

## ORIGINAL ARTICLE

# Sjögren's syndrome sufferers have increased oral yeast levels despite regular dental care

KCM Leung<sup>1</sup>, AS McMillan<sup>1</sup>, BPK Cheung<sup>2</sup>, WK Leung<sup>3</sup>

<sup>1</sup>Oral Rehabilitation, <sup>2</sup>Oral Bio-Sciences and <sup>3</sup>Periodontology, Faculty of Dentistry, The University of Hong Kong, Hong Kong, China

**AIM:** To investigate the prevalence and quantity of oral yeasts and their association with oral candidiasis in Sjögren's syndrome (SS) patients receiving regular dental care.

**MATERIALS AND METHODS:** Yeasts in oral rinse and full-mouth supra-gingival plaque samples from 25 primary SS, 27 secondary SS and 29 control subjects were selectively cultured. All yeasts except single-species isolates were genotyped using pulsed field gel electrophoresis (PFGE).

**RESULTS:** Ten (19%) SS sufferers had symptomless candidiasis. SS subjects had a higher prevalence (73% vs 7%) and quantity of yeasts than controls in both oral rinse and plaque samples ( $P < 0.05$ ). The prevalence of yeasts in plaque was associated with candidiasis regardless of denture wearing ( $P \leq 0.04$ ). *Candida albicans* was the predominant yeast isolated. PFGE showed 20 (66% of total) *C. albicans* isolate pairs, i.e. *C. albicans* species isolated from plaque and oral rinse samples of the same individual, were of closely related genetic clonal types ( $P < 0.01$ ).

**CONCLUSIONS:** Despite effective oral hygiene, more SS subjects than controls had detectable levels of oral yeasts and their presence in supra-gingival plaque was associated with candidiasis. *Candida albicans* colonized supra-gingival biofilm even in well-maintained SS individuals, posing a challenge to the control of oral candidiasis.

Oral Diseases (2008) 14, 163–173

**Keywords:** *Candida albicans*; candidiasis, oral; dental plaque; mycology; Sjögren's syndrome; xerostomia

Sjögren's syndrome (SS) is a chronic, autoimmune disease characterized by lymphocytic infiltration of the exocrine glands, especially the lacrimal and salivary glands, leading to keratoconjunctivitis sicca and

xerostomia. This syndrome is subclassified into primary SS (pSS), consisting of keratoconjunctivitis sicca and xerostomia, and secondary SS (sSS) when other connective tissue diseases such as rheumatoid arthritis are also associated (Fox, 2003).

Reduction in salivary output is the oral hallmark of SS. The oral manifestations of SS include dry mouth, oral soreness and ulceration, dysphagia, dysgeusia, an increased rate of dental caries, a higher prevalence of missing teeth, salivary gland enlargement and oral candidiasis (Baudet-Pommel *et al*, 1994; Leung *et al*, 2004; McMillan *et al*, 2004).

Previous studies have indicated a high rate of yeast colonization in individuals with SS detected using oral rinse (Abraham *et al*, 1998; Radfar *et al*, 2003) and tongue or palate swabs (Rhodus *et al*, 1997). The prevalence of clinical oral candidiasis in these subjects appears to range widely (0% to more than 80%) (Tapper-Jones *et al*, 1980; Baudet-Pommel *et al*, 1994; Lundström and Lindström, 1995; Rhodus *et al*, 1997; Soto-Rojas *et al*, 1998; Almståhl *et al*, 1999; Pedersen *et al*, 1999), most likely due to those surveyed having differing oral hygiene status and/or different criteria used to diagnose oral candidiasis. The candidiasis state is generally symptomless. A variety of yeast species have been isolated from SS using different culture techniques (Kindelan *et al*, 1998; Radfar *et al*, 2003). Most reports indicate that *Candida albicans* is the predominant yeast isolated, although *Candida glabrata* and *Candida tropicalis* have also been found, albeit infrequently (Kindelan *et al*, 1998; Torres *et al*, 2002). A Swedish study demonstrated increased prevalence (60% vs 25% in controls) but not proportion (%) of *C. albicans* from pooled supragingival plaque samples taken from the posterior teeth of non-denture-wearing pSS subjects (Almståhl *et al*, 1999). No report is available describing the corresponding microbiology in sSS subjects.

An earlier study by this research group reported that southern Chinese SS sufferers in Hong Kong had a higher DMFT than controls despite good oral hygiene (Leung *et al*, 2004). In addition, SS subjects had significantly more clinical signs of candidiasis-related mucosal conditions than controls (35% vs 17%).

Correspondence: W. Keung Leung, Periodontology, Faculty of Dentistry, The University of Hong Kong, Room 3B39, Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong SAR, China. Tel.: +852 2859 0417, Fax: +852 2858 7874, E-mail: ewkleung@hkucc.hku.hk  
Received 7 April 2006; revised 15 June 2006, 31 August 2006, 24 October 2006; accepted 8 January 2007

The present study aimed at investigating oral yeast colonization in pSS and sSS patients who were dentally well-maintained and had good oral hygiene. Putative associations between oral yeasts isolated from oral rinse or full-mouth supra-gingival plaque and oral candidiasis were also investigated. The hypothesis tested was that for pSS, sSS and control subjects under regular dental care, a similar proportion and minimal amount of yeast would be detectable from their oral rinse samples and supra-gingival plaque; and oral yeast detection would be independent of the clinical candidiasis state.

## Subjects and methods

### Subjects

Sjögren's syndrome sufferers were recruited from the Rheumatology Clinic, Faculty of Medicine, The University of Hong Kong, Queen Mary Hospital, Hong Kong, China. The subjects were further classified as pSS or sSS group depending on the clinical diagnosis, based on the revised version of the European Community Diagnostic Criteria for the Classification of SS (Vitali *et al*, 2002). All control and SS subjects had attended regular dental review at 6 month intervals for at least 12 months before study commencement. The control group comprised medically clear patients attending the Prince Philip Dental Hospital. No subjects were under active dental treatment at the time of the study. Exclusion criteria included subjects with a history of systemic autoimmune connective tissue disease, prior radiotherapy in the head and neck region, or any concurrent condition other than SS in test subjects which might cause altered saliva flow. Participants in the control group were selected for similar age and gender using the age/gender characteristics of both pSS and sSS groups. All subjects in the study were dentate southern Chinese. The Faculty of Dentistry Ethics Committee, University of Hong Kong, approved the study. Written informed consent was obtained from each participant prior to admission to the study.

### Oral examination

All clinical examinations and sampling were performed by one calibrated examiner (K.C.M.L.). The presence of clinical signs of oral candidiasis, i.e. angular cheilitis, erythematous lesions, or white removable plaque, was recorded (Soto-Rojas *et al*, 1998). Oral hygiene was assessed using the plaque (PI) (Löe and Silness, 1963) and calculus indices (CI) (Silness and Löe, 1964). Denture stomatitis in denture wearers, if any, was classified as reported by Newton (1962). In brief, the condition at the denture-bearing area was classified as follows. Stage 1: pin point hyperaemia; stage 2: diffuse hyperaemia; stage 3: granular inflammation, i.e. the mucosa has a nodular appearance with a hyperaemic surface normally present over the entire denture-bearing area but is more commonly restricted to the central areas and, in particular, under relief areas. Denture hygiene of denture wearers was assessed by scoring the cleanliness of the fitting surface as described by Blair *et al* (1995): 0 = no visible plaque detected by scraping

fitting surface with flat plastic; 1 = no visible plaque but plaque detectable by scraping of fitting surface; 2 = plaque visible upon careful examination; 3 = plaque deposits clearly visible; 4 = gross plaque deposits.

### Sialometry

All subjects were asked to rinse their mouths for 60 s with 10 ml of sterile 0.01 M phosphate-buffered saline (pH 7.2) (oral rinse microbial sampling; as described below) before stimulated whole saliva (SWS) sampling. SWS was then obtained as described in an earlier report (Leung *et al*, 2004). In brief, each subject was instructed to chew on a piece of sterilized silicone rubber tubing for 5 min and to expectorate all SWS into a sterile, pre-weighed plastic cup. All samples were collected between 9 AM and 12 noon. The flow rate was determined and expressed as ml min<sup>-1</sup>, as described previously (Leung *et al*, 2004).

