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A 6-month study of the effects of 0.3% triclosan/copolymer dentifrice on dental implants

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Abstract

Aim: Supportive therapy to maintain dental implants is increasingly important. This study examined the effect of a 0.3% triclosan/2% copolymer dentifrice on oral biofilms and gingival inflammation (GI) on dental implants and peri-implant tissues.

Materials and Methods: One hundred and twenty adults with a dental implant and contra-lateral tooth were enrolled in this 6 month, double-blind, two-treatment, parallel group study. Sixty subjects were randomly assigned to a triclosan/copolymer dentifrice test group and 60 subjects to a fluoride dentifrice control group and instructed to brush twice daily for 6 months. At baseline, 3, and 6 months, a calibrated dentist assessed dental plaque, GI and collected supragingival dental plaque for microbiological analysis.

Results: Subjects in the triclosan/copolymer group demonstrated significantly lower levels of dental plaque, gingivitis, and bleeding on probing at 3 and 6 months at both the implant and contra-lateral tooth compared with the fluoride group ($p < 0.05$). There were significantly fewer Gram-negative anaerobes in the triclosan/copolymer group ($p < 0.05$) including $>90\%$ reductions in *Aggregatibacter actinomycetemcomitans*, *Campylobacter rectus*, *Eubacterium saburreum*, *Fusobacterium nucleatum*, *Porphyromonas gingivalis*, *Prevotella melaninogenica*, *Solobacterium moorei*, and *Tannerella forsythia*.

Conclusions: Twice daily use of a triclosan/copolymer dentifrice may enhance dental implant maintenance by reducing dental plaque and GI.

Key words: bacteria; biofilm; dental implant; gingivitis; triclosan

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Dental implants represent an increasingly important treatment modality for both partially edentulous and completely edentulous patients. It is estimated that more than three million Americans have dental implants with half a million more added each year (http://www.aaid.com/about/Press_Room/Dental_Implants_FAQ.html). Although the success rate for dental implants is high, the dental implant and peri-implant tissues are susceptible to inflammatory lesions similar to those that occur on natural teeth. Among the peri-implant diseases, peri-implant mucositis is a reversible inflammatory reaction of mucosa that occurs in about 80% of patients and in about 50% of implant sites and is analogous to gingivitis around natural teeth (Zitzmann & Berglundh 2008). Peri-implantitis is an inflammatory reaction of mucosa together with loss of supporting bone that occurs in 28–56% of patients and in 12–43% of implant sites analogous to chronic periodontitis around natural teeth (Zitzmann & Berglundh 2008).

Oral biofilms form on both dental implants and teeth and are considered to be the primary aetiology of both periodontal diseases and peri-implant diseases (Heuer et al. 2007, Elter et al. 2008). Similar to chronic periodontitis, peri-implantitis is associated with infection by Gram-negative anaerobes such as *Porphyromonas gingivalis*, *Treponema denticola*, and *Tannerella forsythia* (Shibli et al. 2008). Like chronic periodontitis, risk factors such as cigarette smoking, which favour infection with Gram-negative anaerobes (Zambon

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et al. 1996), increase the risk for peri-implantitis (Heitz-Mayfield 2008). Therefore, inhibition of oral biofilms may be important in preventing and managing peri-implant diseases.

Oral hygiene – toothbrushing and flossing – is used to control oral biofilms but most people demonstrate less than perfect plaque control (Löe 2000, Claydon 2008). Consequently, toothpastes are often formulated with chemotherapeutic agents to enhance oral hygiene. The antimicrobial agent triclosan is added to the dentifrice containing 0.243% sodium fluoride together with polyvinylmethyl ether maleic acid copolymer (Gantrez), which enhances the retention and uptake of triclosan. This 0.3% triclosan/2.0% copolymer dentifrice inhibits dental plaque and gingivitis and may retard the progression of periodontitis (Rosling et al. 1997, Hioe & van der Weijden 2005, Gunsolley 2006, Davies 2008). We hypothesize that the 0.3% triclosan/2.0% copolymer dentifrice may similarly inhibit dental plaque and mucositis around dental implants. The present study evaluated the clinical and microbiological effects of routine oral hygiene with a 0.3% triclosan/2.0% copolymer dentifrice on dental implants and natural teeth compared with a fluoride control dentifrice.

Materials and Methods

Study population

The study population consisted of adults in good oral and general health, 18 years of age or over, residing in community settlements (Kibbutzim) throughout Israel. Each subject accepted into the study had at least 20 teeth, at least one endosseous dental implant supporting a restoration and a contra-lateral natural tooth. Subjects who were current smokers, who had systemic diseases requiring prescription medications or who exhibited numerous or severe caries, generalized moderate to severe chronic periodontitis, or significant soft tissue pathology were excluded from the study. Two hundred and twenty-two subjects were screened for entry into the study. Eighty-two were excluded for not meeting the entrance criteria.

The nature of the study was explained to potential subjects who met the criteria and they indicated their acceptance by voluntarily signing an informed consent (Hadassah Medical Organization-Helsinki Committee-IRB approved). Subjects were recruited starting 1 June 2007 and ending August 2007 with follow-up beginning September 2007 and ending November 2007. Acceptable subjects were enrolled into the study by Dr. J. Mann who also performed the randomization of subjects into test or control groups.

Clinical procedures

In each subject, a dental implant and a contra-lateral natural tooth were identified for clinical examination and microbiological sampling. Clinical assessments included; (a) dental plaque using the modified dental plaque index (PI) for implants (Mombelli et al. 1987) and the PI for natural teeth (Silness & Löe 1964); (b) gingival inflammation (GI) using the gingival index (Löe & Silness 1963); and (c) gingival bleeding on probing (BOP) using the modified sulcus bleeding index for implants (Mombelli et al. 1987) and the sulcus bleeding index for teeth (Muhlemann & Son 1971).

Two investigators (J. M. and Y. V.) completed clinical calibration exercises for teeth and implants before the start of the study. Kappa scores for inter-examiner and intra-examiner variability were 0.88 and 0.86 for plaque and gingivitis, respectively. One examiner (Y. V.) completed all clinical examinations associated with the study.

