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ORIGINAL ARTICLE

Malodour in denture wearers: an ill-defined problem

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Denture plaque has not been studied to the same extent as dental plaque, and although there are many similarities in microbial composition, there are some significant differences. Denture-induced stomatitis is associated with poor denture hygiene, a more acidogenic plaque and the presence of *Candida albicans*. Obligate Gram-negative anaerobic micro-organisms, although present in denture plaque, have rarely been specifically investigated. Opportunist pathogens including coliforms and staphylococci have been isolated from dentures. Teeth adjacent to partial dentures are more susceptible to caries and periodontal diseases, perhaps due to an increased plaque buildup at the prosthesis/tooth interface. Little work has been published on malodour associated with dentures. The inert material provides a substratum for the plaque biofilm, which encompasses a range of odour-producing species. The microbiology of the tongue in denture wearers has not been specifically studied. Thus the nature, origin and extent of malodour in denture wearers is ill-defined, but many species capable of producing malodorous compounds are present. The wide age and health range presented by denture wearers further confounds investigation. There is a need for further work in the area, both for cosmetic- and health-associated reasons in the increasing elderly population.
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Introduction

A significant proportion of the adult population wears complete or partial dentures. The factors associated with tooth loss – dental caries, loss of periodontal support, a history of dentoalveolar trauma, a history of dental care – are additive over time, thus denture wearing is more associated with an older population. In the past, false teeth were sourced from ivory, or animals, or the poor – whose diet was less damaging to the dentition than that of the wealthier population. These prostheses of biological origin were subject to caries and spoilage: the fan thus became a useful aid to hide the sight and smell of both false and true dentition! The origin of denture odour is now potentially less diverse and more easily controlled. Dentures are now made of synthetic polymers, particularly polymethacrylate, using casts constructed from impressions taken in the mouth. Soft liners, or more temporary tissue conditioners, are applied to the prosthesis to improve comfort and fit. Denture adhesives are also commercially available.

Thus a range of inert materials placed in close proximity to oral tissues over extended time periods provides a hard, non-shedding substratum in a relatively stagnant environment, enabling the attachment and colonization of micro-organism and the formation of denture plaque. The oral condition particularly associated with the wearing of dentures is denture-induced stomatitis. The bulk of the literature concerning denture plaque focuses on the aetiological agent, generally deemed to be *Candida albicans*, and associated causative factors, particularly poor denture hygiene and consequent plaque (and calculus) accumulation (Verran, 1999). Malodour associated with dentures is rarely addressed directly in the literature, although reference is frequently made in passing (Myatt *et al*, 2002), and many denture-cleaning products claim breath freshening properties. The implication behind these claims is that there is a potential odour problem, yet no evidence could be found in the literature of a comprehensive study on the topic. This paper brings together some of the evidence associating denture wearing with possible malodour, and outlines some of the areas where further work is needed.

Demographics

Numbers of denture wearers are significant, and it is generally recognized that the elderly population is increasing in many of the developed countries. Currently there are 60 million denture wearers in Europe, 15 million of them in the UK. Of these, approximately 40% wear full dentures, 20% one full denture only, 17% one full denture and one partial, and 23% partial dentures only. In the US, in 1900, 3% of the population were over 65: in the year 2000, the figure had risen to over 13% (corresponding to 37 million individuals, of whom

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4 million were over 85). In Japan, it is predicted that the elderly will comprise over 25% of the total population by 2025 (Shay, 2000; Senpuku *et al*, 2003). India has a large geriatric population (60+) of 77 million, comprising almost 8% of the population (Shah *et al*, 2004).

Clearly there are many issues to be addressed as a result of these significant demographic shifts, and perhaps denture malodour is not amongst those of most concern. However, oral health is an important aspect to the care of the elderly, not only those who are hospitalized (O'Reilly, 2002), but also those in residential homes where socializing and eating tend to occur together (Shay, 2000), or in their own homes, where odour, either perceived or actual, presents embarrassment and discomfort to the individual and to their family and friends.

