Motiv Emot (2006) 30:295–306
DOI 10.1007/s11031-006-9035-8

ORIGINAL PAPER

Motivational Predictors of Change in Oral Health: An Experimental Test of Self-Determination Theory

Anne E. Münster Halvari · Hallgeir Halvari

Published online: 2 August 2006

Abstract We tested the hypothesis that a psychosocial dental intervention formulated in terms of self-determination theory would increase patients' perceived competence and autonomous motivation for dental care and would decrease their plaque and gingivitis over a seven month period, compared to standard dental treatment. We also tested a process model in which the intervention was expected to increase perceived dental competence and autonomous motivation, that they would be positively associated with oral health behaviors (i.e., brushing and flossing), which was expected to decrease plaque and, in turn, decrease gingivitis. We also examined whether: changes in perceived competence and autonomous motivation would mediate the effect of the intervention on dental-health behaviors; dental-health behaviors would mediate the links from changes in perceived competence and autonomous motivation to change in plaque; and change in plaque would mediate the relation of dental health behaviors to change in gingivitis. Finally, we examined the fit of the overall model with structural equation modelling. Results supported all predictions.

Keywords Autonomous motivation · Autonomy support · Oral care · Oral health

A. E. M. Halvari (✉)
Faculty of Odontology, Department of Dental Hygienist Education, University of Oslo,
Geitmyrsveien 69/71,
0455 Oslo, Norway
e-mail: ahalvari@odont.uio.no

H. Halvari
Faculty of Education in Business Administration,
Buskerud University College,
Kongsberg, Norway

Dental caries (i.e., tooth decay) and gingivitis (i.e., inflammation and bleeding of gums) are among the most widespread of all human diseases (Newman & Listgarten, 1999), and some forms of gingivitis can lead to periodontitis (i.e., bone destruction around the teeth) (Willmann & Chaves, 1999). Pathogenic bacteria in dental plaque is an initial cause of these diseases (Harris, 1999; Newman & Listgarten, 1999) and can be brought on by poor oral hygiene and a sugar-rich diet (Koch, 1988; von der Fehr, Löe, & Theilade, 1970). Further, the diseases can be reversed by improved oral hygiene with effective mechanical plaque removal and application of topical fluoride, in addition to careful daily plaque removal through flossing and tooth brushing and consumption of a healthier diet with less sugar (Koch, 1988; von der Fehr et al., 1970; Thylstrup, Brunn, & Holman, 1994).

Professional mechanical plaque removal has been shown to yield large reductions in caries and gingivitis in normal populations (see Axelsson, 1981). However, diligent flossing and brushing must supplement professional plaque removal for healthy teeth because plaque begins to form within two hours of the time it has been removed (Bhaskar, 1977), and research has shown that allowing plaque to accumulate on clean teeth surfaces for 2 to 3 weeks can cause gingivitis (Löe & Silness, 1963). Thus, ongoing home dental care appears essential, and indeed studies have found that thorough daily plaque removal does decrease the risk of caries, gingivitis, and periodontitis (Willmann & Chaves, 1999).

An effective dual approach involving periodic professional teeth cleaning and performing daily dental home care requires effective oral hygiene instruction by professionals, and it also requires patients to be motivated to carry out these important, though tedious, behaviors (Axelsson, 1981). There has been very little exploration of the role of motivation in adherence to dental-care regimens and to the primary prevention of oral disease. It is known that

nonadherence to behavioral regimens is a monumental problem for health care (Horwitz & Horwitz, 1993), but evidence also indicates that adherence to behavioral regimens and medication prescriptions can be improved by enhancing patients' autonomous motivation and perceived competence (e.g., Williams et al., 2006; Williams, Rodin, Ryan, Grolnick, & Deci, 1998). Thus, the current study was designed to examine the role of the self-determination theory concepts of autonomous motivation and perceived competence in promoting persistent dental-health behaviors and oral health.

Self-determination theory (SDT; Deci & Ryan, 1985; Ryan & Deci, 2000) research has indicated that providing health information in an autonomy-supportive way is important for patients to improve their health-care behaviors and health (e.g., Williams, Cox, Kouides, & Deci, 1999; Williams, McGregor, Zeldman, Freedman, & Deci, 2004). Autonomy-supportive contexts are defined as "ones in which significant others offer choice, provide a meaningful rationale, minimize pressure, and acknowledge the target individual's feelings and perspectives" (Williams, Grow, Freedman, Ryan, & Deci, 1996, p. 117). Autonomy-supportive health-care contexts have much in common with the biopsychosocial approach to patient care (Engel, 1977), in which health care practitioners are empathic, patient-centered, and sensitive to patients' psychological and social needs in order to provide high-quality patient care (Williams & Deci, 1996).

The present study was designed to extend recent SDT health-care research to the area of dental health care by testing the effectiveness of an autonomy-supportive approach to providing dental health care, relative to standard dental care. Thus, the standard biomedical approach to dental care was compared to the experimental approach in which the important elements of the biomedical approach were embedded within an interpersonal process that was attentive to the patients' psychosocial concerns. We hypothesized that having dental professionals supplement standard treatment with an autonomy-supportive information session would lead to positive changes in patients' oral health over time.

The self-determination theory process model of change

Self-determination theory (Ryan & Deci, 2000) maintains that effective long-term maintenance of behavior change requires patients' motivation for change to be autonomous, as opposed to controlled. When autonomously motivated, people experience volition and choice, and they feel as though the behavior emanates from their sense of self. The behavior has an internal perceived locus of causality (deCharms, 1968). In contrast, when controlled in their motivation, people experience pressure to behave and feel like the behavior is coerced or seduced by interpersonal or intrapsychic forces. Thus, the behavior has an external perceived locus of causality. SDT further suggests that effective behavior change not only requires people to feel autonomous in doing the behavior; they need also to perceive themselves as competent to enact the requisite behaviors in order to yield desired outcomes.

Due to a lack of dental research based on self-determination theory we address studies of other health-related behaviors in deriving our hypotheses. Recent research supports that autonomous motivation (i.e., autonomous regulation of behavior) and perceived competence for making change were important for adherence to exercise programs and long-term maintenance of weight loss in morbidly obese patients (Williams et al., 1996), involvement in physical activity (Bagøien & Halvari, 2005), smoking cessation (Williams, Gagné, Ryan, & Deci, 2002), long-term medication adherence (Williams, Rodin et al., 1998), better self-management of diabetes behaviors and better glucose control for patients with diabetes (Williams, Freedman, & Deci, 1998; Williams et al., 2004), active participation in an alcohol treatment program (Ryan, Plant, & O'Malley, 1995), and more positive affect and well-being (Baard, Deci, & Ryan, 2004; Nix, Ryan, Manly, & Deci, 1999). Thus, in the present study, we hypothesized that changes in autonomous motivation and perceived competence for dental care would be positively related to ongoing oral health behavior, and that changes in oral health behavior would predict improvements in oral health outcomes.

