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Self-Determined Motivational Predictors of Increases in Dental Behaviors, Decreases in Dental Plaque, and Improvement in Oral Health: A Randomized Clinical Trial

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Objective: The present study tested the hypotheses that: (a) a dental intervention designed to promote dental care competence in an autonomy-supportive way, relative to standard care, would positively predict perceived clinician autonomy support and patient autonomous motivation for the project, increases in autonomous motivation for dental home care, perceived dental competence, and dental behaviors, and decreases in both dental plaque and gingivitis over 5.5 months; and (b) the self-determination theory process model with the intervention and individual differences in autonomy orientation positively predicting project autonomous motivation and increases in perceived dental competence, both of which would be associated with increases in dental behavior, which would, in turn, lead to decreased plaque and gingivitis. ***Methods:*** A randomized two-group experiment was conducted at a dental clinic with 141 patients (M_{age} = 23.31 years, SD = 3.5), with pre- and postmeasures (after 5.5 months) of motivation variables, dental behaviors, dental plaque, and gingivitis. ***Results:*** Overall, the experimental and hypothesized process models received strong support. The effect sizes were moderate for dental behavior, large for autonomous motivation for the project and perceived competence, and very large for perceived autonomy support, dental plaque, and gingivitis. A structural equation model supported the hypothesized process model. ***Conclusions:*** Considering the very large effects on reductions in dental plaque and gingivitis, promoting dental care competence in an autonomy-supportive way, relative to standard care, has important practical implications for dental treatment, home care, and health.

Keywords: autonomous motivation, autonomy support, perceived competence, dental behavior, oral health promotion and prevention of oral disease

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Dental plaque is defined as a biofilm on a tooth surface containing bacteria (Marsh, 2006), and the amount of plaque is conventionally considered as an indicator of the quality of oral hygiene efforts. Clinical experiments have concluded that accumulation of plaque on healthy gingiva produces gingivitis (viz, inflamed gums; Löe, 2000), which is the most prevalent of all periodontal diseases (Armitage, 2004). Depending on the study and subpopulation, 50% to 80% of Americans have overt gingivitis and signs of gingival bleeding (Albandar & Rams, 2002; American Academy of Periodontology, 2005). Gingivitis is conceived as a risk factor for periodontitis (viz, attachment loss around the teeth). The prevalence of severe generalized periodontitis is about 5% to 15% in any population, but the majority of adult populations have some degree of mild or moderate chronic periodontitis, which is compatible with healthy functioning. Gingivitis and mild to moderate periodontitis, which are plaque induced, can be prevented or reversed in most people by regular oral hygiene home care and dental clinic preventive procedures (American Academy of Periodontology, 2005).

Effective removal of dental plaque is essential to dental and periodontal health throughout life (see Löe, 2000). It is therefore recommended that promotion of oral health and prevention of these diseases require removal of dental plaque performed by toothbrushing with fluoride toothpaste twice a day, followed by interdental cleaning (e.g., flossing), improved nutrition and regular meals, and dental-professional plaque control (Kay & Locker, 1998; Löe, 2000; Marsh, 2006; Ramsay, 2000). Studies indicate that a significant proportion of people brush and floss their teeth less than recommended (Ramsay, 2000; Schüz, Sniehotta, Wiedemann, & Seemann, 2006).

The evidence concerning the effects of educational interventions (Watt & Marinho, 2005) has been inconsistent concerning change in dental behavior and clinical assessments of dental plaque and gingivitis. However, three recent interventions supplementing dental health education, with specific plans and commitments for dental behaviors, led to increases in flossing (Schüz, Wiedemann, Mallach, & Scholz, 2009) and toothbrushing (Clarkson, Young, Ramsay, Bonner, & Bonetti, 2009) over 8 weeks, and to more flossing and less dental plaque, but to no difference in gingivitis, over 3 months (Jönsson, Lindberg, Oscarson, & Öhrn, 2006).

