were reviewed by this study's authors (LG, ZGL), and relevant articles obtained. Data related to epidemiology and etiology were extracted and summarized for this review. Additional articles addressing the potential impact of denture materials on denture stomatitis were reviewed and summarized.

Results and discussion

Epidemiology

Table 1 summarizes studies evaluating the prevalence of denture stomatitis. Prevalence rates, as prevalence among denture wearers only, are reported, as this is the at-risk population for denture stomatitis. Individuals wearing complete versus partial dentures, or combinations of complete and partial dentures were not separated into classes, as many of the articles did not provide this information. Several studies categorized denture stomatitis by severity, which was generally assessed using scales developed by Newton[10] or Budtz-Jorgensen and Bertram.[11]

Several studies reported denture stomatitis prevalence based on general population surveys. NHANES III (3rd National Health & Nutrition Examination Survey), surveyed a representative U.S. population sample. The study included 33,994 individuals, of whom 17,235 underwent dental examination and 3450 had at least one removable denture.[12,13] In the United States, about 20% of adults wear removable dentures. The prevalence of denture stomatitis among denture users reported in the NHANES III study was 28% (Table 1), with prevalence rates of 35% and 18% among persons wearing removable complete maxillary and mandibular dentures, respectively. National and regional population-based studies conducted in Denmark, Slovenia, Spain, and Turkey reported prevalence of denture stomatitis among denture wearers of 65%, 14.7%, 19.6%, and 18.5%, respectively.[14,15-17] The high incidence of denture stomatitis observed in the Danish study was associated with poor denture hygiene and a high prevalence of associated *Candida* infection in an elderly population.[14] The study from Turkey involved dental exams in 765 randomly selected residents of the Kartal region of Istanbul. Twenty-six percent of this study population wore removable dentures, and the incidence of denture stomatitis was quite low (18.5%).[15] Two population-based studies have been conducted in Finland, one a national sample[18] and the other an age-stratified sample of home-living elderly residents in Helsinki.[19] The studies reported a prevalence of denture stomatitis of 48% and 35%, respectively. The representative national population-based survey conducted in Finland in 1984 included 7190 adults, of whom 3856 wore removable dentures, suggesting that almost 44% of adults in Finland had dentures.[18] A national population-based survey conducted in Germany in 1997, the Third German Oral Health Study, reported denture stomatitis prevalence in the general population (not exclusively denture wearers) to be 2.5% and 18.3% in cohorts aged 34 to 44 and 65 to 74 years, respectively.[3]

Over a dozen studies have evaluated denture stomatitis prevalence exclusively among elderly populations, reporting prevalence ranging from 15% to 71%.[14,18,20-30] The studies assessed elderly living in both community and in nursing-home or long-term care facility settings. A 1987 publication by Vigild reported a 34% prevalence of denture stomatitis among elderly denture wearers living in nursing homes and long-term care facilities in Denmark.[21] This is about one-half the rate of stomatitis reported in a 1975 study conducted among community-dwelling elderly Danes by Budtz-Jorgensen et al[14] Two studies have evaluated denture stomatitis among elderly residents of Finland, reporting prevalence rates of 35% and 25% among home-living and institutionalized denture wearers, respectively.[18,23] Studies conducted in South America reported a prevalence of denture stomatitis of 34.5%, 58.2%, and 54% among elderly community residents in Santiago, Chile, elderly denture wearers in a rural community in Brazil, and elderly patients in Brazilian long-term care facilities, respectively.[20,25,30]

Several studies reporting prevalence of denture stomatitis focused on denture wearers visiting dental or prosthetic clinics for treatment, adjustment, or replacement of dentures. The studies included sites in Canada (three studies), Mexico, Brazil, Turkey (three studies), Jordan (two studies), Scotland, and Spain.[31-42] This group of studies mostly involved single sites. To reduce inter-patient variability, the designs usually involved a single investigator at each site conducting examinations and diagnosing and categorizing denture stomatitis. Denture stomatitis prevalence ranged from 17% to over 77%, with eight of the twelve studies reporting prevalence of 45% or more. The size of the individual studies varied, and this may have impacted the outcomes; the prevalence of stomatitis in six studies evaluating 200 or more denture wearers was 17% to 55.5%,[31,33-36,42] while in four studies involving 100 or fewer subjects, prevalence ranged from 45% to 77.5%.[37-39,41]