Preservation of some or much of the dentition into old age has become more common in recent decades. However, the growth of the proportion of the population living in their 70s, 80s, 90s and beyond results in a continued growth in the number of older persons requiring replacement dentition, even as the proportion of older people requiring dentures has declined (Gordon, 1989). Thus there will be a denture-wearing population for some time to come.

The denture-wearing population could be divided into two groups: the active and debilitated elderly. The former enjoy a full and active social life, and present a significant consumer base. Denture and oral hygiene products would be in demand for this group, primarily for aesthetic purposes. The debilitated and more aged elderly are unable to carry out their own oral care procedures, and require assistance to do so in order to maintain the best possible oral health status. A knowledge of the significance of malodour in the denture-wearing population, of factors involved in the cause, and of any significant differences between malodour in denture wearers and the dentate population, would enable the development of appropriate treatment, control (and marketing) strategies to address the needs of these two very different denture-wearing groups.

Oral microbiology in denture wearers

The oral flora of the elderly has been likened to that of the baby (Socransky and Manganiello, 1971), the main similarity being the lack of natural teeth. However, in terms of malodour, differences would be anticipated, for example due to the effect of the lifelong diet and health experience of the adult (Percival *et al*, 1991). If the origin of malodour is the tongue flora, then one might anticipate some alterations in the tongue flora with age: the tongue is deemed to be a reservoir for many oral species, being present in the mouth before and after teeth have erupted and departed!

In comparison with the dentate individual, the mouth of the denture wearer presents additional sites and environments to support the growth of micro-organisms. For example, teeth adjacent to partial prostheses are more prone to caries and gum disease, presumably due to the enhanced accumulation of plaque held close to the host tissues by the inert denture (Verran, 1999).

The tongue

The tongue supports a significant microbial population (Hartley *et al*, 1999), but the nature of the tongue biofilm and coating in denture wearers has not been studied, thus comparisons with the composition of the tongue in the dentate cannot be made. One might speculate that there would be an increased likelihood of isolating *C. albicans*, as there is a significant carriage of the yeast on dentures. As full denture wearers have no gingival crevices, and no periodontal disease, one might presume the absence of periodontal species: would they then be present on the tongue? Certainly *Fusobacteria* and *Prevotella* species have been isolated from denture plaque (Gusberti *et al*, 1985). In our laboratories they have been particularly associated with more mature plaque (Figure 1). The involvement of these micro-organisms (and others) in classic oral malodour surely merits some investigation of their presence in the relatively unexplored milieu of denture plaque. It should also be noted that the composition of a 'healthy' tongue biofilm in the dentate has yet to be defined in any detail.

Oral epithelia

Lip and cheek cells are in transient contact with denture material rather than teeth. Cells will be shed from these surfaces, and biofilm will not accumulate. However, some of the oral epithelia will be occluded by the denture-fitting surface. Inflammation of the maxillary mucosa in denture-induced stomatitis results from the activities of micro-organisms in the adjacent denture plaque.

Denture

The prosthesis itself will support the development of denture plaque and calculus, but presents different environments to the colonizing species. The fitting surfaces are exposed to high nutrient concentrations and low salivary flow rates, and provide a roughened topography to support and protect the plaque (Figure 2). *Candida albicans* is found more frequently on this fitting surface (Verran, 1988). The non-fitting surface is more exposed: plaque tends to accumulate at the 'tooth–gum interface' (Figure 3) much as it does on natural teeth, again due to the protection from shear provided by the surface features.