Systematic reviews of the intervention literature (Kay & Locker, 1998; Watt & Marinho, 2005) showed improved oral health over the short term, but the evidence for long-term reductions in plaque and gingivitis is very limited. Further, none of the studies used self-determination theory (SDT) measures to examine mediating motivational processes, which is unfortunate, because other research has shown that changes mediated by autonomous (relative to controlled) motivation have been better maintained and accompanied by more positive affect (e.g., Williams, 2002). Thus, examining mediating variables for dental intervention effects would seem to be very important.

The present study tested whether an SDT-based intervention designed to promote dental care competence in an autonomy-supportive way, relative to standard care, as well as the personality variable of autonomy orientation, would increase recommended dental behaviors, decrease dental plaque, and improve oral health (viz, decrease gingivitis). It further examined whether autonomous motivation and perceived dental competence would mediate these relations.

Autonomous Orientation

Studies have shown that people high in the relatively stable autonomy orientation tend to be autonomously motivated and high in perceived competence for specific tasks (Williams, Grow, Freedman, Ryan, & Deci, 1996). Accordingly, the autonomy orientation is expected to predict people taking greater responsibility and showing more initiative for their dental home care behaviors if they understand the importance of the behaviors. Autonomy orientation is a personality-level factor that influences situational experiences, motivations, and behaviors (Vallerand, 1997), in addition to influences from the social context (e.g., dental professionals' support). Thus, regardless of what a dental professional might do, patients' autonomy orientation may also significantly affect their long-term changes in quality of motivation, dental competence, home care behaviors, and oral health. Studies in related fields provide support for some of these expectations. In a weight loss study among morbidly obese patients, autonomy orientation predicted autonomous treatment motivation after 5–10 weeks, which predicted program attendance and maintained reductions in body mass index at a final follow-up after 23 months (Williams et al., 1996). Related findings are also presented for physical exercise among working adults (Rose, Markland, & Parfitt, 2001). Thus, we hypothesized that autonomy orientation would be positively associated with change in autonomous motivation for both the dental project and dental home care, and with an increase in perceived dental competence.

Autonomy Support at the Dental Clinic

A central SDT prediction, which has been well supported, is that providing competence-relevant information in an autonomy-supportive context will facilitate autonomous motivation and perceived competence, which are critical for long-term behavior and health change (Deci & Ryan, 2000; Williams, 2002).

Autonomy support is defined, first, by dental professionals offering choice and encouraging self-initiation (Williams et al., 1996). Examples are dental professionals teaching patients to manage perceived pain during treatment by raising an arm to stop treatment and decide whether to proceed (Milgrom, Weinstein, & Getz, 1995). Self-initiation can also be facilitated by encouraging patients to ask questions about treatment options. Thus, being able to actively participate in their own treatment and consider proposals before they are implemented may increase patients' experiences of choice and volition, and may facilitate their autonomous treatment motivation and perceived dental competence (Halvari, Halvari, Bjørnebekk, & Deci, 2010).

Second, competence-promoting autonomy support involves dental professionals listening attentively to patient's disease history and perceived problems, and acknowledging their feelings and perspectives (Williams et al., 1996). This is theorized to minimize perceived pressure and threat, and to strengthen feelings of being understood and responded to at the clinic. It also includes dental professionals educating patients about oral health promotion and prevention of plaque-related diseases, and providing meaningful behavior-health contingencies related to patients' perceived problems or challenges. This entails providing rationales such as "brushing your teeth twice a day and flossing daily helps the gingiva and teeth stay healthy." (Halvari et al., 2010).

Third, dental professionals spending time demonstrating effective and adequate brushing and flossing skills on a model, allowing patients to exercise the skills in their own mouths, and providing positive and constructive feedback can strengthen patients' competence and help them carry out these behaviors. Past research in other domains has confirmed that this type of structure supports people's competence and autonomous engagement (e.g., Jang, Reeve, & Deci, 2010).