SDT further argues that autonomy-supportive contexts will facilitate autonomous motivation and perceived competence, which are the critical prerequisites for long-term behavior change. Recent research supports that medical students who perceived their instructors as more autonomy-supportive became more autonomous in their learning and perceived themselves to be more competent, which in turn led them to be more effective when they interviewed a simulated patient six months later (Williams & Deci, 1996). Other research has highlighted the importance of autonomy-supportive patient care for (1) increases in autonomous motivation and perceived competence for attendance at a weight-loss program and for long-term maintained weight loss (Williams et al., 1996); (2) facilitating autonomous motivation for taking medications which in turn led to patients' medication adherence (Williams, Rodin et al., 1998); and (3) enhancement of autonomous motivation and perceived competence for diabetes self-management and improved glycemic control for patients with Type 2 diabetes (Williams et al., 2004). We expected that the same will be true with respect to patients engaging in effective oral health care. Consequently, we hypothesized that supplementing standard dental treatment with an autonomy-supportive information session would lead to enhanced autonomous motivation and perceived competence, which would lead to more careful

and persistent dental self-care behaviors, and in turn to less plaque and less gingivitis.

In sum, we tested the hypotheses that an autonomy supportive dental intervention, relative to standard care, would: (i) result in increased autonomous motivation and perceived competence for dental health and to enhanced dental health; (ii) result in more persistent dental self-care behaviors and more positive attitudes and feelings about dental self-care; and (iii) in the SDT process model, facilitate enhanced autonomous motivation and perceived competence, which would be associated with better dental-health behaviors and, in turn, lead to decreased plaque and gingivitis.

Method

Participants

A sample of 90 persons from the schools of medicine and social sciences at the University of Oslo, the Police University College of Oslo, the Akershus Vocational Educational University College and friends of these students volunteered for the study. They were the first 90 persons who responded to announcements on bulletin boards and who met the selection criteria (age: 20–35 years; good spoken Norwegian language). The flyers said that a free dental examination and a free teeth cleaning were part of the study.

Two volunteers were excluded due to periodontal disease, and two others withdrew. Thus, 86 participants completed the project, 44 of whom had been randomly assigned to the experimental group, and 42 to the control group. The sample was 65% female and 35% male, and the average age of the participants was 27.34 years ($SD = 3.99$, range = 21–35 yrs.).

Experimental procedure

A randomized two-group experiment was conducted in a dental clinic with a high commitment to primary preventive dental health care. At Time 1 (T1; baseline) and Time 3 (T3; 7 months after T1) autonomous motivation for dental care was assessed with the Treatment Self-Regulation Questionnaire (TSRQ: Ryan & Connell, 1989; Williams et al., 1996), and perceived dental competence was assessed with the Dental Coping Beliefs Scale (Wolfe, Stewart, Meader, & Hartz, 1996). Further, all participants received a dental examination (see below for a description) to assess plaque, gingivitis, and caries. In addition, at T3, participants completed a short questionnaire about the degree to which they engaged in dental health care behaviors and their degree of positive attitudes and affect about caring for their own oral health. The dentist who was responsible for and performed the oral health examination, together with the dental hygienist, was unaware of the experimental condition of participants. Each session lasted approximately 90 min.

One month after the T1 assessments, all participants ($n = 86$) met at the clinic for a 60-min individual teeth cleaning. A dental hygienist removed calculus and overhanging fillings and polished the teeth thoroughly. This was done to facilitate preventive home-care for participants in both conditions. One month after the teeth cleaning (i.e., two months after the T1 assessments), the intervention was conducted at Time 2 (T2) for the 44 participants who had been randomly assigned to the experimental condition. In the intervention condition, participants spent 60 min in an autonomy-supportive oral-care informational session with the dental hygienist. At this intervention no technical treatment of teeth was performed.

The dental hygienist started the intervention[1] by asking participants about their perceived dental problems, and listening to and acknowledging their feelings and perspectives, before giving highly personalized information about their perceived problems (profylactic rationale). This information was related to participants' X-rays and indexes, illustrated by pictures and examples, and integrated with information about the development of caries, gingivitis, and periodontitis. After this, autonomy support was emphasized more strongly by having the dental hygienist offer choice and options for preventive behaviors that the participants could choose to adopt on a regular basis in order to manage their dental home-care. In addition, in line with self-determination theory, a meaningful rationale was provided for each activity offered (Deci, Eghrari, Patrick, & Leone, 1994). The dental hygienist also demonstrated correct brushing and flossing behaviors for the participants, allowed them to practice the behaviors, conveyed confidence in their abilities to perform the self-care behaviors regularly, and minimized any pressuring or controlling language or attitude. Finally, participants were given toothbrushes, dental floss, and a dental-health brochure.

Participants in the control condition had received the standard oral-health assessment from a dentist and the teeth cleaning from a dental hygienist, just as the intervention participants had, but control-group participants did not receive the T2 autonomy-supportive session with a dental hygienist. Thus, the difference between the two groups was that the control-group participants did not have as much opportunity to discuss problems, ask questions, talk about their feelings, and learn about oral health because they did not attend the informational session with a hygienist. The control-group condition, which represented standard care, was intended to reflect the biomedical orientation to patient care, whereas the experimental condition was intended to reflect a

[1] A full 5-page version of the intervention is available from the authors on request.

biopsychosocial approach to participant care (Engel, 1977; Williams & Deci, 1996).

Oral health assessments

Plaque

Scores for degree of plague were given at T1 and T3 according to the Dental Plaque Index developed by Silness and Löe (1964; see also Löe, 1967, p. 41). This index measures bacterial substances at the tooth surface and is anchored by no overt plaque on the tooth (score 0). A low degree of plaque (score 1) is indicated by a film of plaque adhering to the free gingival margin and adjacent area of the tooth. At this degree of plaque, it can be seen *in situ* only after application of a disclosing solution or by using a probe on the tooth surface. The next level (score 2) indicates moderate accumulation of soft deposits within the gingival pocket, or on the tooth and gingival margin. It can be seen with the naked eye. The highest degree of plaque (score 3) is indexed for abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin.