A number of studies (Table 1) either report, or allow calculation of, denture stomatitis prevalence in men and women. The two population-based studies conducted in Finland reported a higher percentage of denture users to be female, and a higher prevalence rate of denture stomatitis among women.[18,19] A similar pattern was observed for a study conducted in Slovenia.[17] The other population-based studies did not provide adequate information to determine gender-associated prevalence for this disorder. Similar to the observations among elderly denture wearers in Finland, a study of elderly Chilean denture wearers reported increased prevalence of stomatitis among women (38.7%) versus men (25.1%). In contrast, a survey of elderly Brazilians living in retirement homes failed to show a significant association between gender and stomatitis prevalence.[21,30] Several studies surveying the prevalence of denture stomatitis among patients visiting dental and prosthodontic clinics have also assessed gender relationships; however, results from these surveys are inconsistent, with three, two, and one of these clinic-based surveys reporting no association of stomatitis with gender, a higher prevalence among women, and a higher prevalence among men, respectively.[32,35,36,38,40,42]

While a large number of studies have reported prevalence of denture stomatitis, there are issues and potential concerns regarding study designs. The US NHANES, German DMSIII, and the oral health survey conducted in Finland are clearly studies conducted in representative population-based samples;[3,12,19] however, several other studies, while claiming to be population-based, enrolled subjects from more limited populations, and the ability to extrapolate data from these studies to a broader,

Table 1 Epidemiology of denture stomatitis

			Subjects with denture stomatitis (DS)			
Study population	Age	# Denture users	Method used to diagnose denture stomatitis	# with DS	DS prevalence	Ref
Random U.S. population sample participating in NHANES III study conducted in 1988 to 1994.	59.2 ± 0.5 yr	3450 *57.7% M* *42.3% F*	Standardized oral examination conducted by trained dentists. DS was graded according to the Newton severity scale.	963	28%	12
Random sample of 10% of residents age >65 yr from 3 communities in Denmark	Mean 74.5 yr (range 65 to 92)	463	In-home examination by one investigator. Method used for DS diagnosis not stated	291	65%	14
Age-stratified, random sample among home-living residents of Helsinki, Finland (Helsinki Aging Study, 1989 to 91)	76, 81, and 86 yr	260 *63 M* *197 F*	Examinations conducted at Univ of Helsinki, Inst. of Dentistry). DS not defined, lesions reported as inflammation, papillary hyperplasia, & fibrotic hyperplasia	91 *17M* *74F*	35% *27% M* *37.6% F*	18
Third German Oral Health Study (DMS III), 1997. Random, age-stratified population-based sample	Young cohort: range 34 to 44 yr Older cohort: range 65 to 74 yr	655[b] *47.3% M* *52.7% F* 1367[b] *44.7% M* *55.3% F*	Standardized dental examinations with DS diagnosed using WHO guidelines	NR[c]	2.5% in young cohort 18.3% in older cohort	3
Representative sample of denture wearers from 1984 Finland oral health survey	NR[c]	3875 *37.3% M* *62.7% F*	Regionally conducted oral examinations. Method to assess DS not reported	1860 *626 M* *1230 F*	48% *43.2% M* *50.6% F*	19
Representative, population-based sample of adults in Istanbul, Turkey	35.6 ± 26.6 yr[a]	178	At-home oral examination using WHO guidelines to diagnose oral lesions	33 *14 M* *19 F*	18.5%	15
Population-based, age-stratified sample of adult residents of Orvieto, Spain	54.3 ± 13.5 yr[a]	102	Oral examination to identify oral lesions. Method to characterize DS not specified.		19.6%	16
Random, age-stratified population-based sample from Ljubljana, Slovenia	Range 25 to 75 yr[a]	163 *78 M* *85 F*	Dental examination	24 *9 M* *15 F*	14.7% *11.5% M* *17.7% F*	17
Population sample of elderly residents (> 65 yrs) of Santiago, Chile stratified by age, gender, and socioeconomic status	65 to 74 yr[a] (n = 560) ≥ 75 yr[a] (n = 329)[d]	574 *179 M* *395 F*	WHO diagnostic criteria for oral lesions graded by a single examiner	198 *45 M* *153 F*	34.5% *25.1% M* *38.7% F*	20
Nursing-home and long-term care facility residents in Denmark	Range 64 ≥ 85 yr	582	Oral examinations conducted by one investigator at institutions. Method used to diagnose DS not indicated.	197	33.9%	21
Elderly full denture wearers in Istanbul, Turkey attending a university denture clinic		70	DS scored with using Budtz-Jorgensen 4-point scale	31	44%	22
Patients at the Laasko long-term care facility (Helsinki, Finland)	83.3 ± 8.1 yr[a]	106 *25 M* *81 F*	Examinations conducted by single investigator; method to characterize DS not specified.		25%	23
Residents from 22 randomly selected nursing homes in Avon, UK	84.5 ± 8.3 yr[a] (range 42 to 102 yr)	331	Clinical examination conducted by single investigator at nursing homes; DS graded using Budtz-Jorgensen scale.	110	33.2%	24
Entire institutionalized population of Taubate, Brazil	74.9 ± 12.9 yr[a] *(only 66% knew their age)*	201	Clinical examination at nursing homes. Method to characterize DS not specified	108	54%	25
Geriatric residents of a long-term care facility (Val Fleuri, Belgium)	85.6 ± 6.9 yr[a] range 66 to 101 yr	146	Clinical examination conducted by single investigator at nursing homes; DS graded using Budtz-Jorgensen scale	104	71%	26
Elderly residents of a long-term care facility in Edmonton Canada	83.4 ± 17.6 yr[a]	38	Oral examination conducted by 1 of 2 previously calibrated clinicians. DS graded using Newton criteria	13	34.2%	27
Population-based sample of elderly community-dwelling and nursing home residents in Greece	Mean age 78 yr[a] range 65 to 99	222	DS graded using Newton criteria	33	14.9%	28