Even when activities are uninteresting (viz, are not enjoyable and are extrinsically rather than intrinsically motivated), as is the case for dental behavior, supporting participants' basic psychological needs for autonomy, competence, and relatedness has been shown experimentally to facilitate more autonomous motivation (Deci, Eghrari, Patrick, & Leone, 1994).

The Current Study

The current randomized clinical trial (RCT) has two groups in which patients met with a dental hygienist (DH) for a standard dental exam and subsequently had a standard teeth cleaning. The exam and the cleaning each took about 45 min. Accepted principles of ethics and promotion of informed choice (Beauchamp & Childress, 2001; Woolf et al., 2005) suggested that participants in both groups should be provided autonomy support. This decision was made because of results from a previous trial (Halvari & Halvari, 2006), which showed that providing autonomy support greatly improved oral health relative to the usual type of standard care. Thus, it seemed to us that it would no longer be ethical to not include autonomy support as part of standard care in the control group. As such, during the exam and cleaning, the DH was responsive, provided rationales, encouraged self-initiation, and emphasized choice in both groups.

The control group was viewed as having received usual care; however, because of ethical considerations, the emphasis on patient autonomy support in this clinic likely made this usual-care condition more autonomy supportive than would have been the case in other clinics. If that were so, it would make the test of the intervention more stringent than if usual care had been provided without the autonomy support, as the primary difference between the two groups would likely have been just the competence-enhancing intervention itself and/or any possible interaction between the intervention and the autonomy support.

The intervention lasted about 45 min and was given to participants in the experimental group between their examination and teeth cleaning (see Figure 1, illustrating the time line for measures and procedures). The intervention focused on providing meaningful information concerning dental health and disease; offering rationales for home care behaviors that are known to promote healthy teeth and gingival, and to prevent plaque-related diseases; and fostering oral care skills with education, demonstrations, and practice. As noted, this competence-promoting intervention was presented in an autonomy-supportive manner. We expected intervention patients to report greater perceived competence because they were becoming better equipped for their own oral home care, and we expected them to experience greater autonomy support because they interacted with the autonomy-supportive DH for a longer period of time.

The current clinical trial differs from a previous one (Halvari & Halvari, 2006), in part, because the control group received autonomy-supportive standard care. It is thus a more stringent comparison than in the previous trial. In the present study, the experimental group received a competence-enhancing intervention component in addition to the standard autonomy-supportive treatment, and this was compared to the standard autonomy-supportive treatment. Thus, the trial tested whether the additional autonomy-supportive contact, in which the competence-promoting structure was provided, would increase both autonomous motivation and perceived competence for oral home care. In addition, we included a measure of the patient personality variable of autonomous orientation as an independent predictor of their autonomous motivation toward the project as well as their autonomous motivation and perceived competence for oral home care.

To summarize, we tested whether an autonomy-supportive competence-promoting dental intervention—relative to autonomy-supportive standard care—would have positive effects on (a) perceived autonomy support and competence, (b) autonomous motivation for the project and for oral home care, and (c) dental behaviors, and also negative effects on plaque and gingivitis over 5.5 months.

The Self-Determination Theory Process Model of Change

Research showed that autonomy-supportive health care contexts facilitated perceived competence and autonomous motivation for health behavior change, which improved (a) morbidly obese patients' adherence to exercise and maintained weight loss over 23 months (Williams et al., 1996), and obese female participants' exercise and weight loss over 3 years (Silva et al., 2011); (b) long-term medication adherence (Williams, Rodin, Ryan, Grolnick, & Deci, 1998); (c) glycemic control for patients with Type 2 diabetes (Williams, McGregor, Zeldman, Freedman, & Deci, 2004); and (d) medication taking and 6-month tobacco cessation (Williams, McGregor, Sharp, Lévesque, et al., 2006) and 12-month prolonged tobacco abstinence (Williams, McGregor, Sharp, Kouides, et al., 2006).