Gingivitis

Gingival inflammation and bleeding was assessed by the Dental Gingival Index, which was developed by Löe and Silness (1963; see also Löe, 1967, p. 38). The index is anchored by observations of normal gums characterized by absence of inflammation, no seepage of plasma, and a tight gingival margin or edge of the gum (score 0). Mild inflammation (score 1) is indexed by slight change in color and little change in texture, but no bleeding when using a probe along the edge of the gum. Moderate inflammation (score 2) is indexed by moderate glazing, redness, oedema, hypertrophy, and bleeding when a probe is applied along the edge of the gum. Severe inflammation (score 3) is indexed by marked redness, hypertrophy and ulceration, and tendency toward spontaneous bleeding.

Questionnaire assessments

Perceived dental competence

This was assessed with the Dental Coping Beliefs Scale (Wolfe et al., 1996). Two items of this 9-item scale are: "I believe I know how to brush my teeth correctly," and "I believe I can remove most of the plaque from my teeth on a daily basis." The items indicate responses to how confident, capable, and able participants are to maintain a healthy dental hygiene and correspond well to indicators of perceived competence (Williams & Deci, 1996).

Each of the items was answered on a five-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). The item scores were averaged to form the score on this variable. Previous research indicates that reliability and validity of the scale is acceptable (Jacobs-Schoen, 1986; Wolfe et al., 1996; Wolfe, Stewart, & Hartz, 1991). In the present study, the Cronbach (alphas) were .73 (T1) and .78 (T3).

Autonomous motivation

This was assessed with the Treatment Self-Regulation Questionnaire (TSRQ; Ryan & Connell, 1989; Williams et al., 1996). The autonomous sub-scale of the TSRQ consists of 5 items. The focus of the scale is on the reasons for seeking dental treatment. Two example items are: "I came for treatment at the clinic because it is important to me personally to deal with any dental problems" and "I will remain in dental treatment because it is in my best interests to do so." Participants responded to each item on a five-point Likert scale, ranging from "not at all true" (1) to "very true" (5). The items were averaged to form the score for autonomous self-regulation for dental care. Previous research in Norway (Cock & Halvari, 1999; Strandkleiv, 1999) using the TSRQ indicated that the reliability of the scale is acceptable. In the present study, the Cronbach alphas were .76 (T1) and .67 (T3).

Dental health behavior

This was assessed at T3 with three questions: "Do you clean the between-teeth surfaces with floss and/or toothpicks? Do you clean the areas between your teeth daily? Do you brush your teeth two times a day or more?" Each question was answered with "no" (1) or "yes" (2). The responses were summed to form the total score for the scale. In the present study, the Cronbach alpha (standardized) was .66.

Attitudes and affect toward dental care

This questionnaire, which contained five items about people's attitudes and affect about their own dental health care, was administered at T3. Sample items were: "During this study I have become more eager and involved in my own oral health." "I now experience a more positive feeling in relation to my own oral health." and "It was interesting to learn more about my own oral-health." Responses were made on a five point Likert scale. In this study, the Cronbach alpha was .85.

Table 1 Means and standard deviations for each study variable at time 1 and 3

Variable	*M*	*SD*	*M*	*SD*
	Perceived competence (T1)		Perceived competence (T3)	
Control group	3.81	0.63	4.00	0.68
Intervention group	3.67	0.66	4.43	0.57
	Autonomous motivation (T1)		Autonomous motivation (T3)	
Control group	3.66	0.74	3.56	0.58
Intervention group	3.46	0.83	3.81	0.72
			Health behavior (T3)	
Control group			3.95	0.14
Intervention group			4.19	0.26
			Health attitudes and affect (T3)	
Control group			3.89	0.72
Intervention group			4.41	0.55
	Plaque (T1)		Plaque (T3)	
Control group	1.53	0.20	1.28	0.33
Intervention group	1.56	0.20	0.83	0.28
	Gingivitis (T1)		Gingivitis (T3)	
Control group	1.36	0.23	1.34	0.21
Intervention group	1.37	0.24	1.10	0.20

Note. $n = 42$ for the Control Group and 44 for the Intervention Group.

Results

Intervention effects

We hypothesized that the autonomy-supportive intervention at T2 would produce increases in perceived competence and autonomous motivation and decreases in plaque and gingivitis from T1 to T3. Also predicted was that the intervention would have a positive effect on dental health behaviors and on attitudes and affect about oral-health care at T3. Table 1 shows the T1 and T3 means and standard deviations for motivation, health behavior, oral health variables, and for attitudes and feelings[2]. We examined the hypothesis for perceived competence, autonomous motivation, plaque, and gingivitis at T1 and T3 using a repeated-measures multivariate analysis of variance (MANOVA), followed by four repeated-measures analyses of variance (ANOVA). Then, for oral-health behaviors at T3 and oral-health attitudes and affect at T3, we used univariate analyses of variance. The MANOVA used the autonomy-supportive versus standard treatments as a between-group factor crossed with T1 and T3 assessments as the repeated measures factor. Perceived competence, autonomous motivation, plaque, and gingivitis were the dependent variables. The analysis yielded two main effects and an interaction. For condition, $F(4,81) = 5.98$, $p < .001$; for time, $F(4,81) = 68.21$, $p < .001$; and for the interaction, $F(4,81) = 18.09$, $p < .001$. In terms of the test of the hypothesis, the interaction is the most important statitstic, as it indicates that the experimental condition changed more from T1 to T3 than did the control condition. The change was large enough that it also produced the two main effects, although those were not needed for support of the hypothesis.

We then performed the repeated measures ANOVAs (see Table 2). For perceived competence, there was a significant main effect for the intervention [$F(1,84) = 16.07$, $p < .001$], a significant main effect for time [$F(1,84) = 45.03$, $p < .001$], and a significant interaction [$F(1,84) = 16.29$, $p < .001$], thus supporting the hypothesis that the intervention would have a significant positive effect on perceived competence from T1 to T3, relative to the control group. For autonomous motivation, there was a significant main effect for the intervention [$F(1,84) = 5.01$, $p < .05$] and a significant interaction [$F(1,84) = 6.20$, $p < .01$], again supporting the hypothesis for an increase in autonomous motivation from T1 to T3, relative to the control group. For plaque, there was a significant main effect for the intervention [$F(1,84) = 50.67$, $p < .001$], a significant main effect for time [$F(1,84) = 213.05$, $p < .001$], and a significant interaction [$F(1,84) = 48.59$, $p < .001$], thus supporting the hypothesis for a decrease in plaque from T1 to T3. For gingivitis, there was a significant main effect for the intervention [$F(1,84) = 28.81$, $p < .001$], a significant main effect for time [$F(1,84) = 25.43$, $p < .001$], and a significant interaction [$F(1,84) = 17.81$, $p < .001$], which indicated that the intervention significantly decreased gingivitis from

[2] For all measures skewness and kurtosis values were between −2 and 2, and reliabilities above .60, and they were judged to be acceptable according to criteria normally set (Muthen & Kaplan, 1985).