Study procedures

Subjects refrained from oral hygiene for at least 12 hours before baseline, 3-, and 6-month examinations. At each appointment, subjects were examined for dental plaque, GI, and BOP and supragingival plaque was collected from both the implant and contra-lateral control tooth for laboratory testing.

The sample size of 120 (60 per group) was determined based on a standard deviation of 0.58 for clinical scores, a significance level of $\alpha = 0.05$, a 10% attrition rate, and an 80% level of power. The study was powered to detect a minimal statistically significant difference between the study group means of 24% or a clinical score difference of 0.31. Sample size calculations utilized historical data from studies that evaluated the effects of formulations on the dental plaque found on teeth (Davies 2008).

Subjects were randomly assigned to either a 0.3% triclosan/2% copolymer dentifrice (TCN/C) test group or a fluoride (F) dentifrice control group. Qualifying subjects were systematically stratified by gender and age and were randomly assigned to one of the dentifrice groups.

Both toothpastes were obtained commercially, overwrapped for blinding and assigned a unique code that was not identified until the study was completed. Subjects were provided a soft-bristled toothbrush and instructed to brush twice daily with their assigned toothpaste for the next 6 months. Subject compliance and test product resupply were monitored by periodic visits and telephone calls. One hundred and twenty subjects entered the study (Fig. 1). One hundred and five subjects completed the study and were analysed for primary outcomes – clinical measures of plaque and GI – and for secondary outcomes – microbiological changes.

Microbiological assessments

Supragingival dental plaque from both the dental implant and the contra-lateral control tooth were collected with a sterile Gracey 9–10 curette (Hu-Friedy, Chicago, IL, USA) and placed into separate individually labelled vials containing 1.5 ml sterile reduced transport media (RTM, Hy Laboratories Ltd., Rehovot, Israel). All samples were transported at 4°C to the microbiology laboratory where they were dispersed by sonication and serially diluted in phosphate buffered saline. Six aliquots from each diluted sample were inoculated onto agar enriched with 5% sheep blood (blood agar, Hy Laboratories Ltd). Triplicate samples were incubated under either aerobic or anaerobic conditions at 37°C. After 7 days, the number of colony-forming units (CFU/ml) was enumerated and the average of the triplicate samples calculated.

The remaining sample was maintained at −70°C for microscopy and DNA probe analysis. Light and phase-contrast microscopy was used to determine the (1) total number of bacterial cells; (2) the proportion of bacterial morphotypes including cocci, rods, fusiforms, filaments, and curved rods; and (3) the proportion of Gram-positive and Gram-negative bacteria (Haraszthy et al. 2007).

DNA–DNA hybridization using 16S rDNA probes was used to determine the presence and relative numbers of 14 different microorganisms including *Aggregatibacter actinomycetemcomitans*, *Campylobacter rectus*, *Capnocytophaga* sp, *Eikenella corrodens*,

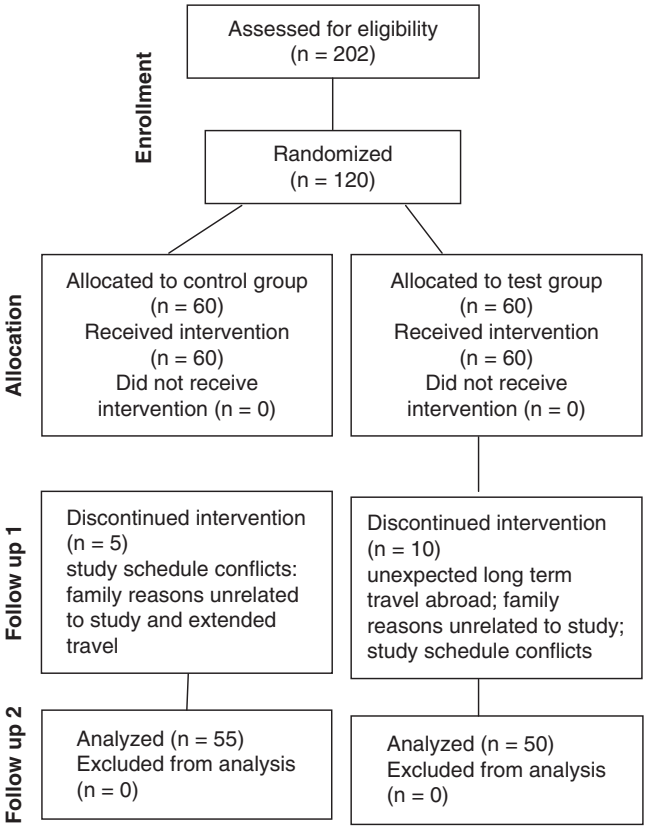

Fig. 1. Subject flow chart: 202 subjects were screened for entry into the study. Eighty-two did not meet the entry criteria. One hundred and twenty subjects were entered into the study. One hundred and five subjects completed the study.

Eubacterium saburreum, *Fusobacterium nucleatum*, *Neisseria* sp, *Prevotella intermedia*, *Prevotella melaninogenica*, *P. gingivalis*, *Solobacterium moorei*, *Streptococcus* sp, *T. forsythia*, and *Veillonella* sp. The bacterial samples were re-suspended in TE buffer (10 mM TRIS, pH 8, 100 mM EDTA) and the bacterial DNA was isolated (Instagene Purification Matrix kit, BioRad Laboratories, Hercules, CA, USA). A polymerase chain reaction (PCR) amplified between 30 and 100 ng of genomic DNA using 16S rDNA primers that are highly conserved among eubacteria (5′-AGAGTTTGATCA/CTGG-3′ and 5′-TACCTTGTTACGACTT-3′). PCR reactions included 1 μmol/l of primers, 2.5 U of Taq polymerase in 1 × buffer, and 0.2 mmol/l of dCTP, dGTP, dATP, and dTTP in a total volume of 100 μl. PCR samples were amplified for 30 cycles of 30 s at 95°C, 30 s at 55°C, and 30 s at 72°C in a thermocycler.