In the dental field, two recent cross-sectional studies found positive links from autonomy support to autonomous motivation and perceived dental competence, which positively predicted dental behaviors, dental clinic attendance, and self-rated oral health, and negatively predicted not making a clinic appointment (Halvari et al., 2010; Halvari, Halvari, Bjørnebekk, & Deci, in press[a]). In a third study, motivational variables positively predicted valuing continued treatment, oral-health-related quality of life, self-rated oral health, and subjective dental well-being (Halvari, Halvari, Bjørnebekk, & Deci, in press[b]). An autonomy-supportive intervention (relative to a neutral control group) yielded increases over 7 months in the two motivation variables, which both enhanced dental behaviors and oral health (Halvari & Halvari, 2006).

In sum, the SDT process model hypothesizes that the intervention and the autonomous personality orientation would both positively predict autonomous motivation toward the project and changes in perceived dental competence, which would positively predict changes in dental behavior, and, in turn, would lead to decreased dental plaque and gingivitis over 5.5 months.

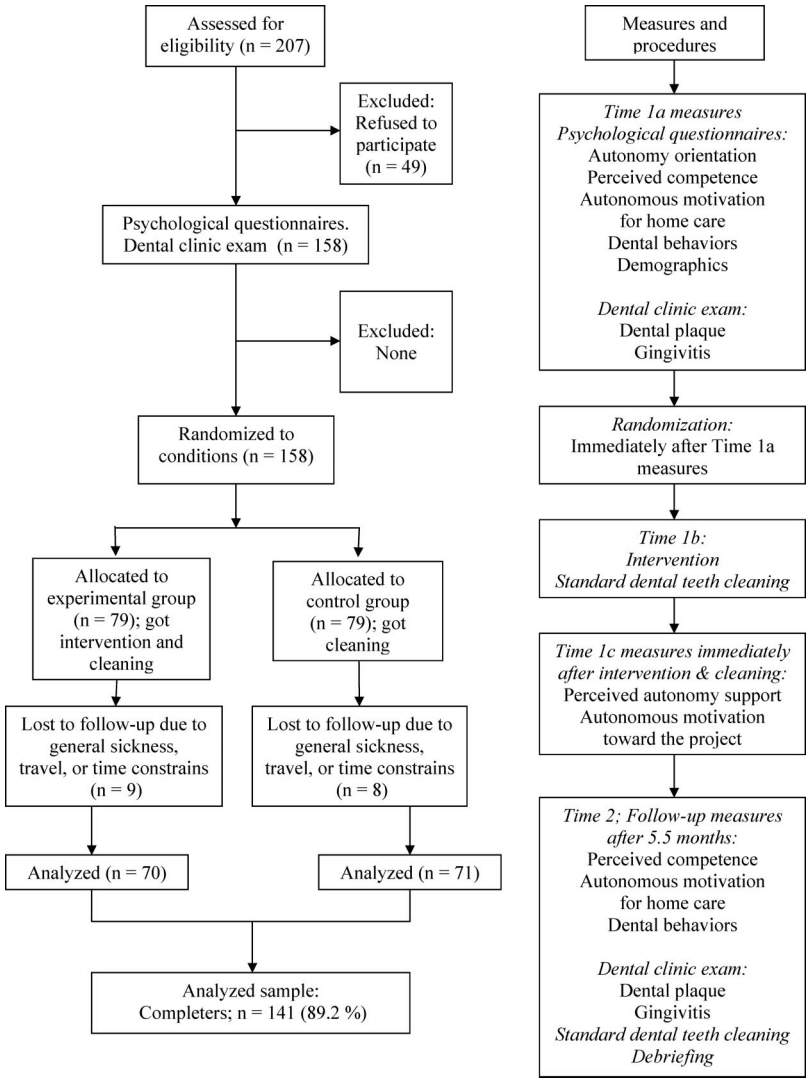

Figure 1. Study flowchart and time line for measures and procedures.