### Microbial sampling

An oral rinse sampling protocol was used as described previously (Leung *et al*, 2000). Dentures, if present, were not removed during rinsing. Supra-gingival plaque samples were collected after the oral rinse. Plaque was removed with a sterile sickle scaler passing along the gingival margins of all standing teeth after air dry and cotton wool isolation. The sample was dispersed into a pre-weighed vial containing 1 ml reduced transport fluid. Care was taken to avoid sampling plaque sub-lingually and at sites covered by removable denture components or with open carious lesions. Full mouth supra-gingival plaque was removed and the net wet weight in grams was calculated.

### Culture and identification of yeast isolates

All oral rinse and plaque samples were used neat, and vortexed for 30 s at maximum setting (Autovortex Mixer SA2; Stuart Scientific, London, UK). Fifty microlitres of each of the oral rinse and plaque samples were serially diluted and spiral plated (Model DU; Spiral Systems, Cincinnati, OH, USA) on to CHROM-agar *Candida* plates (Becton Dickinson Europe, Le Pont de Claix, France), then incubated aerobically for 48 h at 37°C. After incubation, plates with appropriate number of colonies that were well separated and evenly dispersed with up to approximately 100 colony-forming units (c.f.u.) were chosen for counting. The number of yeast c.f.u. per ml of oral rinse or per gram wet weight of plaque was calculated. A stainless steel template was then used to subdivide the agar into sectors with a defined area (Leung *et al*, 2005). A sector with 6–10 colonies including all different colony morphotypes observed was selected and all colonies within the sector were subcultured using Sabouraud's dextrose agar (SDA; Oxoid, Unipath Ltd, Basingstoke, Hampshire, UK) to obtain pure isolates. For samples that gave rise to ≤10 yeast colonies, all colonies were subcultured. The estimated lowest detection level for yeast using the current protocol is 20 c.f.u. ml<sup>-1</sup> oral rinse or 20 c.f.u. per full-mouth plaque sample.

The yeasts were identified and speciated based on the following: colony morphology in CHROMagar and SDA, cell morphology, Gram staining reaction, germ tube test, and API 20C AUX test (Leung *et al*, 2000). To differentiate *C. albicans* from *C. dubliniensis*, all isolates with the appropriate presumptive identity were incubated aerobically on SDA, 48 h at 45°C, and on phenol red agar for 48 h at 26°C and 37°C respectively (Sancak *et al*, 2005). All plates were examined macroscopically for colony morphology and then microscopically for chlamydospore formation. Isolates from the same specimen with identical characteristics/test results based on the above identification protocol were considered as one isolate in the following experiments. Isolates that could not be identified in this manner were further characterized by MicroSeq D2 LSU rDNA fungal identification system (Applied Biosystems, Foster City, CA, USA). Yeast strains, of the same species, isolated from both oral rinse and plaque samples of an individual with identical biochemical or API 20C AUX characteristics, or identical MicroSeq D2 LSU rDNA fungal identification result, i.e. of same presumptive biotype or genetic identification, were considered to be an isolate pair. Their genetic relatedness would then be tested by pulsed field gel electrophoresis (PFGE).

#### Total anaerobic plaque bacteria count

All plaque samples were vortexed for 20 s at maximum setting (Autovortex Mixer) and then serially diluted in 10-fold increments up to 10 000-fold in trypticase soy broth. The diluted samples were plated onto enriched Columbia blood agar (CBABS, Columbia agar base with 5% defibrinated horse blood, 0.0005% hemin and 0.00005% vitamin K) (Leung *et al*, 2005) using a Spiroplater. CBABS plates were incubated in an anaerobic chamber (Forma Scientific Inc, Marietta, OH, USA) under an atmosphere of 10% CO<sub>2</sub>, 10% H<sub>2</sub>, 80% N<sub>2</sub> for 5–7 days at 37°C.

CBABS plates with appropriate number of colonies that were well separated and evenly dispersed were selected, i.e. plates with 30–300 c.f.u., were chosen for counting. With reference to the counts, inoculum size and the dilution factor, the total anaerobic viable counts (TVC) per gram wet weight supra-gingival plaque were measured. The percentage proportion of yeast over the corresponding TVC was then calculated.

#### Chromosomal analysis of yeast isolates by PFGE

All yeast isolates were subjected to PFGE analysis. Preparation of the yeast DNA was performed according to the instruction manual of CHEF Genomic DNA Plug kits (Bio-Rad Laboratories, Hercules, CA, USA).

The chromosomes of the yeast isolates were separated employing the contour-clamped homogeneous electric field (CHEF) technique using the CHEF-DR III Variable angle system (Bio-Rad Laboratories) in 0.5× TBE buffer at 10°C as described earlier with modifications (Leung *et al*, 2000). The electrophoretic conditions used were as follows: two-state mode with linear ramping factors; run time, 72 h; initial and final switching times, 3 and 17 min respectively; constant voltage of 3 V cm<sup>-1</sup>, switching

angle, 106°. *Hansenula wingei* and *Saccharomyces cerevisiae* chromosomes (Bio-Rad) were used as the molecular size standards. The resulting gel was stained with 0.5 µg ml<sup>-1</sup> ethidium bromide (Sigma, St Louis, MO, USA) in distilled water for 15 min and then destained in distilled water for 3 h. DNA bands were visualized and photographed under UV transillumination. The PFGE profiles of the yeast isolates were confirmed by repeating the assay two more times on separate occasions.

#### Dendrogram analysis of yeast isolates

The PFGE pattern of all yeast strains group under the same species, except those of a single isolate was analysed using the Dendron® 3.0 Program (Soll-tech, Oakdale, CA, USA). The unweighed pair group method with arithmetic means (UPGMA) was used for clustering of the isolates on the dendrogram. The method was applied to 61, 5, 4, 3 and 2 strains each of *C. albicans*, *C. parapsilosis*, *C. tropicalis*, *S. cerevisiae*, and *C. dubliniensis*, *C. glabrata*, or *Trichosporon mucoides* respectively. One strain each of *C. guilliermondii*, *C. krusei*, and *C. lusitanae*, *C. pelliculosa*, *C. pseudointermedia* isolate from control or sSS oral rinse samples, respectively, was not analysed. Closely related genetic clusters of individual yeast species were identified and the genetic similarities were measured. Isolate pairs were considered to be of the related genetic clonal type when  $S_{AB} \geq 0.85$  (Clemons *et al*, 1997).

#### Statistical analysis

The demographic and microbiological parameters were analysed and compared among the pSS, sSS and control groups. Differences in categorical variables among the three groups were tested by chi-squared test or Fisher's exact test whichever appropriate. One-way ANOVA, unpaired *t*, or Kruskal–Wallis tests, whichever appropriate, was performed for evaluating differences in continuous variables among the three groups. Multiple comparisons were carried out with Bonferroni correction of *P*-values. Spearman's rank correlation coefficient was used to explore associations between parameters of interest. A 5% level of significance was used for the statistical tests. All data were analysed using SPSS for Windows 12.0.1.

## Results

#### Participants

The study population consisted of 25 pSS (one male; mean age 50.7, range 33–74) and 27 sSS (one male; mean age 42.7, range 26–66) patients. The mean time since diagnosis was for 7.2 and 3.9 years, respectively, for pSS and sSS. The control group had 29 participants (two men; mean age 43.9, range 27–75). All except one woman in the control group were non-smokers. There was no age-related difference among the three groups (*P* > 0.05). Duration of last dental recall visit was from within 5 months and 2 weeks to 6 months and 2 weeks for all participants. All subjects were partially or fully dentate. Other than fluoridated toothpaste, no control or SS subject used home care fluoride products. None of

the SS patients were taking medication for dry mouth symptoms. Seven (28%) pSS and eight (30%) sSS patients were taking hydroxychloroquine for management of extra-glandular manifestation of SS. None of the patients were receiving anticholinergic therapeutic agents. Eighteen sSS patients had SLE, four had RA, two had sicca symptoms, two had SLE-like disease and one had autoimmune hepatitis.