Commercially obtained probes and oligonucleotides were labelled at the 3′-end with digoxigenin-11-ddUTP (Genius 5, Boehringer Mannheim, Indianapolis, ID, USA). PCR products were blotted onto charged nylon membranes (Hybond-N, Amersham, Arlington Heights, IL, USA) using 10X standard salt phosphate EDTA buffer and hybridized with the digoxigenin-labelled oligonucleotide probes at the appropriate temperature for each probe. All hybridized membranes were washed twice at room temperature with high-salt solution [2 × SSC (0.15 M NaCl plus 0.015 trisodium citrate, pH 7.0) in 0.1% sodium dodecyl sulphate] and twice at 55°C with a low salt solution (0.1 × SSC in 0.1% sodium dodecyl sulphate) and finally prepared for chemiluminescence (Genius 3, Boehringer Mannheim). Intensities of each colour reaction were compared with standards prepared from pure cultures of each target microorganism.

Statistical analysis

Primary analysis of clinical variables (PI, GI, and BOP) was conducted on an ''intention-to-treat'' (ITT) basis with the subject as the statistical unit. Thus, ITT included all measured sites from all subjects ($N = 120$) who were enrolled into the study with analyses conducted in accordance with randomized treatment assignment and statistical significance reported at $p < 0.05$. For the 15 subjects who did not complete the study (dropouts) and had missing data, the last available observation was carried forward to represent all subsequent evaluations.

Microbiological culture was calculated as the mean CFU/ml of the triplicate cultures and transformed to $\log_{10}$ before analysis. *T*-test analyses compared viable counts for test and control groups for implants and natural teeth at baseline with the 3- and 6-month data. Microscopy results were analysed by the analysis of covariance (ANCOVA) with the corresponding baseline as covariate and statistical significance was reported at $p < 0.05$.

Results from DNA probe analyses were transformed ($\log_{10}$) for analysis. A preliminary ANCOVA model evaluated interactions between treatments (fluoride and triclosan/copolymer dentifrice) and sites (tooth and implant). When there were no observed interactions ($p > 0.1$), analyses were conducted by a reduced ANCOVA model without the interaction term. As described previously (Socransky et al. 1991), a value of $p < 0.003$ was utilized to report statistically significant differences in multiple comparisons of the 14 evaluated microorganisms. Analyses were conducted using Minitab, (Minitab, State College, PA, USA).

Results

Subject demographics

One hundred and twenty subjects including 56 males and 64 females entered the study. One hundred and five adults (average age 54.9 years; age range 20–75 years) including 50 males and 55 females completed this study (Table 1, Fig. 1). Reasons for subjects leaving the study included travelling abroad for work and family problems. Fifty subjects (average age 56.5 years; age range 26–72 years) including 24 males and 26 females randomly assigned to the 0.3% triclosan/2.0% copolymer dentifrice test group completed the study and 55 subjects (average age 54.7 years; age range 20–75 years) including 26 males and 29 females randomly assigned to the fluoride

dentifrice control group completed the study. No subjects reported any adverse events. Additional demographic characteristics for each treatment group are presented in Table 1. Analysis of the test and control groups at baseline revealed no significant differences.

Table 1. Demographics of subjects who completed the study

	Parameter	Study population	Males	Females
Study population	Number of subjects	105	50	55
	Age (mean)	54.952	56.18*	53.836*
	Age (SD)	10.559	11.262	9.848
	Age (SE)	1.030	1.592	1.327
	Age (median)	56	58.5	55
	Age (min)	20	20	26
	Age (max)	75	75	73
	Age (range)	55	55	47
Fluoride dentifrice control group	Number of subjects	55	26	29
	Age (mean)	54.709	55.653†‡	53.862#‡
	Age (SD)	9.614	11.063	8.210
	Age (SE)	1.296	2.169	1.524
	Age (median)	56	58	56
	Age (min)	20	20	36
	Age (max)	75	75	73
	Age (range)	55	55	37
Triclosan/copolymer dentifrice test group	Number of subjects	50	24	26
	Age (mean)	55.22	56.75†§	53.807#§
	Age (SD)	11.604	11.685	11.575
	Age (SE)	1.641	2.385	2.270
	Age (median)	56.5	60.5	55
	Age (min)	26	35	26
	Age (max)	72	72	71
	Age (range)	46	37	45

*p value = 0.805.
†p value = 0.734.
‡p value = 0.495.
#p value = 0.983.
§p value = 0.375.
min, minimum; max, maximum.

Clinical parameters

Frequency distributions for PI, GI, and BOP are shown in Table 2. At baseline, plaque scores of 2 were most frequent on both teeth and dental implants for either treatment group with no statistical differences in mean plaque scores between the two groups (Fig. 2). At the 3-month recall visit, a score of 1 was observed in approximately 30% of the surfaces in comparison with baseline. While these results corresponded with reductions in mean plaque scores for both treatment groups from baseline, average reductions were more pronounced in the triclosan/copolymer treatment group and were significantly lower than those observed in the fluoride treatment group by ITT analysis ($p < 0.05$). At the 6-month examination, dental plaque distributions between the two treatment groups demonstrated marked differences. A plaque score of 1 was observed on 36% of the evaluated surfaces in the triclosan/copolymer treatment group and was twice as frequent as the 16.8% of sites in the fluoride group with this score. Correspondingly, scores of 2 and 3 were more common in the fluoride than in the triclosan/copolymer group. ITT analysis demonstrated significantly lower mean plaque scores on teeth in the triclosan/copolymer treatment group than in the fluoride treatment group at both the 3- and 6-month recall visits ($p < 0.05$). At the 6-month evaluation, the triclosan/copolymer treatment group demonstrated a 15% reduction in dental plaque