Method

Participants

Two hundred and seven potential participants from the University of Oslo indicated interest in the study on motivation and dental behavior after seeing a poster or being approached by the researcher (see the study flowchart in Figure 1). They were informed that they would get a free dental examination, a free dental cleaning, and a chance to win travel worth NOK kr10000 (about USD $1700). A power analysis using data from a previous study (Halvari & Halvari, 2006) indicated that the necessary number of participants in each group should be 14 for dental plaque, 18 for gingivitis, and 56 for perceived competence to detect significant differences (using *t* tests) between averages for the experimental and control groups with a power of .90 ($\alpha = .05$). Based on the power estimates and an unknown participant dropout from Time 1 to Time 2, 79 participants were randomly assigned to each condition and were considered to be sufficient. Of the 207 students, 158 (ages 18–32 years; 71% female) (a) showed up at the clinic, (b) did not have periodontal pockets ≥4.0 mm, as measured by a pocket probe, and/or serious bone loss visualized by digital X rays during the dental examination, (c) did not have significant additional oral or other diseases, (d) were not pregnant, (e) understood Norwegian, and (f) gave informed consent.

Experimental Procedures

A randomized two-group trial was conducted in a dental clinic. When participants first arrived at Time 1a (T1a; see Figure 1 for the time line of measures), they completed a survey assessing autonomy orientation, autonomous motivation for dental home care, perceived dental competence, dental behaviors, and demographics.

The standard oral examination. The exam lasted about 45 min for all participants, during which time T1a oral health vari-

ables were assessed. The DH was autonomy supportive when giving the information about the examination. The DH addressed an introduction to the exam (5 min); measures of dental plaque and gingivitis on all teeth surfaces (112 for patients with all teeth intact; 20 min); clinical and X-ray exam for caries (5 min); and pocket exam (5 min). The final dialogue lasted about 10 min and included information on how caries looks and how to detect it on patients' own X rays, and the importance of choice and self-initiation regarding treatment options in order to promote an informed basis for patient choice and decision making (Beauchamp & Childress, 2001). See Appendix A of the online supplemental materials for a full exam description.

Randomization. After the exam, 79 participants were randomly assigned to each condition. Immediately thereafter, a 45-min intervention took place for the experimental group, whereas control group participants went directly to a 45-min standard teeth cleaning. The experimental group received the cleaning after the intervention. The cleaning in both groups was done in an autonomy-supportive way.

The intervention at T1b. The DH started the intervention by asking participants about their perceived oral health and problems, and listening to and acknowledging their feelings and perspectives, before giving competence-related information about their perceived oral health and problems. Based on this conversation, the contents of the intervention were (a) education in plaque-related diseases such as gingivitis, periodontitis, and caries; (b) demonstrating effective brushing and flossing, with participants practicing these tasks and receiving positive feedback and corrections; (c) giving health promotion and disease preventive information, and offering rationales for the dental behaviors by explaining the relations of behaviors to disease prevention and health; (d) giving information about the value of fluorides and regular meals; and (e) offering choice and options concerning their dental home care. For a full description of the intervention, see Appendix B of the online supplemental materials.

The standard teeth cleaning at T1b. This 45-min cleaning was given to the control group after the exam and to the experimental group after the intervention. The DH focused on the importance of removing calculus in order to make participants' dental home care easier to perform. The cleaning made the baseline the same for both groups.

Finally, at T1c, all participants responded to questionnaires assessing perceived clinic autonomy support and autonomous motivation for the dental project.

At T2 (after 5.5 months), participants responded to all the same questionnaires completed before the teeth exam at T1a, except autonomy orientation and demographics, which were not included at T2. Then, the second teeth examinations were conducted by a different DH than the one for T1a. The second DH was blind to experimental conditions. After the exam, since the trial was finished, the DH uncovered the experimental conditions and control group participants were offered the intervention. Finally, the DH completed a standard teeth cleaning for both groups.