#### Sialometric parameters

Sjögren's syndrome sufferers had significantly lower SWS flow than the controls (pSS/sSS/control:  $0.3 \pm 0.4/0.4 \pm 0.4/0.9 \pm 0.5 \text{ ml min}^{-1}$ , ANOVA  $P < 0.001$ ; pSS/sSS < control, Bonferroni multiple comparison).

#### Oral hygiene and denture status

Among the pSS/sSS/control subjects, 88/89/100% tooth sites, respectively, had plaque score of  $\leq 1$  and 84/78/79% respectively had a calculus score of 0 (calculus free) ( $P = 0.111$  and  $0.884$ , respectively, chi-squared test), indicating on average a satisfactory level of oral cleanliness. There was a statistically significant difference in the number of removable denture wearers between groups ( $P = 0.001$ , Fisher's exact test, control vs total SS). Eight pSS subjects (32%) wore at least one removable denture, no sSS subjects wore removable dentures whereas six (22%) of them presented with fixed prostheses in at least one jaw. Two control subjects (7%) wore a single removable partial denture and one had a mandibular fixed prosthesis. Regarding denture hygiene

(Blair *et al*, 1995), four pSS subjects had score 0, three had score 1, one had score 2 while the two control denture wearers had score 0. None of the subjects surveyed had denture stomatitis.

#### Soft tissue

The prevalence of oral candidiasis based on clinical signs among the three groups is shown in (Table 1). None of those affected experienced symptoms. There was a statistically significant difference in the prevalence of oral candidiasis between the control and SS subjects (Table 1).

#### Isolation of oral yeasts

The mean wet weight of full-mouth supra-gingival plaque sampled was  $10.4 \pm 32.0 \text{ mg}$  (range 0.3–295.2 mg). The prevalence and quantity of yeast colonization are summarized in Table 1. More pSS (84%) and sSS (63%) sufferers than control subjects (7%) had oral yeast detectable from either oral rinse or full-mouth plaque samples ( $P < 0.0001$ , chi-squared test). For SS cases as a whole, the prevalence of yeast was 56% for both oral rinse and plaque, and 73% for either oral rinse or plaque in SS subjects. Fifteen SS subjects had no detectable level of yeast in plaque or oral rinse samples. Primary SS subjects also had a significantly higher mean yeast count in both samples compared with sSS subjects and controls ( $P < 0.001$ ). In all SS patients who wore dentures oral yeast was detected in both samples. A positive correlation was detected between oral

	pSS (n = 25)	sSS (n = 27)	Control (n = 29)
% oral candidiasis <sup>a</sup>	20	18.5	0
% yeast colonization			
Oral rinse <sup>b</sup>	72.0	48.1	6.9
Plaque <sup>b</sup>	84.0	55.6	0.0
Oral rinse and plaque <sup>b</sup>	72.0	40.7	0.0
% denture wearers with yeast colonization	n = 8	n = 0	n = 2
Oral rinse	100.0	NA <sup>c</sup>	50.0
Plaque <sup>c</sup>	100.0	NA	0.0
Oral rinse and plaque <sup>c</sup>	100.0	NA	0.0
Yeast count (mean $\pm$ s.d.)			
Oral rinse (c.f.u. ml <sup>-1</sup> ) <sup>d</sup>	1025.5 $\pm$ 3882.1	155.0 $\pm$ 327.2	2.1 $\pm$ 8.2
Denture wearers	2689.8 $\pm$ 6836.3	NA	20.0 $\pm$ 28.3
Non-denture wearers <sup>d</sup>	242.4 $\pm$ 351.3	155.0 $\pm$ 327.2	0.7 $\pm$ 3.9
Plaque ( $\times 10^6$ c.f.u. g <sup>-1</sup> ) <sup>d</sup>	1.8 $\pm$ 4.1	0.4 $\pm$ 0.8	0.0
Denture wearers	0.9 $\pm$ 1.0	NA	0.0
Non-denture wearers <sup>d</sup>	2.3 $\pm$ 5.0	0.4 $\pm$ 0.8	0.0
Candida count (mean $\pm$ s.d.)			
Oral rinse (c.f.u. ml <sup>-1</sup> ) <sup>d</sup>	1017.5 $\pm$ 3883.7	149.1 $\pm$ 322.7	2.1 $\pm$ 8.2
Plaque ( $\times 10^6$ c.f.u. g <sup>-1</sup> ) <sup>d</sup>	1.8 $\pm$ 4.1	0.4 $\pm$ 0.8	0.0
% per total anaerobic viable count in supra-gingival plaque			
Yeast ( $\times 10^{-3}$ ) <sup>d</sup>	0.4 $\pm$ 0.7	1.2 $\pm$ 5.2	0.0
Denture wearers	0.5 $\pm$ 0.5	NA	0.0
Non-denture wearers <sup>d</sup>	0.3 $\pm$ 0.7	1.2 $\pm$ 5.2	0.0
Candida ( $\times 10^{-3}$ ) <sup>d</sup>	0.4 $\pm$ 0.7	1.1 $\pm$ 4.8	0.0

**Table 1** Quantity and prevalence of yeast isolated from oral rinse and supra-gingival plaque samples

NA, not applicable.

<sup>a</sup> $P = 0.012$ , Fisher's exact test, pSS and sSS subjects grouped together.

<sup>b</sup>Significant difference among the groups,  $P < 0.0001$ ,  $\chi^2$  test.

<sup>c</sup> $P = 0.022$ , Fisher's exact test; no removable denture wearer in sSS group.

<sup>d</sup>Significant difference among the groups,  $P < 0.001$ , Kruskal–Wallis test.

colonization by yeast and removable denture wearing ( $r_s = 0.334$ ,  $P = 0.004$ ). Similarly, in non-denture wearers, more number of yeasts were detected from oral rinse or full-mouth supra-gingival plaque of SS than in control subjects [pSS/sSS/control;  $n = 17/27/27$ ; mean oral rinse yeast count:  $242.4 \pm 351.3/155.0 \pm 327.2/0.7 \pm 3.9$  c.f.u.  $\text{ml}^{-1}$ ; mean full-mouth supra-gingival plaque yeast count ( $\times 10^6$ ):  $0.0 \pm 0.0/2.3 \pm 5.0/0.4 \pm 0.8$  c.f.u.  $\text{g}^{-1}$  wet weight; mean percentage proportion yeast per total viable anaerobic count ( $\times 10^{-3}$ ):  $0.0 \pm 0.0/0.3 \pm 0.7/1.2 \pm 5.2\%$ ,  $P < 0.001$ , Kruskal-Wallis test]. Four pSS, 10 sSS and 27 control subjects did not carry yeasts above detectable level in their oral rinse or full-mouth plaque samples.

A total of 84 yeast strains were isolated. Six pSS and six sSS sufferers harboured more than one species of yeast, and three species of yeast were recovered from two sSS sufferers. The most predominant yeast isolated was *C. albicans*, with 28 and 33 strains isolated from oral rinse and full-mouth supra-gingival plaque samples respectively. Growth characteristics, API 20C AUX test and chlamydospore production on phenol red agar confirmed the identity for all *C. dubliniensis* and all except five *C. albicans* isolates which had an API 20C AUX profile preliminary identified as *C. albicans* but did not grow under  $45^\circ\text{C}$  and formed chlamydospores on phenol red agar at  $26^\circ\text{C}$ . The final *C. albicans* identity of these isolates was confirmed by MicroSeq D2 LSU rDNA fungal identification. Yeast types cultivated from both samples are shown in Table 2. No statistically significant difference was detected between the mean c.f.u. of the various yeast species among the three groups apart from *C. albicans* ( $P < 0.001$ ).