(*Continued*)

Table 1 (*Continued*)

Study population	Age	# Denture users	Subjects with denture stomatitis (DS): Method used to diagnose denture stomatitis	# with DS	DS prevalence	Ref
Elderly complete denture wearers living in retirement homes in southern Brazil	66.7 ± 10.2 yr	59 *24 M* *35 F*	Examination conducted by expert in stomatology with DS graded per Newton classification	26 *11 M* *15 F*	44.1% *45.8% M* *42.9% F*	29
Residents, age ≥ 60 from 2 rural communities in Brazil	NR[c]	146	Examination conducted by one investigator at local dental clinic. Method used to characterized DS not indicated		58.2%	30
Edentulous referral patients treated (1976 to 1983) at dental clinic of Univ of BC, Vancouver, BC, Canada	Range 24 to 90 yr	200 *24% M* *76% F*	Chart review. Method to characterize DS stomatitis not reported.	ND	17%	31
Edentulous patients wearing dental protheses examined at a prosthodontic clinic in Mexico	Mean 67 yr	105 *43 M* *62 F*	Examination at clinic. Method to characterize DS not specified.	50 *21 M* *29 F*	47.6% *48.8% M* *46.8% F*	32
Denture wearers seeking treatment at a university dental clinic in Brazil	62 ± 12.8 yr	236 *25% M* *75% F*	Sequential patients seeking dental care at clinic. Method to characterize DS not specified.	ND	42.4%	33
Consecutive denture patents seeking dental treatment at clinic of medical school in Istanbul, Turkey	Mean 65 yr range 45 to 81 yr	234	Patient questionnaire and clinical examination; method to characterize DS not specified.	130	55.5%	34
Patients attending 2 prosthodontic clinics in Jordan for denture replacement or adjustment	65 ± 10.1 yr range 18 to 100 yr	321 *203 M* *118 F*	Method to characterize denture stomatitis not specified	94 *45 M* *49 F*	29% *22.2% M* *41.5% F*	35
Complete denture wearers, over age 60 seen at dental clinic at a medical school in central Turkey for replacement or adjustment of dentures	65.7 ± 2.7 yr range 60 to 85 yr	310 *159 M* *151 F*	Clinical examination with DS identified and categorized per Newton classification	111 *56 M* *55 F*	35.8% *35.2% M* *36.4% F*	36
Complete denture wearers seen at a university dental clinic in Glasgow, Scotland for denture replacement	Mean 73 yr range 49 to 89 yr	37	Clinical examination. DS classified per Newton classification	26	70.3%	37
Otherwise healthy subjects with complete dentures consulting university dental clinic (Ataturk Univ, Turkey)	range 36 to 82 yr	70 *39 M* *31 F*	Clinical examination with DS diagnosed and classified per Budtz-Jorgensen scale	49 *30 M* *19 F*	70% *76.9% M* *61.3% F*	38
Outpatients seen at prosthodontic clinic of the Univ of Montreal for replacement of complete maxillary or maxillary and mandibular dentures	Mean 64.5 yr	40 *11 M* *29 F*	Oral examaination performed by a single investigator with confirmatory diagnosis. DS classified per Newton typing.	31	77.5%	39
Follow-up to clinical trial evaluating complete dentures (n = 76) and mandibular implant overdentures (n = 97) after 1 year	72.1 ± 4.4 yr	173 *80 M* *93 F*	Oral examination conducted by 2 calibrated examiners. DS diagnosed by Newton classification.	110 *48 M* *62 F*	63.6% *60.0% M* *66.7% F*	40
Otherwise healthy patients seen at university prosthodontic clinic in Bilbao, Spain	Mean 65.1 yr[a] range 40 to 87 yr	100	Oral examination with DS diagnosed using Newton classification	45	45%	41
Patients attending prosthodontic clinic of the Jordan Univ. of Science & Technology	Mean 59 and 54 yr for M and F range 39 to 100	300 *175 M* *125 F*	Oral examination to assess presence of DS. DS categorized using Newton classification	157 *89 M* *68 F*	52% *50.9% M* *54.4% F*	42