Table 2. Frequency distribution for each clinical parameter*

Scores	Teeth						Implant					
	baseline		3 months		6 months		baseline		3 months		6 months	
	TCN (%)	F (%)	TCN (%)	F (%)	TCN (%)	F (%)	TCN (%)	F (%)	TCN (%)	F (%)	TCN (%)	F (%)
(a) Dental plaque												
0	0	0	2	0	2	0	0	0	2	0	2	0
1	3.5	1.4	31	24.5	36.5	16.8	27.5	8.2	60.5	47.3	50.5	34.1
2	64.5	73.2	49.5	55.9	48	60.9	69.5	86.4	37.5	43.2	47.5	60.5
3	32	25.5	17.5	19.5	13.5	22.3	3	5.5	0	9.5	0	5.5
(b) Gingival inflammation												
0	0	0	17.5	18.2	34	23.2	0	0	20	15	30.5	24.5
1	41.5	38.6	47.5	34.5	31	24.1	47	43.6	48	42.3	39.5	26.8
2	58.5	61.4	35	45.9	35	52.7	53	56.4	32	42.7	30	48.6
3	0	0	0	1.4	0	0	0	0	0	0	0	0
(c) Bleeding on probing												
0	41.5	37.3	65.5	52.7	65	47.3	47	43.6	68	57.3	70	51.4
1	53.5	34.5	17.5	17.2	16.5	17.7	39.5	37.7	15.5	20.5	15	15.9
2	5	28.2	17	30	18.5	35	13.5	18.6	16.5	22.3	15	32.7
3	0	0	0	0	0	0	0	0	0	0	0	0

*Results are from 105 subjects who completed the entire study.
F, Fluoride; TCN, triclosan/copolymer dentifrice.

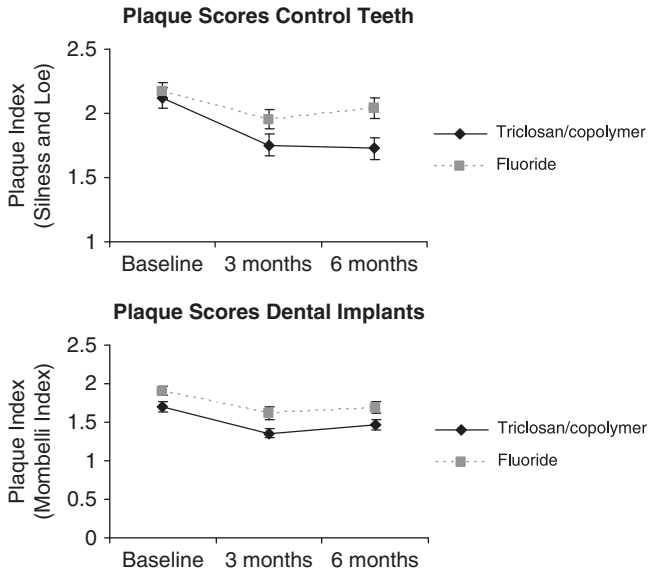

Fig. 2. Dental plaque scores on teeth (upper panel) and dental implants (lower panel) at baseline, 3, and 6 months. Subjects in the test group (dotted line) had lower plaque scores at 3 and 6 months compared with the control group (solid line). Shown in figure are average and standard error at each evaluation. Statistically significant reductions at the 3 and 6 month post treatment evaluations were observed for the triclosan/copolymer group by intention-to-treat analysis ($p<0.05$).

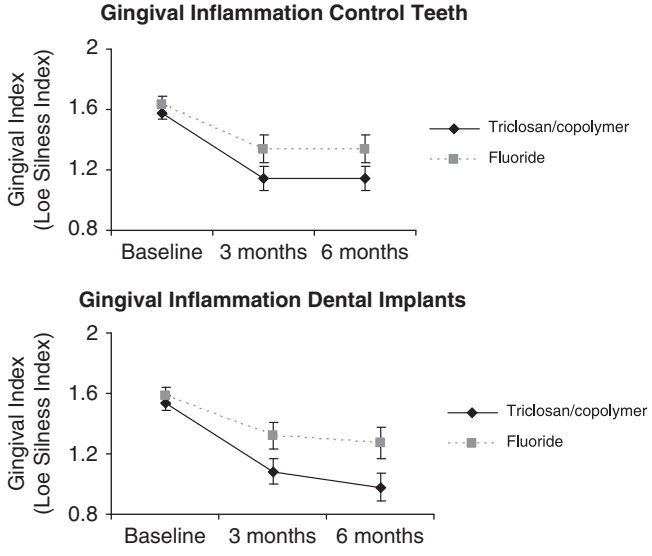

Fig. 3. Gingival inflammation scores on teeth (upper panel) and dental implant (lower panel) at baseline, 3 and 6 months. Subjects in the test group (dotted line) had less gingival inflammation at 3 and 6 months compared with the control group (solid line). Shown in figure are average and standard error at each evaluation. Statistically significant reductions at the 3 and 6 month post treatment evaluations were observed for the triclosan/copolymer group by intention-to-treat analysis ($p<0.05$).

on the teeth compared with the fluoride treatment group by ITT ($p<0.05$). Plaque scores for subjects assigned to the triclosan/copolymer dentifrice treatment group who completed the entire study were reduced by 24% ($p<0.001$) compared with subjects in the fluoride dentifrice treatment group at the final recall visit.

Over the course of the study, frequencies for each dental plaque score on implants followed the overall patterns observed on teeth (Table 2a). While hygiene improved in both treatment groups from baseline to each recall visit, more surfaces in the triclosan/copolymer were observed with a score of 1 than for the fluoride group. At each recall visit, $>50\%$ of the sites in the fluoride group were observed with scores of 2 and 3. In contrast, there were no implant surfaces in the triclosan/copolymer group with a score of 3 at either the 3- or 6-month clinical examinations. Correspondingly, at both recall visits, mean plaque scores in the triclosan/copolymer treatment group were significantly lower compared with the fluoride treatment group (Fig. 3) by ITT analysis with a 13% reduction observed at the 6-month evaluation ($p<0.05$). Among subjects who completed the entire study, implant plaque scores in the triclosan/copolymer treatment group were reduced by 20% at the 6-month clinical examination ($p<0.01$).