### Oral yeast isolation and candidiasis

In 7 of 10 SS subjects with candidiasis yeast were detected from both oral rinse and plaque samples. One sSS subject with candidiasis had detectable yeast from supra-gingival plaque while the remaining two affected SS subjects did not have any detectable yeast from plaque or oral rinse samples. They were all non-denture wearers. Among the two with no detectable yeasts, one subject (pSS) had no intra-oral mucosal lesions except mild angular cheilitis. The other sSS subjects had clinical oral mucosa manifestations of candidiasis. SS subjects with oral candidiasis tended to have higher mean yeast and *C. albicans* counts in both oral rinse and plaque samples than those who did not, although the difference was not statistically significant (SS subjects with candidiasis vs without candidiasis: mean yeast/*C. albicans* in oral rinse,  $426/418$  vs  $361/355$  c.f.u.  $\text{ml}^{-1}$ ; mean yeast/*C. albicans* in plaque,  $2.7 \times 10^6/2.7 \times 10^6$  vs  $4.3 \times 10^5/4.2 \times 10^5$  c.f.u.  $\text{g}^{-1}$ ). However, a positive correlation was observed between the prevalence of oral candidiasis and the prevalence of yeast isolated in plaque but not in the oral rinse ( $r_s = 0.269$ ,  $P = 0.02$  and  $r_s = 0.223$ ,  $P = 0.082$  respectively). Despite the high isolation rate of yeast associated with removable denture wearing (Table 1), there was no correlation between the prevalence of oral candidiasis and appliance usage among subjects in all three groups ( $P = 0.604$ ). When denture wearers were excluded from the data analysis, subjects with oral candidiasis had higher but not statistically significant mean yeast or *C. albicans* counts in both oral rinse and plaque samples (mean yeast/*C. albicans* in oral rinse,  $467/460$  vs  $73/68$  c.f.u.  $\text{ml}^{-1}$ ; mean yeast/*C. albicans* in plaque,  $3.3 \times 10^6/3.2 \times 10^6$  vs  $3.8 \times 10^5/3.8 \times 10^5$  c.f.u.  $\text{gm}^{-1}$ ). Nonetheless, positive correlations

**Table 2** Identity, frequency and quantity of cultivable yeast isolated from oral rinse samples and full-mouth supra-gingival plaque<sup>a</sup>

	Oral rinse						Supra-gingival plaque <sup>b</sup>			
	pSS (n = 25)		sSS (n = 27)		Control (n = 29)		pSS (n = 25)		sSS (n = 27)	
	Prevalence (%)	Mean viable count (c.f.u. $\text{ml}^{-1}$ )	Prevalence (%)	Mean viable count (c.f.u. $\text{ml}^{-1}$ )	Prevalence (%)	Mean viable count (c.f.u. $\text{ml}^{-1}$ )	Prevalence (%)	Mean viable count (c.f.u. $\text{g}^{-1}$ )	Prevalence (%)	Mean viable count (c.f.u. $\text{g}^{-1}$ )
<i>Candida</i>										
<i>Candida albicans</i> <sup>c</sup>	16 (64)	1015.1	12 (44)	149.1	0	0	18 (72)	$18 \times 10^5$	15 (56)	$4 \times 10^5$
<i>Candida dubliniensis</i>	0	0	0	0	0	0	1 (4)	5846	1 (4)	898
<i>Candida glabrata</i>	2 (8)	1.6	0	0	0	0	0	0	0	0
<i>Candida guilliermondii</i>	0	0	0	0	1 (3)	1.4	0	0	0	0
<i>Candida krusei</i>	0	0	0	0	1 (3)	0.7	0	0	0	0
<i>Candida lusitanae</i>	0	0	1 (4)	0.7	0	0	0	0	0	0
<i>Candida parapsilosis</i>	2 (8)	2.4	2 (7)	1.5	0	0	1 (4)	143	0	0
<i>Candida pelliculosa</i>	0	0	1 (4)	1.5	0	0	0	0	0	0
<i>Candida pseudointermedia</i>	0	0	1 (4)	0.7	0	0	0	0	0	0
<i>Candida tropicalis</i>	1 (4)	2.4	1 (4)	0.7	0	0	2 (8)	$1.7 \times 10^4$	0	0
Non- <i>Candida</i>										
<i>Saccharomyces cerevisiae</i>	1 (4)	1.6	1 (4)	0.7	0	0	0	0	1 (4)	6173
<i>Trichosporon mucoides</i>	1 (4)	2.4	0	0	0	0	1 (4)	1739	0	0

<sup>a</sup>Some individuals carried more than a single yeast species.

<sup>b</sup>No yeast was detected from full-mouth supra-gingival plaque of control subjects ( $n = 29$ ).

<sup>c</sup>Significant difference regarding c.f.u. counts (per ml oral rinse or per gram wet weight supra-gingival plaque) among the groups,  $P < 0.001$ , Kruskal-Wallis test.

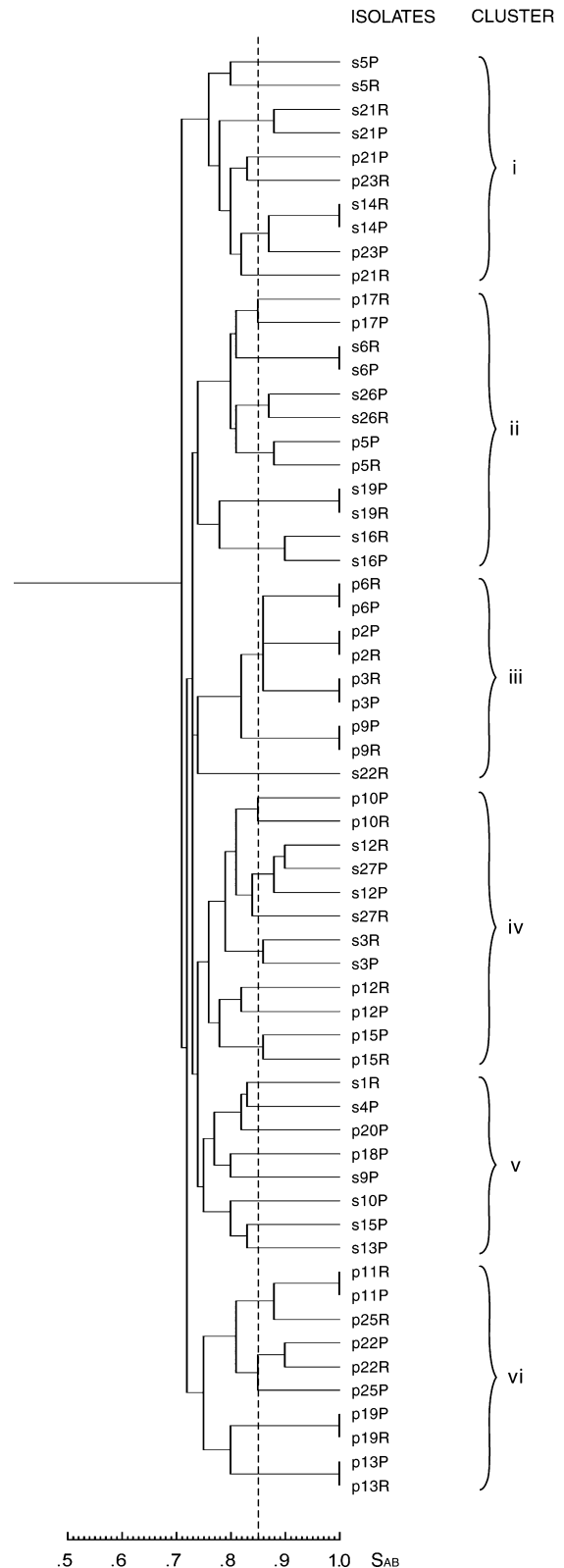
were observed between the prevalence of oral candidiasis and the prevalence of yeast isolated from oral rinse or plaque in non-denture wearers ( $r_s \geq 0.257$ ,  $P \leq 0.044$ ).