Completers Versus Dropouts

Of the 158 Participants, 9 dropped out of the experimental group and 8 dropped out of the control group from T1 to T2. Thus, 141 participants (89.2%) completed the study. We used logistic regression to predict study continuation from experimental conditions and the 8 variables measured at T1a and c, and analysis of variance (ANOVA) to analyze whether dropouts differed from completers on demographics (see time line for measures in Figure 1). Analyses indicated that dropout was not due to baseline or background characteristics. Among completers, the experimental and control groups were not significantly different in baseline measures (logistic regression), demographics, or in the time between T1 and T2 assessments (ANOVA). There were, however, significant gender differences in the make-up of the two groups, χ^2 (1, 141) = 7.12, $p < .01$, with more females (57.42%) in the control group than in the experimental group (42.58%), and more males (67.5%) in the experimental group than in the control group (32.5%). Thus, we controlled for gender in the subsequent multivariate analysis of variance (MANOVA).

Questionnaire Assessments

The scales for measuring motivation variables were found reliable in previous research: autonomy orientation ($\alpha = .70$, test–retest over 2 months = .73, Rose et al., 2001; $\alpha = .74$, test–retest over 2 months = .74, Deci & Ryan, 1985), autonomy support ($\alpha = .96$, Williams et al., 1996), autonomous motivation toward the dental project ($\alpha = .85$, Halvari & Halvari, 2006), perceived competence and autonomous motivation for home care (αs = .88 and .81, respectively, Halvari et al., 2010, in press[a]).

Autonomy orientation (T1a). Autonomy orientation was assessed with the Dental Care Autonomy Orientation Scale, adapted in the present study from the Exercise Causality Orientations Scale (Rose et al., 2001) and the General Causality Orientations Scale (Deci & Ryan, 1985). A sample of the five items used is, "Your dental professional has informed you about setting goals for your oral home care. How probable is it that you would set your own interesting and challenging goals?" Responses were on a 7-point Likert scale, from 1 (very unlikely) to 7 (very likely).

Perceived autonomy support (T1c). Perceived autonomy support was measured with the 6-item version of the Health Care Climate Questionnaire (Williams et al., 1996). A sample item is, "I feel that my dental professional has provided me choices and options in relation to my daily oral home care." Responded to on a scale of 1 (strongly disagree) to 7 (strongly agree), this measure indexed whether the intervention increased patients' perceptions of the clinic's autonomy support.

Autonomous motivation for the Dental Project (T1c). This aspect of the study was assessed by the Evaluation of Dental Project Scale (Halvari & Halvari, 2006). Four items focused on participants' interest, engagement, and curiosity toward the project. A sample item is, "In this project I have become more interested in my dental health." Responses were rated from 1 (not at all true) to 7 (very true).

Autonomous motivation for dental home care (T1a and T2). A 3-item identified subscale of the Self-Regulation for Dental Home Care Questionnaire (Halvari et al., in press[a]) measured autonomous motivation. A sample item is, "I do my dental home care because I think it is the best for me, and it is in my interest to do so." Participants responded on a 7-point Likert scale, ranging from 1 (not at all true) to 7 (very true).

Perceived dental competence (T1a and T2). This was assessed by the Dental Coping Beliefs Scale (Wolfe, Stewart, Meader,

& Hartz, 1996) using the five items with the best factor loadings (see Halvari & Halvari, 2006) and two added items from a previous study (Halvari et al., 2010). A sample item is, "I believe I can remove most of the plaque from my teeth on a daily basis." Responses were based on a scale of 1 (not true at all) to 7 (very true).