[a]Age only given for total study population; [b]total population (no value given for denture wearers); [c]NR, Not Reported; DS, denture stomatitis.

representative national population is questionable. In addition, while most studies used questionnaires to retrieve information regarding denture care, none include the actual questionnaires in the publication. This limits the ability to compare outcomes between studies and to reproduce studies by reusing or adapting questionnaires. It should be noted that characterizing denture stomatitis relies on different grading scores. While scores proposed by Newton[10] and Budtz-Jorgensen and Bertram[11] are quite similar (grades obtained from either scale can be interpolated to the other), some studies do not report having used

standardized scales for grading or characterizing severity of stomatitis.

Etiological associations

The epidemiology studies discussed above identify several factors associated with denture stomatitis. Demographic factors include increasing age of denture wearers, female gender, smoking, and concurrent illnesses that compromise immune function. Factors related to denture use itself include poor-fitting dentures, which exacerbate oral mucosal trauma and irritation, increasing age of the denture, use of maxillary versus mandibular dentures, lack of appropriate denture care and hygiene, the presence of pathogenic microbial infection (primarily *Candida*), and continual wearing of dentures. These factors have been considered in prior reviews.[1,2,4,5,12,43] Past reviews also suggest a potential role of contact allergy from denture materials in denture stomatitis. While an allergic response may have been a significant contributory factor in denture stomatitis in the past, use of modern denture materials have virtually eliminated allergic response as a significant risk factor in denture stomatitis.

The current view is that the etiology of denture stomatitis is multifactorial, and has a number of associative factors rather than a single cause.[2] Poor denture hygiene, pathogenic *Candida* infection, and continual wearing of dentures appear to be the predominant associated etiological factors for denture stomatitis and represent likely targets for interventions using a combination of pharmacological therapy provided by healthcare professionals and improved denture hygiene by denture users. This review discusses several etiological factors, including associations of denture stomatitis with denture-induced trauma and denture hygiene.

Association of denture stomatitis with denture-induced trauma

Budtz-Jorgensen and Bertram[11] reported an association of simple localized inflammation, a level of palatal inflammation similar to Newton's Type I, with poor denture fit and related irritation and trauma. Poorly fitting dentures have been reported by others to be associated with higher risk for denture stomatitis.[21] More extensive forms of stomatitis that manifested with granular inflammation were found to be more strongly associated with poor hygiene and *Candida* infection.[11] Several epidemiological studies have reported the relative incidence of Type I compared to Type II and III denture stomatitis, and suggest localized inflammation to be present in about one-half of individuals with this disorder (Fig 1).[15,17,24,27,37-39] A recent study by Emami et al[40] tested the hypothesis that increased occlusal pressure can contribute to mucosal trauma in denture stomatitis. These authors compared the incidence of denture stomatitis among 173 elderly edentulous patients who randomly received new conventional maxillary and mandibular dentures (n = 76) with those receiving two-implant mandibular overdentures (n = 97), which provided improved stability and fit and reduced occlusal pressure. After 1 year, the overall incidence of dentures stomatitis was 64%, with severity approximately equally divided among Newton's Type I and Type II; however, patients with conventional dentures were significantly more likely to have denture stomatitis than those with mandibular overdentures (OR: 4.52; 95% CI: 2.24-9.14; $p < 0.0001$). There were no differences in cleanliness or how subjects wore dentures between the groups. Improved stability appeared to reduce risk for stomatitis.

Association of denture hygiene with denture stomatitis

Poor denture hygiene is clearly accepted as a critical risk factor for denture stomatitis (Fig 2). As summarized later, numerous studies demonstrate a clear association between poor denture hygiene and increased risk for and prevalence of denture stomatitis.[11,22,24,31,33-35,44-47] These studies report that many denture wearers attempt to maintain denture hygiene only by brushing dentures, as one would brush natural dentition; however, this is inadequate for maintaining proper denture hygiene, and other methods, such as use of commercial disinfectant solutions, or soaking dentures in dilute sodium hypochlorite, are required as part of daily and routine denture maintenance. Not removing dentures at night while sleeping has also been associated with poor hygiene and increased risk for developing denture stomatitis.[11,23,31,33-35,44,46,47] In addition to poor hygiene, constant denture wearing maintains relatively anaerobic and low-pH conditions between the denture base and the mucosa, which can promote opportunistic overgrowth of pathogenic yeasts, such as *Candida*.