#### PFGE analysis of yeast isolates from SS subjects

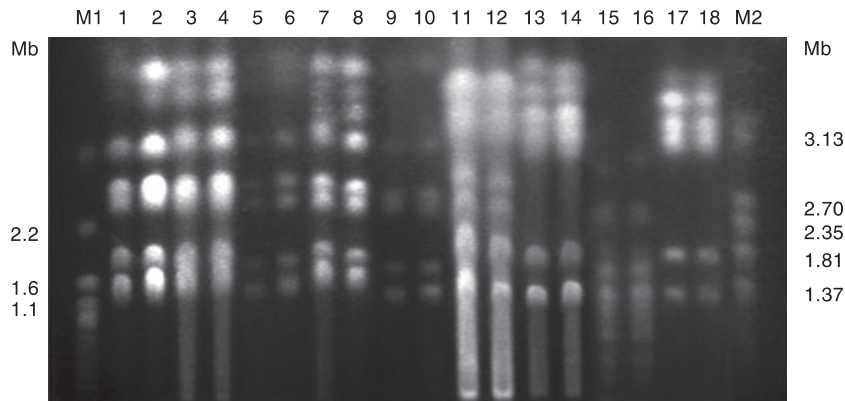
All yeast isolates except one strain each of *C. guilliermondii*, *C. krusei*, *C. lusitanae*, *C. pelliculosa* and *C. pseudointermedia* isolate were subject to PFGE karyotyping as described above. The genetic relatedness of the total 61 *C. albicans* strains are shown in Figure 1, a dendrogram constructed based on UPGMA clustering analysis of the PFGE results. The  $S_{AB}$  values of the *C. albicans* isolates ranged from 0.71 to 1.0. There were six clusters (i–vi) showing fairly even distribution of the isolates. Subjects harbouring *C. albicans* belonging to cluster vi were significantly older than the corresponding subjects of cluster i (58.8 vs 37.0 years,  $P = 0.032$ , Bonferroni multiple comparison). Subjects harbouring *C. albicans* belonging to cluster v had (a) lower quantity of the yeast in oral rinse samples than subjects with cluster vi (mean *Candida*: 38 vs 4060 c.f.u. ml<sup>-1</sup>,  $P = 0.01$ , Kruskal–Wallis test), or (b) larger quantity of the yeast in full-mouth supra-gingival plaque than subjects with cluster iv (mean *Candida*:  $4.2 \times 10^6$  vs  $5.9 \times 10^4$  c.f.u. g<sup>-1</sup>,  $P = 0.047$ , Bonferroni multiple comparison).

Using  $S_{AB} \geq 0.85$  to identify subgroups with closely related genetic clonotypes or karyotypes, fourteen (78%), and eight (80%) of the identified *Candida* isolate pairs from pSS and sSS groups, respectively, were found to be closely related ( $P < 0.001$ , Kruskal–Wallis test). One pSS sufferer had one isolate pair of PFGE identical *C. parapsilosis* while another pSS sufferer had an identical pair of *C. tropicalis* (Figure 2). Twenty *C. albicans* isolate pairs out of a total of 61 isolates showed close karyotypic or genetic identity ( $S_{AB} \geq 0.85$ , Figure 1). Out of these 20 pairs, seven and three isolate pairs from the pSS and sSS groups, respectively, were karyotypically identical, i.e.  $S_{AB} = 1.0$  ( $P = 0.008$ , Kruskal–Wallis test). One isolate pair each of *C. parapsilosis*, *C. tropicalis*, *S. cerevisiae* and *T. mucoides* isolates showed close or identical karyotypes ( $S_{AB} \geq 0.85$ ). One pSS subject had two karyotypically identical isolate pairs, i.e. one pair each of *C. albicans* and *T. mucoides*. The rest of the yeast isolates did not appear to be karyotypically related to each other. In summary, 22 of 52 SS subjects (42%) had genetically related *Candida* or

yeast strains that could be isolated from oral rinse sample and supra-gingival plaque at the same time, five more subjects had positive *Candida* isolates from both oral rinse and supra-gingival plaque but were apparently



**Figure 1** Dendrogram showing the genetic divergence of 61 strains of *Candida albicans* isolated from oral rinse (R) and full-mouth supra-gingival plaque (P) of pSS (p) and sSS (s) subjects analysed by pulse-field gel electrophoresis (PFGE). The dendrogram was constructed by unweighed pair group method with arithmetic means (UPGMA clustering analysis). A dashed line is drawn at  $S_{AB} = 0.85$  to denote the threshold selected to demarcate genetic relatedness of isolates (Clemons et al, 1997). Note that the *C. albicans* isolates formed six PFGE karyotype clusters ( $S_{AB} \geq 0.73$ , clusters i–vi). Ten isolate pairs of *C. albicans* (seven and three pairs from pSS and sSS respectively) were karyotypically/genetically identical, i.e.  $S_{AB} = 1.0$ ; another 10 isolate pairs appeared to be genetically related. Representative *C. albicans* PFGE patterns are shown in Figure 2



**Figure 2** Representative pulse-field gel electrophoresis separation of chromosome-sized DNA of yeast isolate pairs of different karyotypic clonal types from oral rinse samples and full-mouth supra-gingival plaque from subjects with SS. Lane M1: *Saccharomyces cerevisiae* chromosome molecular size standard (Bio-Rad); lanes 1, 3, 5, 7, 9: *C. albicans* strains isolated from oral rinse samples; lanes 2, 4, 6, 8, 10: *C. albicans* strains isolated from full-mouth supra-gingival plaque sample of the corresponding subjects; lanes 11 and 12, 13 and 14, 15 and 16, 17 and 18: *C. tropicalis*, *C. parapsilosis*, *S. cerevisiae* or *T. mucoides* isolate pairs from oral rinse sample and full-mouth supra-gingival plaque from the same subject respectively; lane M2: *Hansenula wingii* chromosome molecular size standard (Bio-Rad). All isolate pairs except lanes 5 and 6, 15 and 16 ( $S_{AB} \geq 0.86$ ) were found to be karyotypically identical, i.e.  $S_{AB} = 1.0$

not genetically related; another SS subject had unrelated *C. albicans* isolate pair which was related to isolates from two other SS individuals. Five or seven subjects had one *Candida* species isolated only from the oral rinse or plaque respectively.

Among SS subjects with a *C. albicans* isolate pair, their oral mucosa (as detected by oral rinse) and full-mouth supra-gingival plaque were apparently colonized by a genetically related, if not identical, strain of the same yeast (*C. albicans* isolates form isolate pairs or not *vs*  $S_{AB} < 0.85$  or  $S_{AB} \geq 0.85$ ;  $P < 0.001$ , Fisher exact test). They also showed a higher but not statistically significant mean *Candida* count than individuals with no *C. albicans* isolate pair detectable (1124 c.f.u. *vs* 44 c.f.u.).

One representative isolate pair from each of the five *C. albicans* karyotypic clusters (except cluster v which lacks isolate pair), and one each of *C. parapsilosis*, *C. tropicalis*, *S. cerevisiae* and *T. mucoides* isolate pair are shown in Figure 2.

## Discussion

The prevalence of clinically detectable oral candidiasis among SS sufferers in the present study was around 20% ( $n = 10$ ), which is at the lower end of the reported range. The low rate of oral candidiasis observed in the current study is possibly due to good oral and/or denture hygiene and the stringent diagnostic criteria for oral candidiasis used (Soto-Rojas *et al*, 1998). The current study revealed that oral candidiasis in the present cohort of regularly dentally cared for SS sufferers seemed to be associated with the presence of yeast in full-mouth supra-gingival plaque. The current understanding that *Candida* residing in oral biofilm is one of the agents in oral mycotic infection (Coogan *et al*, 2006) provided theoretical support for this observation. The fact that no swab or imprint sample was taken at candidiasis sites apparently prevented the direct comparison between the

yeast causing the infection and those residing in supra-gingival plaque. Hence one must consider this limitation when interpreting the current data. It is known however that the turnover rate for the intact oral epithelium layer is 4–14 days (Squier *et al*, 1976) implying the quick exfoliation of the superficial cell layers. Therefore, for successful colonization by yeasts, a recurring source of 'pioneering micro-colonies of yeasts' from an already established biofilm reservoir would be pivotal.