Table 2 ANOVA of study variables (repeated measures) and the intervention

Effect	*F*	(*df*)	*p*
Perceived competence			
Intervention	16.70	1, 84	.001
Time (T1 & T3)	45.03	1, 84	.001
Intervention × Time	16.29	1, 84	.001
Autonomous motivation			
Intervention	5.01	1, 84	.05
Time (T1 & T3)	1.77	1, 84	ns
Intervention × Time	6.20	1, 84	.01
Health behavior (only at T3)			
Intervention	19.58	1, 86	.001
Health attitudes and affect (only at T3)			
Intervention	14.28	1,86	.001
Plaque			
Intervention	50.67	1, 84	.001
Time (T1 & T3)	213.05	1, 84	.001
Intervention × Time	48.59	1, 84	.001
Gingivitis			
Intervention	28.81	1, 84	.001
Time (T1 & T3)	25.43	1, 84	.001
Intervention × Time	17.81	1, 84	.001

T1 to T3, relative to the control group. Finally, an ANOVA indicated that the intervention affected health behaviors at T3 [$F(1,86) = 19.58$, $p < .001$] as well as health attitudes and affect [$F(1,86) = 14.28$, $p < .001$]. Thus, the first two hypotheses received strong support. That is, the autonomy-supportive intervention increased perceived competence and autonomous motivation, decreased plaque and gingivitis, and also influenced T3 oral-health behaviors and T3 oral-health attitudes and affect, as expected.

The self-determination theory process model

The third hypothesis concerned the relations among variables, including mediated processes, within the overall SDT-based process model of dental-health care that appears in Fig. 1. The relevant results begin with a correlation matrix (Table 3) for all variables in the study. Then we created residualized change scores for perceived competence, autonomous motivation, plaque, and gingivitis by using

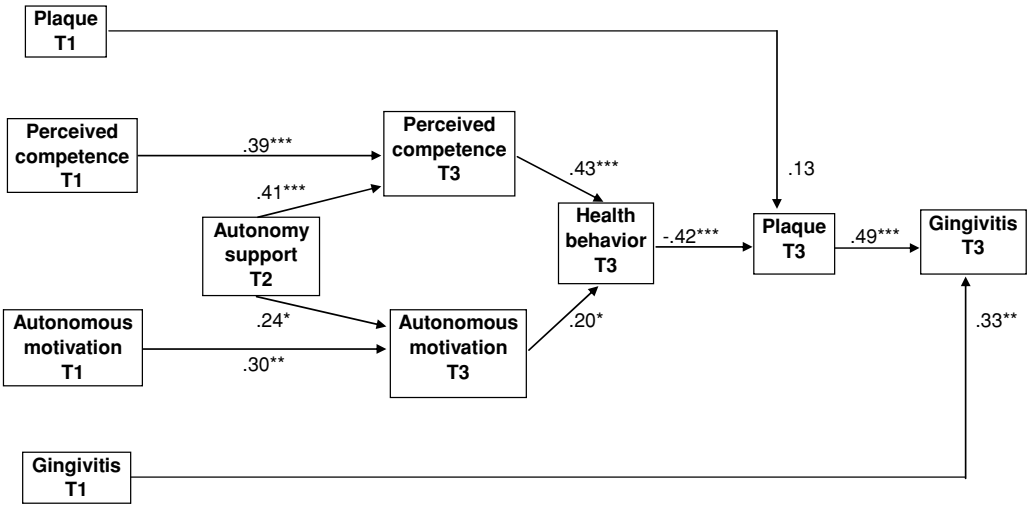

Fig. 1 The change model, with change in perceived competence and change in autonomous motivation mediating the relation between autonomy support and health behavior; with health behavior mediating the relations of change in both perceived competence and autonomous motivation to change in plaque; and change in plaque mediating the relation between health behavior and change in gingivitis. Notes: T1 = baseline; T2 = 2 months; T3 = 7 months. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Table 3 Correlations (Pearson *r*'s) among motivation variables, health behavior, and oral health variables

Measure (and time)	1	2	3	4	5	6	7	8	9	10	11
1. Perceived competence (T1)	—										
2. Autonomous motivation (T1)	.14	—									
3. Plaque (T1)	−.20	.03	—								
4. Gingivitis (T1)	−.07	.08	.30**	—							
5. Intervention (autonomy support) (T2)	−.12	−.11	.06	.02	—						
6. Oral health behavior (T3)	.18	−.27*	.03	.11	.44***	—					
7. Perceived competence (T3)	.40***	−.02	−.21*	.11	.33**	.54***	—				
8. Autonomous motivation (T3)	.21	.28	−.20	−.01	.19	.27**	.39***	—			
9. Plaque (T3)	−.10	.06	.20	−.10	−.59***	−.41***	−.29**	−.38***	—		
10. Gingivitis (T3)	−.17	.03	.22*	.23*	−.49***	−.28**	−.30**	−.20	.48***	—	
11. Oral health attitudes and affect (T3)	.19	.12	−.03	.21	.38***	.34***	.47***	.44***	−.32**	−.32**	—

Note. Spearmans point-biserial coefficient is used between the intervention and other variables.
*$p < .05$, **$p < .01$, ***$p < .001$, two-tailed.

regression analyses to remove the T1 value for a variable from the T3 value for that variable. Table 4 presents the correlations among these four residualized change scores; plus the intervention, which was a dichotomous, dummy-coded variable, and both dental-health behaviors and dental-health attitudes and affect, which were assessed only at T3. As with the zero order correlations in Table 3, the correlations among change scores in Table 4 are all in line with the hypotheses.

To test the SDT process model shown in Fig. 1 we took a dual approach. In the first set of analyses, we examined the links between all contiguous variables in the model and then we examined mediation at each section of the model. For example, we began by examining the relations between the intervention and changes in both perceived competence and autonomous motivation, and between changes in both perceived competence and autonomous motivation and health behaviors. Then we tested whether changes in perceived competence and autonomous motivation mediated the relation between the intervention and health behaviors at T3. In the second phase of this dual approach we used LISREL to test the fits to the data of the measurement model and the structural model. The n for this study was only 86, with 10 parameters, so we did not present the LISREL analyses as the primary analyses. Still, we tested the overall fit of the structural model to supplement the use of regression to examine the process model.