Budtz-Jorgensen and Bertram reported poor denture hygiene to be associated with increased denture and oral mucosal colonization with *Candida,* greater mucosal trauma, and increased severity of inflammation among 58 stomatitis patients (mean age 57.7 years) who had used full dentures for an average of 26.8 years.[11] Several other studies comparing adult denture wearers with and without denture stomatitis report stomatitis to be significantly associated with poor denture cleanliness.[22,31,34,44]

Inadequately cleaned dentures rapidly develop an adherent biofilm and accumulate pathogenic denture plaque. Biofilm and plaque contain bacteria and yeasts that reside on the denture surfaces and can also colonize the oral mucosa (Fig 3). The biofilm and yeast contaminants have a role in oral inflammation in denture stomatitis.[48,49] The microbial ecology of the biofilm is complex. A recent study that identified bacterial and yeast contaminants from swabs of denture biofilms reported 82 bacterial phylotypes and three fungal species. While many bacteria were common to biofilms from both healthy individuals and denture stomatitis patients, the study identified 26 and 32 bacterial phylotypes unique to healthy subjects and those with stomatitis. Of fungal species, *C. albicans* was the only fungal species found in the denture biofilms of stomatitis patients; it was also present in healthy subjects, but these subjects had other *Candida* species present (Fig 4).[48]

While poor denture hygiene can increase the risk for denture stomatitis, maintaining hygiene has been shown to prevent recurrence. Following successful therapeutic treatment of *Candida*-associated denture stomatitis, 18 of 22 patients were reported to maintain remission for 3 years through stringent denture hygiene.[45]

An association between poor denture hygiene and denture stomatitis is clear. Unfortunately, the majority of persons who wear dentures are elderly and many may have impairments that

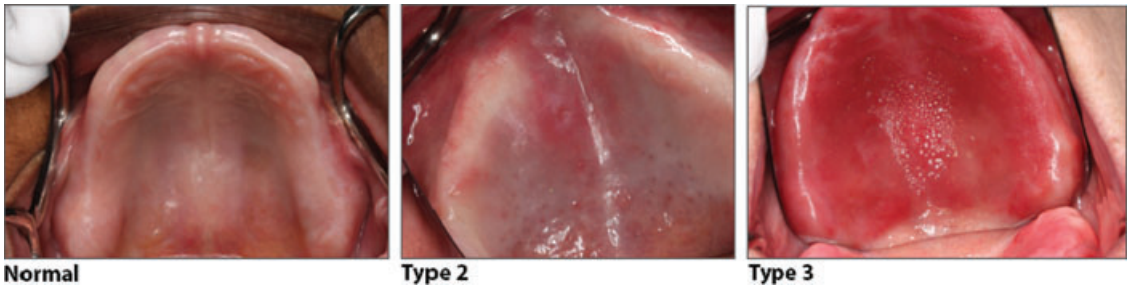

Figure 1 Denture stomatitis clinical photographs based on Newton classification (courtesy of Professor Steven Offenbacher).

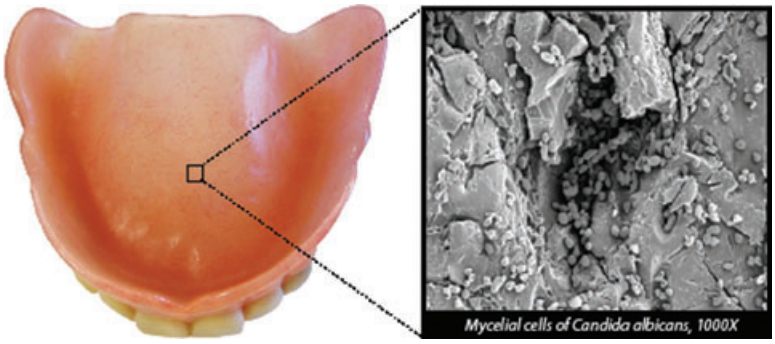

Figure 2 Microscopic representation of attached microbial cells on the surface of a denture.