Analysis of GI scores on the teeth and implants demonstrate similar results as observed for dental plaque scores (Table 2b). While hygiene reduced the number of sites with scores of 1 and 2, at either recall visit, more sites in the triclosan/copolymer treatment group reported scores of 0 and 1 on the teeth and dental implants compared with the fluoride treatment group. Irrespective of oral surface evaluated, the fluoride treatment group consistently demonstrated higher frequencies of higher GI scores at each recall visit; a score of 2 was observed in 42–52% of all evaluated sites. Shown in Fig. 3 are the mean GI scores over the study. Differences between the fluoride and triclosan/copolymer group for GI scores were statistically significant at both the 3- and 6-month evaluations for teeth and implants by ITT analysis ($p<0.05$). Compared with the fluoride group, the triclosan/copolymer group demonstrated a 22% reduction in gingival index scores around dental implants ($p<0.05$) and a 14% ($p<0.05$) reduction in gingival index scores around teeth during the 6-month evaluation. A 59% reduction in gingival scores around dental implants ($p<0.001$) and 36% ($p<0.022$) reduction around teeth was observed at the 6-month examination for subjects who completed the entire study.

Frequencies for BOP scores for the two treatment groups (Table 2c) indicate improvements for both treatment groups from baseline to the 3-month examination. However, these improvements were more prominent for the triclosan/copolymer group with a score of 0 observed on $\sim 65\%$ of both teeth and

implants compared with <57% for the fluoride group. At the 6-month evaluation, a score of 0 was observed on ~ 65% of the teeth and 70% of implant surfaces for the triclosan/copolymer group in contrast with 47% of the teeth and 51% of implant surfaces among the fluoride group. Sites with a score of 2 were approximately twice as frequent in the fluoride than in the triclosan/copolymer group for both the teeth and implants at both recall visits. Average BOP scores (Fig. 4) at the 3- and 6-month evaluations demonstrated statistically significant reductions in the triclosan/copolymer group compared with the fluoride group by ITT analysis. On average, BOP in the triclosan/copolymer dentifrice group decreased by 48% after 6 months around the dental implants ($p<0.05$) and by 45% around the teeth ($p<0.05$) compared with the fluoride dentifrice group. For subjects who completed the entire study, BOP scores in the triclosan/copolymer dentifrice group decreased by 21% after 6 months around the dental implants ($p<0.001$) and by 20% around the natural teeth ($p<0.003$) compared with a 1% decrease for both dental implants and natural teeth in the fluoride dentifrice control group.

Microbiological data

Comparisons of the number of viable bacteria (log CFU/ml) on the dental implants and the control teeth over time and between groups are shown in Table 3. The triclosan/copolymer dentifrice test group demonstrated significant reductions in the number of anaerobic and aerobic bacteria on both the dental implants and control teeth at both 3 and 6 months ($p<0.05$). The fluoride dentifrice control group demonstrated significant reductions in the number of aerobic bacteria on the dental implants at both 3 and 6 months ($p<0.05$) and significant reductions in the number of anaerobic bacteria on both the dental implants and control teeth at 3 months ($p<0.05$).

Results of the microscopic analyses are shown in Table 4. Compared with the fluoride dentifrice control group, there were significant increases in the proportions of Gram-positive bacteria and decreases in the proportions of Gram-negative bacteria in the triclosan/copolymer dentifrice test group at both 3 and 6 months ($p<0.05$). There were significantly reduced numbers of total bacteria, cocci, and rods on both the dental implant and the natural teeth among the triclosan/copolymer dentifrice test group at both 3 and 6 months ($p<0.0001$). Fusiforms and filaments were significantly reduced in the triclosan/copolymer dentifrice test group compared with the fluoride dentifrice control group at 6 months ($p<0.05$).

Table 5 shows the results of the DNA probe assays. Consistent with the clinical, microbial culture, and microscopic assessments, the triclosan/copolymer dentifrice test group exhibited >90% reductions in a number of target microorganisms including *A. actinomycetemcomitans*, *C. rectus*, *P. melaninogenica*, *Solobacterium*, and *T. forsythia* and 80–90% reductions in *E. corrodens*, *E. saburreum*, *F. nucleatum*, *P. gingivalis*, and *Veillonella* sp, compared with the

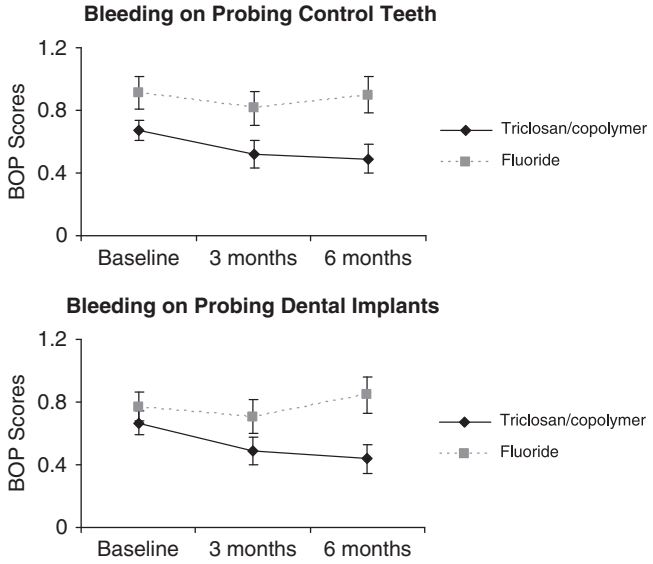

Fig 4. Bleeding on probing scores on teeth (upper panel) and dental implants (lower panel) at baseline, 3, and 6 months. Subjects in the test group (dotted line) had less bleeding on probing at 3 and 6 months compared with the control group (solid line). Shown in figure are average and standard error at each evaluation. Statistically significant reductions at the 3 and 6 month post treatment evaluations were observed for the triclosan/copolymer group by intention-to-treat analysis ($p<0.05$).