Although many sampling methods for oral mucosal flora have been devised, it is now generally recognized that the oral rinse sampling method designed by Samaranayake *et al* (1986) two decades ago is the simplest and practical method for the purpose, especially when focal erythematous or pseudo-membranous lesions are unapparent. Furthermore, the employment of this standard methodology provides a comparator useful for relative assessment between different studies conducted in the past for normal, non-SS (Leung *et al*, 2003), SS (Kindelan *et al*, 1998; Radfar *et al*, 2003) or other xerostomic subjects (Leung *et al*, 2000).

No report, however, is available reporting how often and how many 'pioneering micro-colonies' would be released from supra-gingival plaque per unit time (60 s in the current case) after oral rinse. On the other hand, considering that the subjects in this study were of generally good oral hygiene (up to 90% tooth sites without visible plaque) and hence with small amount of supra-gingival plaque and thus the total surface area of oral mucosa exposed to oral rinse sampling is substantially greater than the supra-gingival plaque, we postulated that our oral rinse sampling 'predominantly detected the mucosal colonization of oral yeast' among the subjects surveyed in this particular situation.

It was in only one sSS subject that negative oral rinse and supra-gingival plaque culture was associated with clinical candidiasis; perhaps infection was associated with yeasts at below the detection level. Another SS subject was classified as suffering from candidiasis

because of angular cheilitis at the left-hand corner of the mouth. The same subject had otherwise normal intact oral mucosa. Failure of yeast detection in that individual was perhaps due to the inability of the oral rinse sample to reach corners of the mouth, or again the offending yeast was at a level below our detection limit, or the possibility that non-mycotic infectious agent might be involved (Dias and Samaranayake, 1995). There is no guideline available regarding the critical yeast count above which clinical signs of oral candidiasis will be evident, although it is generally agreed that oral candidiasis is observed in individuals with high yeast counts, e.g. reported median c.f.u. of 1349 as measured by oral rinse or swab (Abraham *et al*, 1998). Comparing the reported data to our current low median level of 280 c.f.u. ml<sup>-1</sup> oral rinse in regularly dentally cared SS subjects with candidiasis, one would readily appreciate why in a small proportion of the affected individual we failed to detect the presence of yeast. The corresponding yeast levels from oral rinse in candidiasis or non-candidiasis SS subjects that were not significantly different might also help explain such an observation. In a cohort of elderly institutionalized people with poor oral hygiene (19% of them were xerostomic), Grimoud *et al* (2005) showed that after a 3-month oral hygiene programme, the prevalence of oral candidiasis and total quantity of yeasts reduced measurably, reflecting that oral yeast colonization in susceptible subjects could be reduced by attention to oral cleanliness. The current SS sufferers and controls, however, demonstrated reasonable oral hygiene with up to 90% tooth sites without visible plaque. Despite the similar levels of oral hygiene, the prevalence of yeast colonization in controls was only detectable from oral rinse samples at a low level (7%) while the corresponding prevalence was ≥50% for SS sufferers. In order to establish a clearer linkage between clinical candidiasis, oral hygiene and oral yeast colonization, a longitudinal investigation, involving a larger sample size, correlating the microbiology, presence or absence of oral candidiasis vs plaque control as well as supra-gingival plaque yeast prevalence or counts would be needed.

Only two of eight pSS denture wearers (25%) surveyed had oral candidiasis, one of whom had a denture hygiene score of 2. In contrast to common belief, candidiasis did not appear to be associated with removable denture wearing in the present SS cohort who incidentally had reasonable denture hygiene and were free of denture-related stomatitis. Such negative findings between candidiasis and denture wearing are supported by Soto-Rojas *et al* (1998).

In the current study, the prevalence of yeast colonization was 84% and 63%, respectively, for the pSS and sSS groups, which is significantly higher than controls (7%). This finding compares favourably with a number of similar studies which reported 59% to almost 100% yeast colonization in SS sufferers (Tapper-Jones *et al*, 1980; Lundström and Lindström, 1995; Abraham *et al*, 1998; Radfar *et al*, 2003). The increased rate of yeast colonization is considered to be the effect of hyposalivation as significantly lower salivary flow rates were observed.

Two previous reports (Kindelan *et al*, 1998; Pedersen *et al*, 1999) have demonstrated a higher rate of yeast colonization in primary, compared with secondary, SS sufferers, which was also observed in the current study. However, those studies did not explain the observation. A lower, but not statistically significant, salivary flow rate has been uniformly detected in pSS sufferers compared to sSS subjects (Daniels *et al*, 1975; van der Reijden *et al*, 1996; Almståhl *et al*, 1999). It is postulated that two factors may account for the higher rate of yeast colonization in the pSS group – reduced saliva production and/or denture wearing. The fact that none of our sSS subjects were denture wearers limited our ability to genuinely substantiate the effect of reduced saliva production and yeast colonization among pSS or sSS subjects.

All SS denture wearers in this study had positive yeast cultures for both oral rinse and plaque samples. A similar observation was also reported by Radfar *et al* (2003), although Tapper-Jones *et al* (1980) reported a slightly lower figure. In the present study, a strong correlation between removable denture wearing and yeast colonization was detected which had not been reported previously in SS patients. Yet, this finding should be interpreted with caution as there were only eight SS denture wearers involved. Nonetheless, removable prostheses wearing has been long recognized as a risk factor for yeast carriage as the effect of diminished salivary flow in SS subjects on yeast growth is further augmented by removable denture wearing. Oral prostheses are believed to cause persistent trauma to the oral mucosa and promote proliferation of yeast (Nyquist, 1992). They also provide microscopically rough surface for the yeast to inhabit (Taylor *et al*, 1998).

Using the oral rinse sampling technique, *Candida* counts of pSS sufferers have been reported to be around 1000 c.f.u. ml<sup>-1</sup> by a number of investigators and is significantly different to healthy controls (Abraham *et al*, 1998; Kindelan *et al*, 1998; Almståhl *et al*, 1999). Our results compare favourably with previous work. A lower mean yeast count was obtained from sSS sufferers, which supports the findings of some researchers (Kindelan *et al*, 1998; Rhodus *et al*, 1998) but not others (Rhodus *et al*, 1997; Almståhl *et al*, 1999). To our knowledge, there is only one study which has reported the amount of *C. albicans* in the supra-gingival plaque of pSS subjects (Almståhl *et al*, 2001). They reported that 60% and 25% of pSS and controls, respectively, had *C. albicans* in supra-gingival plaque samples, and a significantly higher mean *C. albicans* count in pSS than in controls. However, a significant proportion of their cohort frequently used saliva stimulant which has been shown to lead to an increased salivary flow rate and a decreased amount of *C. albicans* colonization (Rhodus *et al*, 1998), making direct comparison with the current report difficult. Nonetheless, it is noteworthy that the mean *C. albicans* count (c.f.u. g<sup>-1</sup> wet weight plaque) of the present pSS cohort was almost 2000-fold than that obtained by the Swedish group while the mean proportion viable count of *C. albicans* in pSS non-denture wearers was 100-fold less than the Swedish report (0.0003% vs 0.04%) (Almståhl *et al*, 2001).



Among the yeast species identified, the majority were *C. albicans* which is in agreement with previous studies (Hernandez and Daniels, 1989; Kindelan *et al*, 1998; Soto-Rojas *et al*, 1998; Torres *et al*, 2002; Radfar *et al*, 2003). This can be explained by the fact that *C. albicans* are more robust and can survive and adapt to diverse environments by phenotypic and/or genotypic switching (Cannon *et al*, 1995; Leung *et al*, 2000). Moreover, six SS subjects from each group (24% pSS and 22% sSS) showed mixed colonization which compares favourably with the 28% noted by Torres *et al* (2002). Mixed colonization has also been observed, though less frequently, in patients with HIV (Tsang and Samaranyake, 2000) and advanced malignancy (Jobbins *et al*, 1992). It is mostly caused by alteration in host defence which promotes colonization by other non-*C. albicans* opportunistic pathogens such as *C. dubliniensis*, *C. krusei* and *C. parapsilosis* (Weems, 1992; Samaranyake and Samaranyake, 1994; Gutierrez *et al*, 2002). Furthermore, the use of CHROMagar *Candida* as the isolation medium has been shown to have high sensitivity and specificity in detection of mixed cultures (Kindelan *et al*, 1998; Willinger and Manafi, 1999).