The overall SDT process model suggests that the intervention, relative to the control condition, would enhance people's perceived competence and autonomous motivation; that these positive changes would predict better dental health behaviors at T3, which in turn would predict decreased plaque and, subsequently, decreased gingivitis. Table 4 shows that the intervention was positively related to change in perceived competence ($r = .41$, $p < .01$) and change in autonomous motivation ($r = .24$, $p < .05$); that changes in perceived competence and autonomous motivation were both related to post-treatment dental-health behaviors ($r = .51$, $p < .001$; $r = .36$, $p < .001$, respectively); that better health behavior was related to decreased plaque ($r = -.42$, $p < .001$); and that decreased plaque was related to decreased gingivitis ($r = .49$, $p < .001$). Because the model shows both change in perceived competence and change in autonomous motivation predicting T3 health behavior, we examined the effects of each controlling for the other by regressing health behavior onto change in both perceived competence and autonomous motivation. The overall model was significant [$F(2,85) = 17.12$, $p < .001$, $R^2 = .29$], and the paths coefficients were ($\beta = .43$, $p < .001$) for change in perceived competence and ($\beta = .20$, $p < .05$) for change in autonomous motivation.

Next, we tested mediation in each section of the model. First, we examined whether changes in perceived

Table 4 Correlations among change in motivation, change in oral health, autonomy support and oral health behavior

Measure (and time)	1	2	3	4	5	6	7
1. Change in perceived competence (T1—T3)	—						
2. Change in autonomous motivation (T1—T3)	.37***	—					
3. Change in plaque (T1—T3)	−.25**	−.37***	—				
4. Change in gingivitis (T1—T3)	−.30**	−.21*	.49***	—			
5. Intervention (autonomy support) (T2)	.41***	.24*	−.61***	−.51***	—		
6. Oral health behaviors (T3)	.51***	.36***	−.42***	−.31**	.44***	—	
7. Oral health attitudes and affect (T3)	.44***	.42***	−.32**	−.38***	−.38***	.34***	—

Note. Change scores (standardized residuals) were created by regression of T3 measures onto T1 measure.

*$p < .05$, **$p < .01$, ***$p < .001$, one-tailed.

competence and autonomous motivation mediated the effect of the intervention on health behavior. As noted in the proceeding paragraph, the intervention was related significantly to each of the potential mediators. Thus, to test mediation, post-treatment behavior was regressed onto the intervention variable and then onto the residuals representing change in perceived competence and change in autonomous motivation. The overall model was significant [$F(2,85) = 9.84, p < .001, R^2 = .35$]. When only the intervention was entered into the equation, the intervention had a significant effect ($\beta = .44, p < .001$). When the residuals were added to the equation, the residual for perceived competence was significant ($\beta = .34, p < .001$) and the residual for autonomous motivation was marginally significant ($\beta = .17, p < .08$). Further, the direct link from the intervention to T3 behavior dropped to ($\beta = .26, p < .05$). The Sobel test indicated that change in perceived competence was a significant mediator ($z = 2.87, p < .01$) and that change in autonomous motivation was a marginally significant mediator ($z = 1.74, p < .08$). Thus, using the criteria for mediation specified by Baron and Kenny (1986), changes in perceived competence and autonomous motivation partially mediated the link from the autonomy supportive intervention to post-treatment behavior. In addition, there was also a direct relation from the intervention to change in behavior ($\beta = .26, p < .05$).

Next, does health behavior at T3 mediate the relations from the residual change in perceived competence and the residual change in autonomous motivation to the residual change in plaque from T1 to T3? First consider change in perceived competence. We regressed plaque at T3 onto plaque at T1 and onto the residual change in perceived competence from T1 to T3. The overall model was significant [$F(2,85) = 9.10, p < .001, R^2 = .18$]. The relation for plaque at T1 was non-significant ($\beta = .12, p > .10$), but there was a significant effect for residual change in perceived competence ($\beta = -.25, p < .01$). As shown above and in Table 4, change in perceived competence also related significantly to T3 health behavior. We then examined whether health behavior at T3 mediated the link from increase in perceived competence to decrease in plaque. We regressed T3 plaque onto T1 plaque and then onto the residual change in perceived competence, and finally onto T3 behavior change. There was a significant overall model [$F(3,85) = 7.14, p < .001, R^2 = .21$], with a significant negative relation for the link from health behavior at T3 to change in plaque ($\beta = -.38, p < .001$). However, as predicted, the relation between the residual change in perceived competence and residual change in the plaque became non-significant ($\beta = -.06, p > .10$). The drop in the relation between change in perceived competence and change in plaque from significant ($-.25$) to non-significant ($-.06$) after health behavior was introduced indicates that health behavior at T3 was essentially a full mediator of the significant negative relation between change in perceived competence (T1–T3) and change in plaque (T1–T3).

Then we examined whether health behavior mediated the relation between the residualized change in autonomous motivation and the residualized change in plaque. First, we regressed plaque at T3 onto plaque at T1 and onto the residual change in autonomous motivation from T1 to T3. The overall model was significant [$F(2,85) = 9.10, p < .001, R^2 = .18$]. The relation for plaque at T1 was non-significant ($\beta = .12, p > .10$), but there was a significant effect for residualized change in autonomous motivation ($\beta = -.38, p < .001$). Then, when health behavior at T3 was added to the equation, the overall model was again significant [$F(3,85) = 9.82, p < .001, R^2 = .26$). Significant negative relations were obtained for health behavior at T3 ($\beta = -.31, p < .01$) and for change in autonomous motivation from T1 to T3 ($\beta = -.27, p < .05$). Thus, the potential mediator related to change in plaque, when controlling for the independent variable (change in autonomous motivation). Further, the direct link from change in autonomous motivation to change in plaque decreased from $\beta = -.38$ to $\beta = -.27$. This decrease was significant according to the Sobel test ($z = 2.83, p < .01$), but the

direct link from change in autonomous motivation to change in plaque was still significant. Thus, health behavior significantly mediated the relations from both change in perceived competence and change in autonomous motivation to change in plaque, although there was the additional direct link from change in autonomous motivation to change in plaque ($\beta = -.27, p < .05$).