Table 3. Microbiological culture of plaque from dental implants and teeth

Test group	Dental implant				Control teeth			
	3 months		6 months		3 months		6 months	
	aerobic	anaerobic	aerobic	anaerobic	aerobic	anaerobic	aerobic	anaerobic
Triclosan/copolymer								
Reduction from baseline*	0.404	0.283	0.445	0.319	0.429	0.431	0.383	0.304
% Reduction	− 153.745	− 91.936	− 178.721	− 108.685	− 168.678	− 169.544	− 141.794	− 101.570
p value	0.001§	0.025§	0.001§	0.044§	0.000§	0.001§	0.002§	0.036§
Fluoride								
Reduction from baseline*	0.213	0.203	0.289	0.193	0.146	0.211	0.177	0.188
% Reduction	− 63.454	− 59.455	− 94.399	− 55.804	− 39.892	− 62.506	− 50.422	− 54.22
p value	0.026§	0.026§	0.003§	0.059	0.110	0.010§	0.099	0.053

*Log CFU/ml.
§$p<0.05$.

Table 4. Microscopic analysis of plaque from dental implants and teeth

Parameter	Dental implant		Control teeth	
	3 months	6 months	3 months	6 months
Gram positive bacteria	**18.66**	**18.77**	**11.23**	**8.49**
	0.0000	*0.0000*	*0.0002*	*0.0174*
Gram negative bacteria	**− 18.42**	**− 18.46**	**− 10.27**	**− 9.63**
	0.0000	*0.0000*	*0.0006*	*0.0077*
Total cell counts (log counts/ml)	**− 0.164**	**− 0.233**	**− 0.192**	**− 0.268**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Cocci	**− 7.04**	**− 8.3**	**− 8.57**	**− 10.46**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Rods	**− 5.82**	**− 7.495**	**− 6.5**	**− 7.13**
	0.0001	*0.0000*	*0.0001*	*0.0001*
Fusiforms	**− 0.063**	**− 2.5374**	**− 0.1**	**− 3.105**
	0.9186	*0.0038*	*0.8684*	*0.0001*
Filaments	**− 0.0969**	**− 0.6246**	**− 0.3542**	**− 0.8344**
	0.7460	*0.0460*	*0.3150*	*0.0190*

Differences between the two treatment groups at each recall visit computed by subtracting least square means (LSM) of the triclosan/copolymer dentifrice group from the fluoride dentifrice group. A positive value that indicates an increase and a negative value a reduction in the triclosan group are shown in bold.

p values following comparisons between the triclosan/copolymer dentifrice group and the fluoride dentifrice group at each recall visit by ANCOVA are shown in italics.

fluoride dentifrice control group. An initial ANCOVA on the entire dataset indicated that dentifrice and surface interactions (that is dentifrice efficacy on either teeth or implant) for antimicrobial effects did not differ by treatments ($p > 0.1$). In other words, the substantially greater antimicrobial effects by the triclosan/copolymer dentifrice were similar regardless of the surface evaluated, i.e. teeth or implants. Multiple comparison analysis in a reduced model determined effects for each microorganism on the implants or teeth. These analyses demonstrated significant effects on pathogenic microorganisms including *A. actinomycetemcomitans*, *C. rectus*, *E. saburreum*, *F. nucleatum*, *P. melaninogenica*, and *T. forsythia*, in addition to *Streptococci* and *Veillonella* sp ($p < 0.003$).

Discussion

As the number of patients with dental implants increases and with the prospect of dental implant therapy assuming a greater role in dental practice, clinical investigations have focused on the prevention and management of diseases of successfully osseointegrated dental implants (Klinge et al. 2005). Oral biofilm accumulation on dental implants can cause peri-implant inflammation as it does in the periodontium around teeth. Although the prevalence of peri-implant disease is unclear, a recent review suggests that >60% of dental implants exhibit peri-implant mucositis and that between 28 and 56% of dental implants exhibit peri-implantitis (Zitzmann & Berglundh 2008). However, only a few studies have examined both clinical and microbiological parameters on dental implants and natural teeth within the same subject.

While previous studies examined the role of a triclosan/copolymer dentifrice in controlling dental plaque, gingivitis and in improving periodontal health around natural teeth (Rosling et al. 1997, Hioe & van der Weijden 2005, Gunsolley 2006, Davies 2008), the present 6-month, double-blind, two-treatment, parallel group study examined the effects of a 0.3% triclosan/2.0% copolymer dentifrice on clinical and microbiological parameters on both dental implants and natural teeth in the same patients. Important novel findings from this study were the concomitant statistically significant reductions in dental plaque and gingivitis on both dental implants and natural teeth at the 3- and 6-month examinations with no significant dentifrice and surface interactions. In other words, the efficacy of the triclosan/polymer dentifrice was demonstrable regardless of the evaluated surface.

Observations from this study demonstrated that subjects assigned to the triclosan/copolymer dentifrice treatment group showed reductions in the frequency of higher dental plaque, gingivitis, and BOP scores on both the implant and teeth compared with subjects assigned to the fluoride dentifrice treatment group. These effects were more pronounced at the 6-month evaluations with 36% of teeth and 50% of implant surfaces having dental plaque scores of 1 among the triclosan/copolymer group. In contrast, approximately 60% of tooth and implant surfaces were observed with a dental plaque score of 2 in the fluoride group. The ITT analysis indicated significantly less dental plaque on teeth and dental implants in the triclosan/copolymer treatment group compared with the fluoride treatment group at the 3- and 6-month evaluations. Six months use of the 0.3% triclosan/2.0% copolymer dentifrice demonstrated a 13% and 15% reduction in dental plaque scores around the dental implants and teeth, respectively. Subjects who completed the entire study demonstrated a 20% and 24% reduction in dental plaque on implants and teeth, respectively.