To our knowledge, this is the first time that oral *Candida* colonization has been characterized and studied from oral rinse and full-mouth supra-gingival plaque samples of SS sufferers. A variety of molecular-based techniques are available including electrophoretic karyotyping, restriction fragment length polymorphisms (RFLP) (Merz, 1990, review), randomly amplified polymorphic DNA (RAPD) (Leung *et al*, 2000; Dassanayake and Samaranyake, 2003, review) and other PCR-based approaches such as repetitive sequence-based PCR (rep-PCR) (Chen *et al*, 2005). High variability or low reproducibility are frequently encountered using RFLP or RAPD particularly under low-stringency conditions (Leung *et al*, 2000; Dassanayake and Samaranyake, 2003) while the rep-PCR technique appears to rectify, to some extent, the shortfall of PCR-based techniques (Chen *et al*, 2005). The PCR or the RFLP-based methods gave high discriminatory indices and were effective in discriminating a particular pathogenic strain of the yeast from regular isolates (Chen *et al*, 2005). On the other hand, to identify clonal relatedness of isolates from the same host, electrophoretic karyotyping appeared to be the best approach (Leung *et al*, 2000; Chen *et al*, 2005) and was thus used in the current study.

Using electrophoretic karyotyping, we were able to show that out of the 52 SS sufferers, 22 (42%) had genetically related *Candida* or yeast strains colonizing the oral mucosa and supra-gingival plaque at the same time. Comparing genetically related *C. albicans* isolation pairs to the other *C. albicans* strains obtained from the same cohort, interesting findings were observed. No two subjects were colonized by *C. albicans* with the same PFGE genetic identity, although 10 subjects colonized by *C. albicans* strains showed PFGE genetic relatedness to a *C. albicans* strain from one other individual among their group, of which the genetic relatedness detected by PFGE (mean  $S_{AB} \pm \text{s.d.} = 0.87 \pm 0.02$ ) was smaller

than that between the *C. albicans* isolate pair from the same individual ( $S_{AB} = 0.94 \pm 0.07$ ,  $P = 0.0003$ , unpaired *t*-test with Welch correction). We postulated that the *C. albicans* recovered from the SS subjects most likely had diverse origins.

In the majority of the subjects the oral mucosa and supra-gingival plaque were colonized by closely genetically related or identical yeast strains which led us to postulate that persistent oral mucosal yeast infections might be aggravated by supra-gingival plaque colonization of the offending yeast or its genetically related form. The fact that sessile rather than planktonic *C. albicans* is more resistant to antifungal *in vitro* (Ramage *et al*, 2001) favours the notion that the yeast would be in a protected, stable environment within the plaque biofilm. The yeast might, from time to time, be released by the biofilm and cause mucosal infection in those who were affected. The observation that *Candida* colonization of the gastrointestinal tract originated from carious teeth, which constituted an ecological niche (Hossain *et al*, 2003), tends to support this hypothesis, albeit indirectly. Further investigations are needed to establish the above hypothesis. We postulate that SS sufferers who had supra-gingival plaque colonized with yeast or *Candida* species might be more readily affected by mucosal colonization of the same or genetically related yeast species.

No *Candida* was recovered in the full-mouth supra-gingival plaque samples of the age- and gender-matched controls but was highly prevalent among all SS sufferers, despite more pSS subjects being denture wearers. This implies that *Candida* is able to establish itself in the supra-gingival plaque, a natural biofilm, of SS sufferers even if they practise good oral hygiene as was the case in our current cohort. Whether this establishment is the result of colonization by biofilm-forming *C. albicans* strains in SS, or is the result of diminished salivary flow rate and defence mechanisms leading to reduced selection pressure against *C. albicans*, or both, needs to be further explored. However, a recent *in vitro* study found no quantitative differences in biofilm formation ability between *C. albicans* from HIV-infected vs HIV-free individuals on a microtitre plate surface (Jin *et al*, 2003) possibly favouring the latter contention. Nonetheless, the clinical implication of such a finding is that once *Candida* is established in plaque, clinical and subclinical oral candidiasis might become persistent and difficult to manage, as treatment might involve not only topical application of antifungal agents to the oral mucosa but also an exceptionally high standard of plaque control. The reason being that the SS subjects had *C. albicans* established in supra-gingival plaque despite good oral hygiene and high dental awareness (Leung *et al*, 2004). Another concern is that *Candida* colonization of supra-gingival plaque can also serve as a reservoir for disseminated infections such as aspiration pneumonia and gastrointestinal infections in compromised individuals (Cannon *et al*, 1995; Hossain *et al*, 2003).

Within the limitations of the present study, Chinese SS sufferers with good oral hygiene appeared to be prone to oral *Candida* colonization. Clinical oral

candidiasis was only relatively commonly detected. *Candida albicans* was the predominant oral yeast isolated. *Candida* species were also found to be established in the supra-gingival plaque of many of the SS sufferers.

## Acknowledgements

This research was funded by grants from the Committee of Research and Conference Grants of the University of Hong Kong (W.K.L., 10202569; K.C.M.L., 10203765). We would like to thank Chak S. Lau and Temy M.Y. Mok for access to the SS patients attending the Queen Mary Hospital, Hong Kong, China.