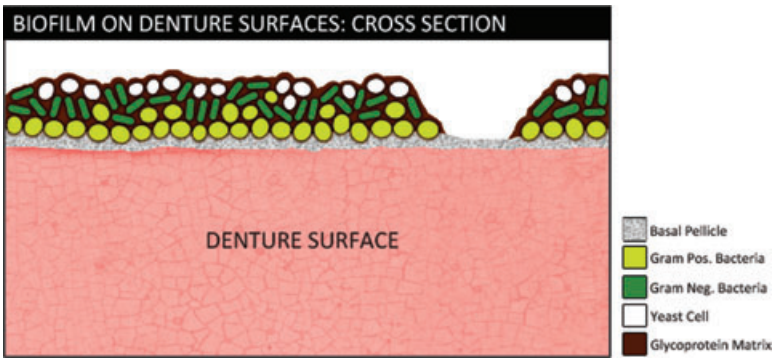

Figure 3 Schematic representation of a biofilm cross section on a denture surface.

make proper cleansing and care of their dentures difficult. In addition, since proper cleaning requires dentures to be removed, persons who report that they continually wear their dentures, especially persons who wear their dentures overnight, cannot practice adequate hygienic maintenance. For cleaning, brushing dentures alone, or washing them with water is not adequate to prevent formation of the surface biofilm. Proper cleaning should include removing dentures and soaking them in a commercial disinfectant solution, or diluted sodium hypochlorite. Using ultrasonic cleaning is an alternative cleansing approach.[50] Two studies have reported success using a microwave to disinfect dentures as a treatment for *Candida*-associated denture stomatitis. Both studies reported that the microwaving regimen reduced *Candida* on dentures, and the study by Neppelenbroek et al reported this to be effective for treating denture stomatitis, and to have a low rate of recurrence over a 3-month follow-up period.[51,52]

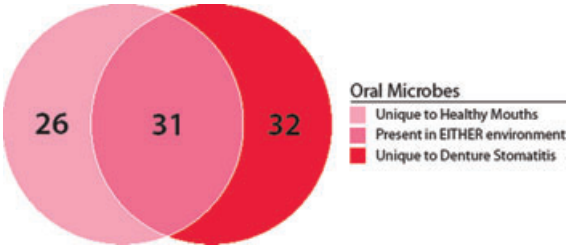

Figure 4 Oral microbe distribution cataloged by state of health.

Association of Candida infection with denture stomatitis

Candida and *C. albicans* are often found on the dentures and oral mucosa of individuals without any signs of denture stomatitis.[53,54] The role of *Candida,* and specifically *C. albicans*, in development of denture stomatitis is associated with pathogenic

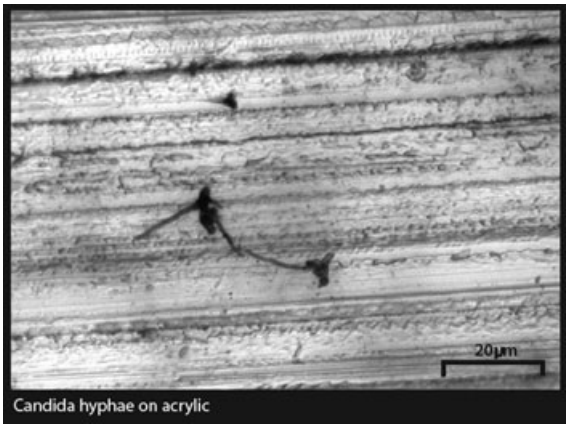

Figure 5 Photomicrograph of *Candida* hyphae on an acrylic surface (courtesy of Professor J. Verran and Sarah L. Jackson).

overgrowth of *Candida* on denture surfaces and the oral mucosa, and is widely accepted as a leading etiological factor in this disorder. A quantitative presence of *Candida* has been found to be associated with denture stomatitis disease manifestation.[55] In their 1970 publication, Budtz-Jorgensen and Bertram reported a significant association between inflammation and yeast colonization in patients with denture stomatitis,[11] and this association has been confirmed in subsequent studies.[22,32,37,38,44,56–58]

It is possible that the etiological role in denture stomatitis occurs in combination with other factors, especially poor denture hygiene and continuous wearing of dentures.[1,2,5,6,11,14,22,37,43,49] As reviewed by Odds,[53] while *C. albicans* is a normal commensal organism, it can become pathogenic in situations that predispose individuals to infection. While most *Candida*-related lesions are acute events, chronic lesions almost always occur on the soft palate and are associated with wearing dentures, where *C. albicans* is the most prevalent Candidial species. Other common oral *Candida* species include *C. glabrata, C. krusei, C. parapsilosis*, and *C. tropicalis*. These species, however, are present with lower prevalence than *C. albicans* and have not been shown to have an increased prevalence or a pathological role in denture stomatitis.