The significant effects by triclosan/copolymer on dental plaque correspond to the clinical observations for GI. While frequencies for lower gingival scores, i.e. 0 and 1 increased at each recall visit for both treatments, this increased frequency was more prominent among subjects assigned to the triclosan/copolymer treatment group. Among subjects randomized to the triclosan/copolymer group, gingival scores of 0 and 1 were observed on at least 60% of implant and tooth surfaces. By contrast, scores of 2 were observed on >40% of both implant and tooth surfaces for the fluoride treatment group. For the fluoride group, the frequency of higher dental plaque and gingival index scores increased between the 3- and 6-month recall visits. Analysis by ITT demonstrated significantly better effects in the triclosan/copolymer treatment group for both the dental implants and control teeth than in the fluoride dentifrice group At the 6-month evaluation, gingival index scores among those assigned to the triclosan/copolymer group were reduced by 22% and 14% around dental implants and control teeth, respectively. Among subjects who completed the entire study, a 59% reduction in gingival index scores around dental implants and a 36% reduction around teeth were observed at the 6-month examination.

Another measure of GI, BOP, comprised an additional clinical analysis for dental implants and teeth. Frequencies of higher BOP scores decreased for the

Table 5. DNA probe analysis of plaque from dental implants and teeth

Microorganism	Dental implant		Control teeth	
	3 months	6 months	3 months	6 months
Aggregatibacter actinomycetemcomitans	− 1.348	− 1.325	− 1.267	− 1.532
	95.512	**95.268**	**94.592**	**97.062**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Campylobacter rectus	− 1.445	− 1.56	− 1.368	− 1.78
	96.410	**97.245**	**95.714**	**98.340**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Capnocytophaga sp.	− 0.148	− 0.088	− 0.15	− 0.233
	28.878	**18.341**	**29.205**	**41.520**
	0.1841	*0.4528*	*0.0898*	*0.0326*
Eikenella corrodens	− 0.571	− 0.76	− 0.648	− 0.735
	73.146	**82.621**	**77.509**	**81.592**
	0.0111	*0.0023*	*0.0036*	*0.0070*
Eubacterium saburreum	− 1.151	− 1.361	− 0.844	− 1.508
	92.936	**95.644**	**85.678**	**96.895**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Fusobacterium nucleatum	− 1.253	− 2.177	− 0.934	− 1.838
	94.415	**99.334**	**88.358**	**98.547**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Neisseria sp.	− 0.45	− 0.17	− 0.13	− 0.044
	64.518	**32.391**	**25.868**	**9.635**
	0.0081	*0.5323*	*0.4630*	*0.8314*
Porphyromonas gingivalis	− 0.858	− 0.92	− 0.983	− 1.12
	86.132	**87.977**	**89.600**	**92.414**
	0.0005	*0.0064*	*0.0000*	*0.0000*
Prevotella intermedia	− 0.691	− 0.526	− 1.238	− 1.204
	79.629	**70.214**	**94.219**	**93.748**
	0.0001	*0.0379*	*0.0000*	*0.0000*
Prevotella melaninogenica	− 1.043	− 1.232	− 1.131	− 1.371
	90.942	**94.138**	**92.603**	**95.744**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Solobacterium moorei	− 1.066	− 1.147	− 1.274	− 1.594
	91.409	**92.871**	**94.678**	**97.453**
	0.013	*0.071*	*0.0000*	*0.0000*
Streptococci	− 1.737	− 2.261	− 1.5	− 1.758
	98.167	**99.451**	**96.837**	**98.254**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Tannerella forsythia	− 1.562	− 1.447	− 1.265	− 1.36
	97.258	**96.427**	**94.567**	**95.634**
	0.0000	*0.0000*	*0.0000*	*0.0000*
Veillonella sp.	− 0.987	− 1.178	− 0.893	− 1.183
	89.696	**93.362**	**87.206**	**93.438**
	0.0000	*0.0000*	*0.0000*	*0.0000*

Differences (log CFU/ml) between the two treatment groups at each recall visit computed by subtracting least square means (LSM) of the triclosan/copolymer dentifrice group from the fluoride dentifrice group. Negative values indicate a reduction in the triclosan/copolymer dentifrice group. Percent differences between the fluoride dentifrice group and triclosan/copolymer dentifrice group at each recall visit computed by (1–10 difference) × 100 are shown in bold.

p values following comparisons between fluoride dentifrice group and triclosan/copolymer dentifrice group at each recall visit by ANCOVA are shown in italics.

triclosan/copolymer group compared with the fluoride group at the 3- and 6-month evaluations. At both these recall visits, at least 65% of teeth and implant surfaces showed BOP scores of 0 among subjects assigned the triclosan/copolymer dentifrice. Our findings are consistent with those described in the recent study by Ramberg et al. (2009) examining dental implant patients with pre-existing mucositis who had higher initial levels of GI compared with subjects in the present study. Six months use of 0.3% triclosan/2.0% copolymer dentifrice reduced BOP scores 48% and 45% on dental implants and teeth, respectively, with corresponding reductions of 21% and 20% among subjects who completed the entire study. Together, these studies indicate that the triclosan/copolymer dentifrice can reduce GI around dental implants and may be useful in the management of peri-implant mucositis.

While triclosan has significant anti-inflammatory effects (Modéer et al. 1996, Mustafa et al. 2005), at least part of the reduction in GI seen with the use of the triclosan/copolymer dentifrice in the present study is likely attributable to its antimicrobial effects. Microbiological data from the analysis of dental plaque on the implants and contra-lateral teeth were consistent with the clinical findings. In the triclosan/copolymer dentifrice group, there were significant reductions in the number of anaerobic and aerobic bacteria and in the proportion of Gram-negative bacteria on both the dental implants and control teeth at both 3 and 6 months. It appears the triclosan/copolymer dentifrice results in a generalized reduction in the number of plaque bacteria, consistent with the clinical plaque measurements, and a shift from Gram negative to Gram positive, presumably, health-associated bacteria. Our findings of reduced plaque and GI demonstrated by clinical measurements and reduced bacterial numbers and shifts toward higher proportions of Gram-positive bacteria demonstrated by microbiological assays agree with recent findings by Haffajee et al. (2009). That study reported significant positive associations between clinical measures of GI and pocket depth and bacterial numbers assessed as total DNA probe counts. Also consistent with the present study, Haffajee and colleagues reported differences in the composition of plaque related to plaque mass with higher proportions of *Actinomyces* sp. *Veillonella parvula*, and *Neisseria mucosa* in plaques of moderate mass and higher proportions of capnocytophaga, *Eikenella corrodens*, *Prevotella intermedia*, and other green and orange complex bacteria in plaques of larger mass.