Denture soft lining materials

Denture soft lining materials present a rubbery and resilient surface to the colonizing micro-organisms. These materials may also leach plasticizer and harden over time. The uneven and potentially porous surface provides an excellent environment for colonization by micro-organisms. Evidence of penetration by yeast has been demonstrated *in vitro* over a 6-week incubation period, but over a 3-month in-use period this phenomenon was not evident, presumably due to the competition provided by other oral species, particularly

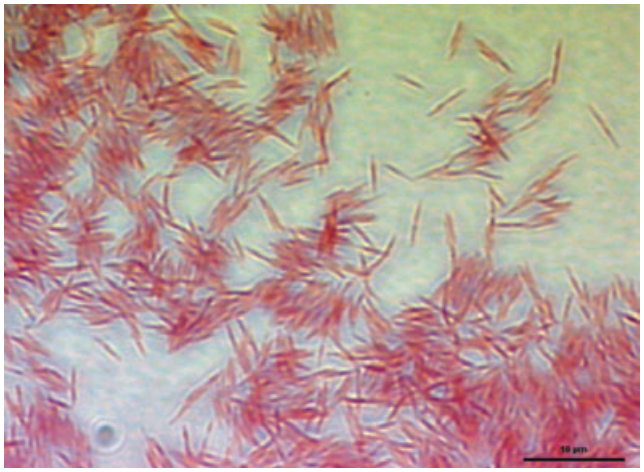

Figure 1 Gram stain of *Fusobacterium nucleatum* isolated from denture plaque, identified by 16sRNA

Figure 2 Disclosed plaque on a denture. Accumulation at the 'tooth–gum interface' is apparent

Figure 3 Undisclosed plaque on the fitting surface of a lower denture

bacteria, absent from the *in vitro* study (Bulad *et al*, 2004). Nevertheless, the fillers are potential substrates for the growth of some micro-organisms, and the accumulation of micro-organisms within the materials will provide a further opportunity for the deterioration and the generation of odour.

Denture plaque

There have been relatively few studies on denture plaque microbiology, the bulk being carried out in the 1980s. Images of denture plaque from the upper fitting surface reveal the presence of a pellicle, a typical biofilm morphology of columnar microcolonies, surmounted by occasional epithelial cells from the maxilla (Budtz-Jorgensen *et al*, 1980).

The composition has been deemed similar to dental plaque particularly that on the occlusal surfaces (Theilade *et al*, 1983; Theilade and Budtz-Jorgensen, 1988). Gram-positive cocci and rods dominate, with Gram-negative rods and yeast less common. Few obligate anaerobes are described (Gusberti *et al*, 1985). These studies comprise a very significant amount of microbiology, but inevitably include only a few individuals, and different sites in the mouth (Budtz-Jorgensen and Theilade, 1983): large variations in the populations of both were observed. Recent studies are few (Verran, 1999). In published work, the isolates obtained are often a direct consequence of the isolation media used. Many publications focus on *Candida* (Kulak *et al*, 1997; Nikawa *et al*, 1998) which comprises only 0–0.45% of the population numerically (Theilade *et al*, 1983) (although its cell mass is more significant). Thus other groups of organisms may be overlooked. This is particularly true for the obligate anaerobes, which are important if oral malodour is the focus of a study (Nakano *et al*, 2002; Tyrrell *et al*, 2003).

Some micro-organisms which are unusual in the oral flora but have been isolated from dentures include respiratory pathogens such as *Escherichia coli*, *Pseudomonas* spp., *Klebsiella* spp. (Sumi *et al*, 2002; Senpuku *et al*, 2003) and staphylococci (including MRSA, Rossi *et al*, 1995). In one study, 48% of dentures sampled harboured members of the Enterobacteriaceae (Goldberg *et al*, 1997; Senpuku *et al*, 2003). Inhalation pneumonia is a common cause of death amongst the elderly debilitated, thus the role of the denture in harbouring such potential pathogens may be significant. Their transient nature (Eliason *et al*, 1992), or otherwise, is unknown.

There is a need for a larger and more comprehensive study on the oral flora of the elderly. Current knowledge in the field often relies on older publications, using relatively few subjects, sampling few sites and targeting specific micro-organisms. More modern molecular methods such as density gradient gel electrophoresis might well demonstrate differences in the total flora, cultivable or otherwise, in different sites in the mouth, in test populations.