C. albicans can grow either as mycelial or hyphal forms. A greater presence of *C. albicans* hyphae has been reported in patients with denture stomatitis. This has led to the hypothesis that *C. albicans* in this form has greater pathological activity.[5,14] It has also been hypothesized that the hyphal form of *C. albicans* can better adhere to and penetrate fissures on denture surfaces and is thus more invasive to the oral mucosa (Fig 5).[5,6] Song et al[59] recently characterized yeast isolates from patients with denture stomatitis; *C. albicans* was the predominant species. The authors noted that yeasts that colonized the dentures and mucosa of stomatitis patients formed colonies with diverse morphologies, while the same yeast species when present in healthy denture wearers formed colonies with smooth morphology.[59] Bilhan et al reported a significantly higher presence of *C. albicans* hyphae among patients with denture stomatitis compared to healthy denture users without palatal inflammation.[60] Emami et al reported a significant association between abundance of myceliated colonies of *C. albicans* with increased severity of denture stomatis.[39] While changes in *C. albicans* morphology have been associated with the presence, and perhaps severity, of denture stomatitis, no variant strains of this yeast having unique virulence factors or pathogenic associations for denture stomatitis have been identified to date.[61,62]

The effectiveness of antifungal therapy in the treatment of denture stomatitis directly supports an etiological role of *Candida* infection in this disorder, and has been reviewed by Lombardi and Budtz-Jorgensen.[63] Double-blind, placebo-controlled studies have reported that treatment with either oral fluconazole (50 mg/day for 14 days) or topical miconazole (2% gel applied to denture fitting surface three times daily for 14 days) significantly reduced the presence of yeasts on oral mucosa and reduced inflammation in denture stomatitis.[64,65] In a controlled trial in patients with denture stomatitis who did not change their normal denture hygiene practices, 2 weeks of daily treatment with nystatin powder (~215,000 IU/day) applied to the maxillary denture fitting surface significantly reduced yeast colonization and palatal inflammation compared to no treatment.[66] DePaola et al[67] and Schwartz et al,[68] respectively, reported nystatin, used either in an oral rinse in combination with a denture soaking solution (oral rinse: 1,000,000 U twice daily plus daily overnight [6 hours] soaking in a nystatin solution for 28 days), or as an oral rinse alone (same dose and regimen), significantly reduced yeast colonization and resolved inflammation in denture stomatitis. A controlled trial reported 14 days treatment with amphotericin B (10 mg) administered as an oral dissolving lozenge, soaking dentures in 0.2% chlorhexidine solution, or the combination of the two treatments significantly and equivalently reduced erythema in denture stomatitis; however, recurrence of inflammation to near baseline severity occurred within 14 days of stopping treatment.[69] Uncontrolled trials have reported capsule and liquid formulations of itraconazole (100 mg b.i.d. for 15 days), fluconazole alone (50 mg orally for 14 days), or in combination with chlorhexidine applied to the denture fitting surface twice daily for 2 weeks, and amphotericin (40 mg oral dissolving lozenges 4 times daily + topical cream applied to the denture fitting surface) all to be efficacious for treating denture stomatitis.[70–73] In general, all studies indicated the various treatments to be well tolerated.

Clearly, antifungal therapy is effective in the acute treatment of inflammation associated with denture stomatitis, and this is considered supportive of the pathogenic role of *Candida* infection in this disorder; however, unless there is an associated improvement in denture cleanliness and reduction of *Candida* contamination on denture surfaces, the effectiveness of antifungal treatment is limited, and rapid recurrence of denture stomatitis can often occur within a short period of time after stopping treatment. For example, Chandra et al reported 16- to >128-fold reductions in the potency of amphotericin, nystatin, chlorhexidine, and fluconazole for inhibiting growth of *C. albicans* grown on denture adherent biofilms in vitro, versus their effects on *C albicans* grown in simple culture.[74] Hence, the rapid recurrence of denture stomatitis that can occur after stopping antifungal treatment likely reflects recontamination by residual yeast that are present on the denture surfaces and which are relatively unaffected or resistant to the treatment.

Role of denture materials in denture stomatitis

Dentures themselves have a role in promoting the development of stomatitis. A primary role is the ability of bacteria and yeast to colonize denture materials, forming a biofilm. Biofilms adhere to denture surfaces, forming the plaque deposit, which provides a source of continued exposure of the mucosa to the organisms contained within this biofilm. In vitro studies have shown that microorganisms within the biofilm appear to have resistance to antifungal and antimicrobial treatment, though the mechanism for this is not fully understood.[6] Whether a decrease in antimicrobial potency represents the biofilm functioning as a simple diffusion barrier, or whether there is a more complex interaction, has not been adequately studied. Therefore, effective decontamination of dentures is a required, and likely separate, treatment approach from that of treating mucosal inflammation and infection in the effective management of denture stomatitis.