Finally, we examined whether residual change in plaque mediated the relation between T3 health behavior and residual change in gingivitis. Gingivitis at T3 was regressed onto gingivitis at T1 and then onto health behavior at T3, and a significant overall model was found [$F(2,85) = 7.14, p < .001, R^2 = .15$]. A significant positive relation was found for gingivitis at T1 ($\beta = .27, p < .05$), and a significant negative relation was obtained for health behavior at T3 ($\beta = -.31, p < .01$). Then, when change in plaque was added to the model, there was a significant effect for the over-all model [$F(3,85) = 11.86, p < .001, R^2 = .30$]. Significant positive relations were obtained for gingivitis at T1 ($\beta = .31, p < .001$) and for change in plaque from T1 to T3 ($\beta = .44, p < .001$), but health behavior at T3 became nonsignificant ($\beta = -.13, p > .10$). The drop in the relation for health behavior at T3 from significant ($\beta = -.31$) to nonsignificant ($\beta = -.13$) when change in plaque was introduced was significant according to the Sobel test ($z = 3.23, p < .01$) indicating that change in plaque significantly mediated the negative relation between health behavior and change in gingivitis.

To summarize, both change in perceived competence and change in autonomous motivation mediated the link from the intervention to T3 health behavior. Further, T3 health behavior mediated the links between change in both perceived competence and autonomous motivation to change in plague. Finally, change in plaque mediated the link from T3 health behvior to change in gingivitis. In addition, there was also a significant direct path from the intervention to T3 health behavior, and there was a direct link from change in autonomous motivation to change in plaque.

Fit of the overall model

First we examined the measurement model using confirmatory factor analysis. The test of the *a priori* measurement model did not fit the data well according to the RMSEA, NNFI, CFI, and IFI fit indices (Bollen, 1989; Hu & Bentler, 1995). Therefore, some re-specifications were made according to the recommended two-step approach (Anderson & Gerbing, 1988). First, items with low factor loadings or item reliability were omitted. Second, items with high cross loadings and high correlated error terms were omitted. This was done utilizing the standardized residuals indicating an underspecified and/or overestimated model (Segars, 1994) and modification indices in LISREL (Jöreskog, 1993) giving us information about items that should be omitted. This procedure resulted in a test of the final measurement model, which fit the data well ($X^2 = 73.29$, $df = 64$, $p = .20$; $X^2/df = 1.15$; RMSEA = 0.04, NNFI = 0.95, CFI = 0.98, and IFI = 0.98). This final model was applied in the structural analyses. The model included 4 items for autonomous motivation (T1 and T3), 2 items for perceived competence (T1 and T3), and 1 T3 dental health behavior measure formed by the sum of the 3 items described in the method section for dental health behavior. The error variances for autonomy support, dental health behavior, plaque, and gingivitis were set to .15.

Structural Equation Modelling was then used to test the third hypothesis combining the measurement and the structural model in the same analysis. This procedure avoids the interpretation of structural parameters for a model with unknown construct validity and reliability that may give inaccurate estimates and yield misleading conclusions (Jöreskog & Sörbom, 1982). Initially, we examined the fit of just the model as it appears in Fig. 1, but the fit was not satisfactory. We then added the two direct paths that emerged from the mediational analyses described above (from the intervention to T3 health behavior change and from change in autonomous motivation to change in plaque). The fit improved but was still not considered acceptable. We then did additional mediational analyses and identified two other important paths: the first is from change in perceived competence to change in autonomous motivation and the second is from the intervention to change in plaque. We added these two paths to the model, and the model fit the data well ($X^2 = 96.08$, $df = 84$, $p = .17$; ($X^2/df = 1.14$) RMSEA = 0.04, NNFI = 0.94, CFI = 0.96, and IFI = 0.96). The unstandardized parameter estimates are shown in Fig. 2.)

Discussion

The results provided strong support for the hypotheses. The autonomy-supportive informational intervention increased patients perceived competence and autonomous motivation for dental-health care from T1 to T3, decreased plaque and gingivitis from T1 to T3, and resulted in better dental self-care behavior and more positive dental-health attitudes and affect at T3. Further, using both regression analyses focused on mediation and LISREL analyses to test the overall structural model, there was substantial support for the self-determination theory process model of oral health. The intervention increased perceived competence and autonomous motivation, which were related to dental-health behavior at T3. Then, better dental health behavior (i.e., brushing and flossing) reduced plaque and, in turn, gingivitis. In addition, there were direct paths from the intervention to T3 dental-health behaviors and the decreases in plaque, and from increases in autonomous motivation to decreases in plaque.

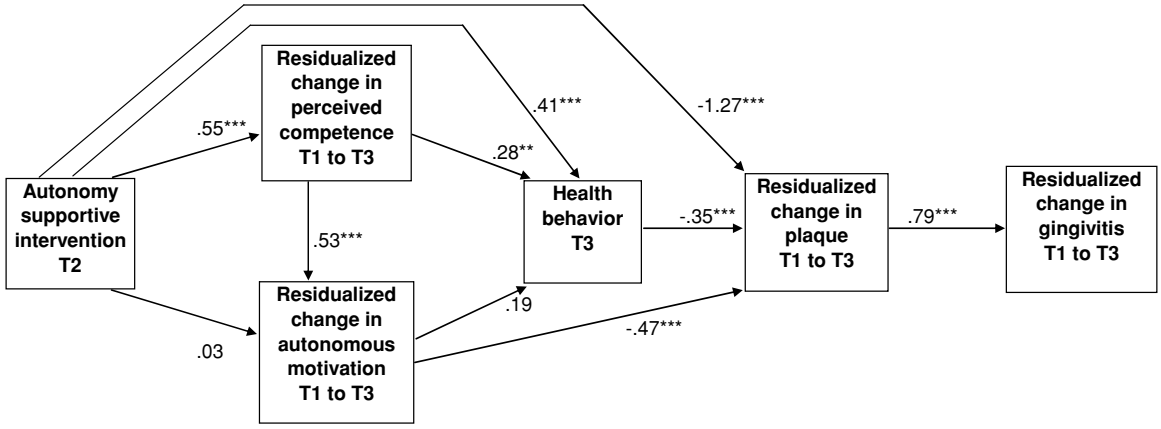

Fig. 2 The change model based on LISREL analysis ($X^2 = 96.08$, $df = 84$, $p = .17$; ($X^2/df = 1.14$) RMSEA = 0.04, NNFI = 0.94, CFI = 0.96, and IFI = 0.96) with unstandardized parameter estimates. Compared to Fig. 1, which emerged from regression analyses, direct relationships based on mediational analyses were added for links from the intervention to health behaviors and change in plaque, from change in autonomous motivation to change in plaque, and from change in perceived competence to change in autonomous motivation. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Finally, as can be seen in Fig. 2, change in perceived competence mediated the link from the intervention to change in autonomous motivation.