Malodour

No evidence could be found in the literature of a study on denture wearers' perceptions of odour associated with denture wearing. One would assume that the adherent plaque on dentures would be unaesthetic in

terms of appearance, tactile sensation, taste and odour, but impairment of taste and smell perception under circumstances of poor denture hygiene has been noted (Hyde *et al*, 1981) implying that individuals may become inured to ongoing unpleasant taste and odour. Dentists and dental technicians comment in passing on odour (personal observations), but the bouquet has not been described or characterized. One reference to a 'sweet but offensive' odour was found (Goldberg *et al*, 1997).

The mouth and the denture may have different odours, but this has not been investigated. Salivary flow will be reduced beneath the denture: this property has been shown to increase the presence of volatile sulphur compounds (VSCs) (Koshimune *et al*, 2003). The source of odour is potentially diverse, as a wide range of odour-producing organisms have been isolated, including members of the Enterobacteriaceae, pseudomonads, Gram-negative anaerobes and yeast, but has not been explored to any great extent (Goldberg *et al*, 1997). The nature of the odour has not been defined. Studies on the breath-freshening effect of denture fixatives could not demonstrate a beneficial effect of the product on VSC production as determined by the halimeter, but a subjective organoleptic assessment proved more useful (Myatt *et al*, 2002). This indicates that malodour associated with dentures is potentially more complex (Table 1), or at least different from, and less well defined than, that in dentate individuals.

Control of malodour associated with dentures

Denture hygiene is the obvious method for ensuring that the denture remains clean. The British Dental Association recommends that to 'keep gums and teeth healthy to avoid bad breath' the denture (and the mouth) is cleaned every day. After being removed from the mouth, the denture should be cleaned over a basin of water (to prevent accidental breakage on dropping). It is recommended that the denture is left out of the mouth for at least 4–6 h, preferably 8 h, in every 24 h (http://www.bda.org). However, it should be recognized that many denture wearers, for reasons of vanity, do not leave their dentures out at night. There are several oral hygiene products available for use by denture wearers. Mouthwashes, chewing gums, toothpastes and denture fixatives all claim to freshen the mouth and keep the prosthesis clean (Shay, 2000; Myatt *et al*, 2002; Simons *et al*, 2002). Regular dental checks are also recommended to ensure that the tissues remain healthy, and that the denture fit is appropriate. However, as malodour associated with dentures is not a well-defined or recognized condition, nor is it perceived as a significant problem, specific approaches for its control or prevention are sidelined by work in more potentially health threatening, or commercially lucrative, areas.

In conclusion, studies on microbiology, and determination of the origin and nature of any malodour associated with denture wearing remains a neglected area in the comprehensive literature on oral microbiology, and the increasing literature on oral malodour, and merits further study (Table 2) in order to benefit the diverse relevant population.

Table 1 Factors associated with malodour in denture wearers (excluding odour of extra-oral origin)

Habitats
The denture and its plaque: the denture has a definite and distinct odour on removal from the patient's mouth
The tongue: the tongue/tongue coating/postnasal drip is generally deemed to be the origin of oral malodour
Substrates
Saliva
Food particles trapped beneath denture
Components of biomaterials
Micro-organisms
Gram-negative volatile sulphur compound (VSC) producing anaerobes on the tongue and in denture plaque
Gram-negative respiratory pathogens (*Klebsiella* and *Enterobacter* spp. produce VSC and cadaverine)
Yeast

Table 2 Factors to be considered in clinical studies on malodour associated with dentures

Differentiate between dentate, partial dentate and edentate population
Determine denture wearing and hygiene habits
General health status, nutrition, age, smoking, alcohol, medication and mobility
Denture status – cleanliness, material and soft liner
Whole mouth odour compared with denture odour
Denture microbiology compared with tongue and saliva microbiology (sampling)
Define nature of odour (gas chromatography-mass spectrometry, VSC and sensors)
Organoleptic training for denture-associated odour detection
Microbial origin of odour

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