## References

- Abraham CM, al-Hashimi I, Haghighat N (1998). Evaluation of the levels of oral *Candida* in patients with Sjögren's syndrome. *Oral Surg Oral Med Oral Pathol Oral Radio Endod* **86**: 65–68.
- Almståhl A, Kroneld U, Tarkowski A, Wikström M (1999). Oral microbial flora in Sjögren's syndrome. *J Rheumatol* **26**: 110–114.
- Almståhl A, Wikström M, Kroneld U (2001). Microflora in oral ecosystems in primary Sjögren's syndrome. *J Rheumatol* **28**: 1007–1013.
- Baudet-Pommel M, Albuisson E, Kemeny JL et al (1994). Early dental loss in Sjögren's syndrome. Histologic correlates. European Community Study Group on Diagnostic Criteria for Sjögren's syndrome (EEC COMAC). *Oral Surg Oral Med Oral Pathol* **78**: 181–186.
- Blair Y, Bagg J, MacFarlane TW, Chestnutt I (1995). Microbiological assessment of denture hygiene among patients in longstay and daycare community places. *Community Dent Oral Epidemiol* **23**: 100–103.
- Cannon RD, Holmes AR, Mason AB, Monk BC (1995). Oral *Candida*: clearance, colonization, or candidiasis. *J Dent Res* **74**: 1152–1161.
- Chen K-W, Lo H-J, Lin Y-H, Li S-Y (2005). Comparison of four molecular typing methods to assess genetic relatedness of *Candida albicans* clinical isolates in Taiwan. *J Med Microbiol* **54**: 249–258.
- Clemons KV, Feroze F, Holmberg K, Stevens DA (1997). Comparative analysis of genetic variability among *Candida albicans* isolates from different geographic locales by three genotypic methods. *J Clin Microbiol* **35**: 1332–1336.
- Coogan MM, Fidel PL Jr, Komesu MC, Maeda N, Samaranayake LP (2006). (B1) *Candida* and mycotic infections. *Adv Dent Res* **19**: 130–138.
- Daniels TE, Silverman S Jr, Michalski JP, Greenspan JS, Sylvester RA, Talal N (1975). The oral component of Sjögren's syndrome. *Oral Surg* **39**: 875–885.
- Dassanayake RS, Samaranayake LP (2003). Amplification-based nucleic acid scanning techniques to assess genetic polymorphism. *Crit Rev Microbiol* **29**: 1–24.
- Dias AP, Samaranayake LP (1995). Clinical, microbiological and ultrastructural features of angular cheilitis lesions in southern Chinese. *Oral Dis* **1**: 43–48.
- Fox RI (2003). Sjögren's syndrome: evolving therapies. *Expert Opin Investig Drugs* **12**: 247–254.
- Grimoud AM, Lodter JP, Marty N et al (2005). Improved oral hygiene and *Candida* species colonization level in geriatric patients. *Oral Dis* **11**: 163–169.
- Gutierrez J, Morales P, Gonzalez MA, Quindos G (2002). *Candida dubliniensis*, a new fungal pathogen. *J Basic Microbiol* **42**: 207–227.
- Hernandez YL, Daniels TE (1989). Oral candidiasis in Sjögren's syndrome: prevalence, clinical correlations, and treatment. *Oral Surg Oral Med Oral Pathol* **68**: 324–329.
- Hossain H, Ansari F, Schulz-Weidner N, Wetzel WE, Chakraborty T, Domann E (2003). Clonal identity of *Candida albicans* in the oral cavity and the gastrointestinal tract of pre-school children. *Oral Microbiol Immunol* **18**: 302–308.
- Jin Y, Yip HK, Samaranayake YH, Yau JY, Samaranayake LP (2003). Biofilm-forming ability of *Candida albicans* is unlikely to contribute to high levels of oral yeast carriage in cases of human immunodeficiency virus infection. *J Clin Microbiol* **41**: 2961–2967.
- Jobbins J, Bagg J, Parsons K, Finlay I, Addy M, Newcombe RG (1992). Oral carriage of yeasts, coliforms and staphylococci in patients with advanced malignant disease. *J Oral Pathol Med* **21**: 305–308.
- Kindelan SA, Yeoman CM, Douglas CWI, Franklin C (1998). A comparison of intraoral *Candida* carriage in Sjögren's syndrome patients with healthy xerostomic controls. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **85**: 162–167.
- Leung KCM, McMillan AS, Leung WK, Wong MCM, Lau CS, Mok TMY (2004). Oral health condition and saliva flow in southern Chinese with Sjögren's syndrome. *Int Dent J* **54**: 159–165.
- Leung WK, Dassanayake RS, Yau JYY, Jin LJ, Yam WC, Samaranayake LP (2000). Oral colonization, phenotypic, and genotypic profiles of *Candida* species in irradiated, dentate, xerostomic nasopharyngeal carcinoma survivors. *J Clin Microbiol* **38**: 2219–2226.
- Leung WK, Yau JYY, Cheung BPK et al. (2003). Oral colonisation by aerobic and facultatively anaerobic gram-negative rods and yeast in Tibetans living in Lhasa. *Arch Oral Biol* **48**: 117–123.
- Leung WK, Jin L, Yau JYY, Sun Q, Corbet EF (2005). Microflora cultivable from minocycline strips placed in persisting periodontal pockets. *Arch Oral Biol* **50**: 39–48.
- Löe H, Silness J (1963). Periodontal disease in pregnancy. I. Prevalence and severity. *Acta Odont Scand* **21**: 533–551.
- Lundström IMC, Lindström FD (1995). Subjective and clinical oral symptoms in patients with primary Sjögren's syndrome. *Clin Exp Rheumatol* **13**: 725–731.
- McMillan AS, Leung KCM, Leung WK, Wong MCM, Lau CS, Mok TMY (2004). Impact of Sjögren's syndrome on oral health-related quality of life in southern Chinese. *J Oral Rehabil* **31**: 653–659.
- Merz WG (1990). *Candida albicans* strain delineation. *Clin Microbiol Rev* **3**: 321–334.
- Newton AV (1962). Denture sore mouth: a possible aetiology. *Br Dent J* **112**: 357–360.
- Nyquist G (1992). A study of denture sore mouth. An investigation of traumatic, allergic and toxic lesions of the oral mucosa arising from the use of full dentures. *Acta Odont Scand* **10**(Suppl. 9): 11–14.
- Pedersen AM, Reibel J, Nordgarden H, Bergem HO, Jensen JL, Nauntofte B (1999). Primary Sjögren's syndrome: salivary gland function and clinical oral findings. *Oral Dis* **5**: 128–138.
- Radfar L, Shea Y, Fischer SH et al (2003). Fungal load and candidiasis in Sjögren's syndrome. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **96**: 283–287.
- Ramage G, Vandewalle K, Wickes BL, Lopez-Ribot JL (2001). Characteristics of biofilm formation by *Candida albicans*. *Rev Iberoam Micol* **18**: 163–170.
- van der Reijden WA, van der Kwaak JS, Veerman ECI, Nieuw Amerongen AV (1996). Analysis of the concentration and output of whole salivary constituents in patients with Sjögren's syndrome. *Eur J Oral Sci* **104**: 335–340.

- Rhodus NL, Bloomquist C, Liljemark W, Bereuter J (1997). Prevalence, density, and manifestations of oral *Candida albicans* in patients with Sjögren's syndrome. *J Otolaryngol* **26**: 300–305.
- Rhodus NL, Liljemark W, Bloomquist C, Bereuter J (1998). *Candida albicans* levels in patients with Sjögren's syndrome before and after long-term use of pilocarpine hydrochloride: a pilot study. *Quintessence Int* **29**: 705–710.
- Samaranayake LP, MacFarlane TW, Lamey PJ, Ferguson MM (1986). A comparison of oral rinse and imprint sampling techniques for detection of yeasts, coliform and *Staphylococcus aureus* in the oral cavity. *J Oral Pathol* **15**: 386–388.
- Samaranayake YH, Samaranayake LP (1994). *Candida krusei*: biology, epidemiology, pathogenicity and clinical manifestations of an emerging pathogen. *J Med Microbiol* **41**: 295–310.
- Sancak B, Colakoglu S, Acikgoz ZC, Arikan S (2005). Incubation at room temperature may be an independent factor that induces chlamydospore production in *Candida dubliniensis*. *Diagn Microbiol Infect Dis* **52**: 305–309.
- Silness J, Løe H (1964). Periodontal disease in pregnancy: II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand* **22**: 121–135.
- Soto-Rojas AE, Villa AR, Sifuentes-Osornio J, Alarcón-Segovia D, Kraus A (1998). Oral candidiasis and Sjögren's syndrome. *J Rheumatol* **25**: 911–915.
- Squier CA, Johnson NW, Hopps RM (1976). *Human oral mucosa. Development, structure and function*. Blackwell Scientific Publications: Oxford.
- Tapper-Jones L, Aldred M, Walker DM (1980). Prevalence and intraoral distribution of *Candida albicans* in Sjögren's syndrome. *J Clin Pathol* **33**: 282–287.
- Taylor R, Maryan C, Verran J (1998). Retention of oral microorganisms on cobalt-chromium alloy and dental acrylic resin with different surface finishes. *J Prosthet Dent* **80**: 592–597.
- Torres SR, Peixoto CB, Caldas DM et al (2002). Relationship between salivary flow rates and *Candida* counts in subjects with xerostomia. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* **93**: 149–154.
- Tsang CS, Samaranayake LP (2000). Oral yeasts and coliforms in HIV-infected individuals in Hong Kong. *Mycoses* **43**: 303–308.
- Vitali C, Bombardieri S, Jonsson R et al (2002). Classification criteria for Sjögren's syndrome: a revised version of the European criteria proposed by the American-European Consensus Group. *Ann Rheum Dis* **61**: 554–558.
- Weems JJ Jr (1992). *Candida parapsilosis*: epidemiology, pathogenicity, clinical manifestations, and antimicrobial susceptibility. *Clin Infect Dis* **14**: 756–766.
- Willinger B, Manafi M (1999). Evaluation of CHROMagar *Candida* for rapid screening of clinical specimens for *Candida* species. *Mycoses* **42**: 61–65.

Copyright of Oral Diseases is the property of Blackwell Publishing Limited and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.