Because the research was a randomized field experiment it is possible to draw causal links from the intervention to the motivational, behavior, health, and affect variables. In other words, we can safely say that the intervention did produce these effects. However, the motivational and health variables were assessed contemporaneously at T1 and T3, so the changes in motivation variables cannot be said to have produced the changes in dental health. The model proposing those relations did fit the data, mediated by T3 health behavior, but it is not possible to rule out bi-directional relations between the motivation and health variables.

Another important strength of the current study, in addition to its being a longitudinal randomized field experiment, is that it used physiological measures as the primary dependent variables (viz., plaque and gingivitis) and found relations between the motivation variables and the physiological dental health outcomes.

In addition to supporting SDT (Deci & Ryan, 1985, 2000), the findings are of great practical significance because they make clear that the use of an autonomy-supportive approach to dental health care by dental professionals can yield substantial changes in self-determined motivational processes, dental health behavior, oral health, and attitudes about dental health. With the large effects for the intervention on reductions in both plaque and gingival the findings are of considerable importance for preventive dental work. The observed gingival reductions are in particular remarkable because research indicates that this cannot be achieved unless adequate dental health behavior is performed regularly over time (Axelsson, 1994). The SDT change model tested suggests that dental-health self-care behaviors do in fact mediate the negative links from changes in both perceived dental competence and autonomous motivation for dental care to change in plaque. In addition, change in plaque mediated the negative relation between health behavior and change in gingivitis.

Although there was significant mediation at each step in the model, there was only one instance of full mediation; specifically, health behavior was a full mediator of the relation between changes in perceived competence and changes in plaque. Thus, there is room for additional research to examine other possible mediators between the autonomy-supportive intervention and oral health outcomes. For example, people often experience stress in relation to dental treatment, so autonomy-supportive social contexts may lead patients to feel less stress, which could be a positive factor in oral-health behavior and oral health. In fact, there is some research indicating that social contexts with elements of autonomy support have reduced stress (Karasek, 1979; Karasek & Thorell, 1990) and improved healthy functioning (North et al., 1993). It would be worth examining whether such factors, which related to autonomy support, also improve immune functions that enhance oral health over and above that accounted for by health behavior.

It is interesting to note that change in perceived competence fully mediated the relation from the autonomy-supportive intervention to change in perceived autonomous motivation. Conversely, in two studies (e.g., Williams et al., 2004, 2006), results showed that autonomous motivation mediated the relation from autonomy support to perceived competence. Further work is necessary in order to clarify when autonomous motivation will mediate between autonomy support and perceived competence, and when perceived

competence will mediate between autonomy support and autonomous motivation. The results indicated that the relation between the autonomy-supportive intervention and change in perceived dental competence was somewhat stronger than the relation between the intervention and change in autonomous motivation for dental health. It is possible that this was a function of the nature of the intervention. Although the intervention was conducted in a very autonomy-supportive way, the substance of the intervention was focused primarily on providing information related to effective self-care, which is likely to have been experienced as highly competence supportive.

In future research, it would be useful to improve the quality of the measures of dental-health behavior. Although the relations between health behavior and change in plaque and gingivitis were $-.42$ and $-.31$, respectively, there is still considerable room for increasing these relations and a better assessment of health behavior could account for more variance in the health outcomes.

The results from this study have important theoretical and practical implications related to the debate between professionals advocating a biomedical versus a biopsychosocial approach to health care (see Engel, 1977; Williams & Deci, 1996). In the present study, patients in the control group were exposed to professionals using a standard biomedical approach who provided a technical examination, teeth cleaning, and short objective answers to questions. This represents standard practice in traditional dental-health offices. In contrast, patients in the experimental group received the same biomedical treatment but they were also given an additional informational session in which they were met by a dental hypienist who used a very autonomy-supportive approach that provided considerable psychosocial content. That is, the professionals were empathic, patient-centered, and sensitive to patients' psychological and social needs.

In dental care, the biopsychosocial approach is often thought of as time-consuming and not worth the extra time and expense. Although the current study did not do a cost-benefit analysis, the results showing substantially better dental health in the condition where psychosocial needs were addressed indicates that this addition to standard care would indeed be worth the modest additional cost, particularly because the informational session was done by a hygienist rather than a dentist. Because the intervention affected positive dental-health behaviors, it is likely that the positive effects on oral health would continue over a period of time greater than the six months between the intervention and the follow up measures of motivation and health. Further, it is possible that if dentists were also trained to be more autonomy-supportive in delivering patient care, they could contribute to improved health behaviors and oral health even without additional time-consuming psychosocial discussions. This is important for preventive dental work, because autonomy-supportive behavior of dental professionals can be learned (Williams & Deci, 1996), so it could be incorporated into their professional education and would likely have a positive effect on the oral health of their patients.

Acknowledgements We express thanks to Edward L. Deci for reading this manuscript and providing helpful suggestions for revisions.

References

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103,* 311–423.

Axelsson, P. (1981). Concept and practice of plaque-control. *Pediatric Dentistry*, *3*(Special Issue), 101–112.

Axelsson, P. (1994). Mechanical plaque control. In N. P. Lang & T. Karring (Eds.), *Proceedings of the 1st European Workshop on Periodontology* (pp. 219–243). London: Quintessence Publishing Co., Ltd.

Baard, P. P., Deci, E. L., Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology*, *34,* 2045–2068.

Bagøien, T. E., & Halvari, H. (2005). Autonomous motivation, involvement in physical activity, and perceived sport competence: Structural and mediator models. *Perceptual and Motor Skills*, *100,* 3–21.

Baron, R. M., & Kenny, D. A. (1986). The moderator—mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, *51,* 1173–1182.

Bhaskar, S. N. (1977). *Synopsis of oral pathology*. St. Louis, Missouri: The C. V. Mosby Company.

Bollen, K. (1989). *Structural equations with latent variables*. New York: Wiley.

Cock, D., & Halvari, H. (1999). Relations among achievement motives, autonomy, performance in mathematics, and satisfaction of pupils in elementary school. *Psychological Reports*, *84,* 983–997.

deCharms, R. (1968). *Personal causation: The internal affective determinants of behavior*. New York: Academic Press.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: The self-determination theory perspective. *Journal of Personality*, *62,* 119–142.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11,* 227–268.

Engel, G. E. (1977). The need for a new medical model: A challenge for biomedicine. *Science*, *196,* 129–136.

Harris, N. O. (1999). Introduction to primary preventive dentistry. In N. O. Harris & F. Garcia-Godoy (Eds.), *Primary preventive dentistry* (pp. 1–18). Stamford, CT: Appleton & Lange.