The bacterial culture assays, as opposed to the microscopic and DNA probe assays, confirm the viability of plaque bacteria. Viable microorganisms are transmissible between sites within individuals and between individuals, are able to produce virulence factors and are able to resist a range of treatments (D'Ercole et al. 2008). While procedures utilized in this study to determine the numbers of viable bacteria were based on well-established practices, several important differences require emphasis. Specifically, the number of viable bacteria was determined by culturing each sample in triplicate both aerobically and anaerobically in order to reduce variability (D'Ercole et al. 2008).

Results from these analyses provide additional support for the clinical and microscopic data. Whereas the fluoride dentifrice control group demonstrated reductions from baseline, the data were inconsistent at 3- and 6-month examinations. On the other hand, the triclosan/copolymer dentifrice test group demonstrated substantially greater reductions from baseline in both aerobes and anaerobes at 3- and 6-month examinations. The observed reductions in clinical plaque indices seen in the triclosan/copolymer dentifrice test group are, therefore, consistent with the observed decreases in bacterial numbers determined by microscopy and decreases in numbers of viable bacterial determined by aerobic and anaerobic culture.

While both microscopic and bacterial culture enumeration are standard methods in clinical oral microbiology, these methods do not enumerate specific organisms. Among a range of currently available methods to assess for specific organisms, our group has been successful in the application of DNA probes based on conserved 16S rDNA base sequences to quantify specific oral microorganisms (Haraszthy et al. 2007). Advantages of this procedure are especially important for larger scale studies such as the present investigation – there were over 15,000 microbiological data points generated from the microbiological assays in this study – and include the ability to reliably quantify each microorganism in addition to establishing quality control procedures to ensure accuracy in microbial detection. Furthermore, the ability of DNA probe methods to analyse small sample volumes and institute repeat analysis of samples to verify results are noteworthy. Important observations following DNA probe analysis include substantial reductions ($>90\%$) for a range of periodontal pathogens including *A. actinomycetemcomitans*, *C. rectus*, *E. saburreum*, *F. nucleatum*, *P. melaninogenica*, and *T. forsythia* along with similar reductions in streptococci and veillonella in the plaque from both dental implants and contra-lateral teeth by multiple comparison tests with p values below 0.003. It is important to emphasize that these effects by the 0.3% triclosan/2.0% copolymer dentifrice were similar on the dental plaque obtained from the dental implants and the natural teeth and were observed during both the 3- and 6-month examinations. These statistical analyses demonstrate that microbial inhibitions by triclosan/copolymer were regardless of surface evaluated, i.e. control teeth or dental implant. Taken together, inhibition of periodontal pathogens offer specific avenues to explain previous results demonstrating improvements in periodontal health for teeth (Rosling et al. 1997, Davies 2008) and dental implants (Ramberg et al. 2009) following the use of the 0.3% triclosan/2.0% copolymer dentifrice.

Assessments of bacteria associated with halitosis comprised an additional component of the DNA probe analysis. Sterer et al. (2008) noted a significant increase in the severity of oral malodour concomitant with an increasing transmucosal implant depth. While previous studies have demonstrated the effects of triclosan/copolymer dentifrice on clinical measures of halitosis (De Vizio 2008), relatively few studies have examined effects on the bacteria associated with halitosis (Fine et al. 2006, Zambon et al. 2008). Our group has associated previously *S. moorei* with oral malodour (Haraszthy et al. 2007). In the present study, plaque from the triclosan/copolymer dentifrice group demonstrated a $>90\%$ reduction of both *S. moorei* and veillonella, a microorganism also associated with halitosis. Similar to the consistency between the clinical and microbiological measures noted above, the microbiological data in the present study demonstrate decreases in the number of bacteria associated with halitosis following the use of the 0.3% triclosan/2.0% copolymer dentifrice consistent with decreases in clinical measures of halitosis demonstrated previously (De Vizio 2008).

It is important to place the microbiological results from the present investigation in the context of available studies. A study by Fine et al. (2006) reported that routine oral hygiene with the 0.3% triclosan/2.0% copolymer dentifrice resulted in $>90\%$ reductions in microbial numbers on surfaces that were not brushed. These antimicrobial effects are likely due to the higher than the minimum inhibitory concentrations achieved following use of the 0.3% triclosan/2.0% copolymer dentifrice. Afflitto et al. (1989) reported that salivary triclosan levels ranged from 19.7 μg/ml 5 min. after brushing to 6.2 μg/ml after 1 h with concentrations in plaque of 25 μg/g after 1 h. This antimicrobial activity could explain the reduced ''microbial load'' noted on the dental implants in this study. It is likely that use of the 0.3% triclosan/2.0% copolymer dentifrice results in antimicrobial levels above the minimum inhibitory concentrations for oral microorganisms (Sreenivasan & Gaffar 2008).

In summary, this investigation evaluated clinical measures on 105 subjects and three different microbiological methods on 630 oral microbial samples resulting in 15,750 microbiological datapoints. This study provides evidence for the efficacy of the 0.3% triclosan/2.0% copolymer dentifrice in patients with dental implants, which also has significance for overall oral health in view of the recently described relationship between oral infection and systemic conditions (Offenbacher et al. 2006, Kinane et al. 2008, Humphrey et al. 2008).

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Clinical Relevance

Scientific rationale for the study: Dental implants often fail as a result of alveolar bone loss associated with bacterial infection. Dentifrice containing 0.3% triclosan/0.2% copolymer inhibits oral biofilm accumulation on teeth. The study examined the effect of this dentifrice on dental implants.

Principal findings: There was less dental plaque, less GI, and fewer bacterial pathogens around dental implants after 3 and 6 months in subjects using a 0.3% triclosan/0.2% copolymer dentifrice compared with subjects using a fluoride dentifrice.

Practical implications: A 0.3% triclosan/0.2% copolymer dentifrice may enhance oral hygiene in patients with dental implants.