The association of poor denture cleanliness with denture stomatitis was shown by Pires et al[75] who achieved significant clinical improvement with denture replacement. Among 39 subjects wearing full dentures and having denture stomatitis, over 80% had poor or deficient denture hygiene, and 100% had *C. albicans* colonization of their dentures and oral mucosa. Denture stomatitis had resolved in almost two-thirds of these subjects 6 months after receiving new dentures and practicing improved hygiene. Replacement also improved denture hygiene within the study group. At the 6-month evaluation, all patients had good (absence of plaque) or regular (removable plaque on inner denture surface only) hygiene, compared to the majority having poor/inadequate hygiene at entry.[75] A similar association was reported by Webb et al in a study conducted in nursing home patients who had poor denture hygiene and denture stomatitis.[51] Subjects were randomized to maintain their usual hygiene procedures, or had their dentures cleaned daily with overnight soaking in sodium hypochlorite solution or microwaving. Relative to the control group, both cleaning techniques reduced bacteria and *Candida* colonization of dentures ~100-fold, reduced *Candida* counts on the palate, and resulted in significant clinical improvement in denture stomatitis.

Several studies have reported electron microscopic analyses of denture plaque. Twenty-three patients with denture stomatitis evaluated in three studies, of which only one included a control group of seven healthy denture wearers, reported plaque to consist of an electron-dense basal pellicle directly on the denture surface, above which was an opaque layer containing Gram-positive and -negative bacteria and yeast cells, reported to be *C. albicans*. In the single controlled study, with the exception of the presence of *C. albicans*, there were no differences in the appearance of plaque between subjects with and without stomatitis.[76–78]

Ramage et al also used scanning electron microscopy to demonstrate the propensity of *Candida* biofilms to adhere along imperfections and cracks on denture surfaces.[6] Filamentous cell forms of *Candida* were shown to become deeply embedded within surface deformities, and this was hypothesized to at least in part be responsible for the resistance of the *Candida* biofilm to antifungal treatment. Von Fraunhofer and Loewy reviewed factors involved in microbial attachment and colonization of denture surfaces, confirming that surface cracks and surface roughness facilitate attachment of microorganisms and development of the biofilm.[79] Furthermore, these authors noted that prolonged brushing of denture acrylic resin with a toothbrush and abrasive dentrifices can create surface scratches that can enhance bacterial attachment and biofilm growth. Denture soft lining materials can also develop increased surface roughness as they age on the denture surface, and a recent study confirms that this enhances attachment and colonization of these materials with *C. albicans*.[80] Finally, surface hydrophobicity has been shown to selectively increase the ability of hyphal forms of *C. albicans* to colonize denture surfaces, and in vitro studies have shown that decreasing surface hydrophobicity by using hydrophilic coating materials can decrease the ability of *C. albicans*, but not other yeasts, to attach and colonize the denture material surface. This may offer an interesting direction for future development of denture materials that can resist development of biofilms leading to denture stomatitis.[81]

Preventing development of the biofilm on dentures is indicated as the best approach for maintaining denture hygiene. Satisfactory denture sanitization using commercial denture cleansers offers a safe and effective approach for biofilm removal;[79] however, the high prevalence of denture stomatitis among denture wearers, and its association with lack of proper denture hygiene, suggests that only a minority of denture wearers actually practice stringent cleaning of their prostheses. The need to continually maintain proper hygiene, and for denture wearers to have regular follow-up appointments, and perhaps regular professional cleansing of their dentures, seems appropriate to help prevent or treat and prevent relapse of denture stomatitis. The review by Von Fraunhofer and Loewy[79] suggests that modifying denture materials to provide a relatively anionic surface, or using coatings that can prevent bacterial attachment may offer future means for reducing biofilm development.

Conclusions

Denture stomatitis affects a large percentage of persons wearing removable complete dentures. It has a multifactorial etiology. Key factors that can dramatically increase the risk of denture stomatitis are poor denture fit, poor denture hygiene, and colonization of the denture surface and oral mucosa, primarily mucosa in contact with denture fitting surfaces, with *C. albicans*. Poor denture care and hygienic maintenance leads to rapid establishment of a biofilm and accumulation of denture plaque. Since this provides the means for denture colonization by *Candida* strains, the correlation between lack of hygiene and propensity for Candida infection is clear. Denture materials themselves can contribute to the risk for denture stomatitis, as areas of surface roughness and the hydrophobicity of denture surfaces can promote attachment of microorganisms and development of the biofilm.

It is important to reduce risk for development of denture stomatitis. Good quality prostheses coupled with clear instructions to denture wearers by dentists and prosthodontists on the importance of diligent maintenance and use of a daily cleaning regimen are required. Denture wearers must take it on themselves to be diligent and practice appropriate denture hygiene.

Additionally, denture wearers should remove their dentures at night. Routine follow-up visits to assess that the prostheses maintain proper fit and function, and that users are maintaining denture hygiene is of extreme importance in reducing risk for developing stomatitis. Finally, treatment of stomatitis appears to rely on stringent cleaning or replacement of dentures, together with appropriate antifungal therapy.

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