Horwitz, R. I., & Horwitz, S. M. (1993). Adherence to treatment and health outcomes. *Archives of Internal Medicine*, *153,* 1863–1868.

Hu, L., & Bentler, P. M. (1995). Evaluating model fit. In R. H. Hoyle (Ed.), *Structural equation modeling: concepts, issues, and applications* (pp. 76–99). Thousand Oaks, CA: Sage.

Jacobs-Schoen, M. (1986). *The effect of a cognitive behavioural counceling intervention on preventive dental hygiene*. Unpublished Doctoral Dissertation. University of California, CA: Los Angeles.

Jöreskog, K. G. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 294–316). London: Sage.

Jöreskog, K. G., & Sörbom, D. (1982). Recent developments in structural equation modeling. *Journal of Marketing Research*, *19,* 404–416.

Karasek, R. (1979). Job demands, job decision latitude and mental strain: Implications for job redesign. *Administrative Science Quarterly*, *24,* 285–308.

Karasek, R., & Thorell, T. (1990). *Healthy work: Stress, productivity and the reconstruction of working life*. New York: Basic Books.

Koch, G. (1988). Importance of early determination of caries risk. *International Dental Journal*, *38,* 203–210.

Löe, H. (1967). The Gingival Index, the Plaque Index and the Retention Index Systems. *The Journal of Periodontology*, *38,* 610–616.

Löe, H., & Silness, J. (1963). Periodontal disease in pregnancy. I. Prevalence and severity. *Acta Odontol Scandinavia*, *21,* 533–551.

Muthen, B., & Kaplan, D. (1985). A comparison of some methodologies for the factor analysis of non-normal Likert variables. *British Journal of Mathematical and Statistical Psychology*, *38,* 171–189.

Newman, H. N., & Listgarten, M. A. (1999). The development of dental plaque: FROM preeruptive primary cuticle to acquired pellicle to dental plaque to calculus formation. In N. O. Harris & F. Garcia-Godoy (Eds.), *Primary preventive dentistry* (pp. 19–39). Stamford, Connecticut: Appleton & Lange.

Nix, G. A., Ryan, R. M., Manly, J. B., & Deci, E. L. (1999). Revitalization through self-regulation: The effects of autonomous and controlled motivation on happiness and vitality. *Journal of Experimental Social Psychology*, *35,* 266–284.

North, F., Syme, S. L., Feeney, A., Head, J., Shipley, M., & Marmot, M. (1993). Explaining socioeconomic differences in sickness absence: the Whitehall II study. *British Medical Journal*, *306,* 361–366.

Ryan, R. M., & Connell, J. P. (1989). Perceived locus of causality and internalisation: examining reasons for acting in two domains. *Journal of Personality and Social Psychology*, *57,* 749–761.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55,* 68–78.

Ryan, R. M., Plant, R. W., & O'Malley, S. (1995). Initial motivations for alcohol treatment: Relations with patient characteristics, treatment involvement and dropout. *Addictive Behaviors*, *20,* 279–297.

Segars, A. H. (1994). Scale development in information systems research: A paradigm incorporating unidimensionality and its assessment. In J. DeGross, S. L. Huff, & M. C. Munro (Eds.), *Proceedings of the 15th International Conference on Information Systems* (pp. 1–12). Canada: Vancouver.

Silness, J., & Löe, H. (1964). Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scandinavia*, *22,* 112–135.

Strandkleiv, O. I. (1999). Subjektivt velvære, indre motivasjon, målorientering, kompetanseoppfatning og klasseromsklima. Unpublished Master's thesis, Universitetet, Oslo.

Thylstrup, A., Brunn, C., & Holman, L. (1994). In vivo caries models–mechanisms for caries initiation and arrestment. *Advances in Dental Research*, *8,* 144–157.

von der Fehr, E. R., Löe, H., & Theilade, E. (1970). Experimental caries in man. *Caries Research*, *4,* 131–136.

Williams, G. C., Cox, E. M., Kouides, R., & Deci, E. L. (1999). Presenting the facts about smoking to adolescents: The effects of an autonomy supportive style. *Archives of Pediatrics and Adolescent Medicine*, *153,* 959–964.

Williams, G. C., & Deci, E. D. (1996). Internalization of biopsychosocial values by medical Students: A test of self-determination theory. *Journal of Personality and Social Psychology*, *70,* 767–779.

Williams, G. C., Freedman, Z. R., & Deci, E. L. (1998). Supporting autonomy to motivate glucose control in patients with diabetes. *Diabetes Care*, *21,* 1644–1651.

Williams, G. C., Gagné, M., Ryan, R. M., & Deci, E. L. (2002). Supporting autonomy to motivate smoking cessation: A test of self-determination theory. *Health Psychology*, *21,* 40–50.

Williams, G. C., Grow, V. M., Freedman, Z., Ryan, R. M., & Deci, E. L. (1996). Motivational predictors of weight loss and weight-loss maintenance. *Journal of Personality and Social Psychology*, *70,* 115–126.

Williams, G. C., McGregor, H. A. Sharp, D., Levesque, C., Kouides, R. W., Ryan, R. M., & Deci, E. L. (2006). Testing a self-determination theory intervention for motivating tobacco cessation: Supporting autonomy and competence in a clinical trial. *Health Psychology*, *25,* 91–101.

Williams, G. C., McGregor, H. A., Zeldman, A., Freedman, Z. R., & Deci, E. L. (2004). Testing a self-determination theory process model for promoting glycemic control through diabetes self-management. *Health Psychology*, *23,* 58–66.

Williams, G. C., Rodin, G. C., Ryan, R. M., Grolnick, W. S., & Deci, E. L. (1998). Autonomous regulation and long-term medication adherence in adult outpatients. *Health Psychology*, *17,* 269–276.

Willmann, D. E., & Chaves, E. S. (1999). The role of dental plaque in the etiology and progress of inflammatory periodontal disease. In N. O. Harris & F. Garcia-Godoy (Eds.), *Primary Preventive Dentistry* (pp. 63–76). Stamford, Connecticut: Appleton & Lange.

Wolfe, G., Stewart, J., & Hartz, G. (1991). Relationship of dental coping beliefs and oral hygiene. *Community Dental and Oral Epidemiology*, *19,* 111–114.

Wolfe, G. R., Stewart, J. M., Meader, L. A., & Hartz, G. W. (1996). Use of dental coping beliefs scale to measure cognitive changes following oral hygiene interventions. *Community Dental and Oral Epidemiology*, *24,* 37–41.