Dental health behavior (T1a and T2). Dental health behavior was assessed by a 4-item formative composite scale (Halvari et al., 2010). The items are (a) "I am very determined to brush my teeth as accurately as possible," using a 1 (not at all true) to 7 scale (very true), (b) "How often do you brush your teeth?" using responses from 1 (quite seldom) to 5 (3 times a day or more); (c) "How often do you use dental floss for cleaning the areas between your teeth" using responses from 1 (never) to 5 (daily); and (d) "How many regular meals do you have per day?" using responses from 1 (1 meal) to 5 (5 or more meals).

Oral Health Assessments (T1a and T2)

Dental plaque was assessed by the Dental Plaque Index (Löe, 1967, p. 613), and gingival inflammation and bleeding was assessed by the Dental Gingival Index (Löe, 1967, p. 610). These two indices are well accepted in the dental literature for measuring plaque and gingivitis (Clarkson et al., 2009; Jönsson et al., 2006). Both plaque and gingivitis were assessed on distal, buccal, mesial, and lingual tooth surfaces on all teeth except third molars. Thus, for the young sample in the present study, this implies, in most cases, that 112 surfaces were measured for each participant. A participant's scores were the sums for plaque and gingivitis, respectively, divided by the total number of surfaces measured. For the purpose of reliability estimation for plaque and gingivitis, we used the averaged scores of each of the four teeth quadrants as indicators, and used observations of plaque in the four teeth quadrants in modeling of latent indicators for plaque in Structural Equation Modeling (SEM).

Plaque (T1a and T2). The Dental Plaque Index (Löe, 1967) reflects soft deposits on the tooth surface and is anchored by a scale ranging from a score of 0 (absence of plaque) to 3 (abundance of soft matter within the gingival pocket and/or on the tooth and gingival margin).

Gingivitis (T1a and T2). The Dental Gingival Index (Löe, 1967) is anchored by scores ranging from 0 (absence of inflammation) to 3 (severe inflammation, marked redness and hypertrophy; tendency for spontaneous bleeding; ulceration.). An Explorer Periodontal double-ended Probe LM23-52B was used for all examination procedures.

Inter-Rater Reliability for Plaque and Gingivitis

Because the first DH (A) performed the measurements at T1a, and a second DH (B) performed the measurements at T2, interrater reliability for plaque and gingivitis were estimated (see the procedure used in Appendix C of the online supplemental materials). The Kappa inter-rater coefficient was .83 for plaque and .93 for gingivitis, both of which are considered good.

Results

Intervention Effects

The autonomy-supportive intervention at T1b was hypothesized to increase autonomous motivation for dental home care, perceived dental competence, and dental behavior, and to decrease plaque and gingivitis from T1a to T2. For measures used only at T1c (after the intervention), the intervention group, relative to the control group, was predicted to have higher scores on autonomous motivation for the project and perceived autonomy support. Means, standard deviations, and reliability coefficients for the variables are presented for measures at T1 and T2 in Appendix Table 1 of the online supplemental materials. Additional reliability and validity indices are given in the Self-Determination Theory Process Model section and in Figure 2. Repeated measures MANOVA was used to examine the hypothesis for perceived dental competence, autonomous motivation for dental home care, dental behavior, plaque, and gingivitis at T1a and T2, followed by five repeated measures ANOVAs. For the one-time measures, we used univariate ANOVA. For the MANOVA, the intervention versus control groups was the between-groups factor crossed with the five T1a and T2 assessments as the repeated measures factor. Gender was used as a covariate and was not significant as a main effect or interaction. The analysis yielded two significant main effects and one interaction: for condition, $F(5, 133) = 12.70$, $p < .001$, eta-squared = .32, Power = 1.0; for time, $F(5, 133) = 145.06$, $p < .001$, eta-squared = .84, Power = 1.0; and for the interaction of Condition × Time, $F(5, 133) = 55.31$, $p < .001$, eta-squared = .67, Power = 1.0. The effect was large for the interaction of Condition × Time, which indicates that the intervention group changed more from T1a to T2 than did the control group, thus supporting our experimental hypothesis. Because it was not significant, gender was not included in the ANOVAs.

Results of repeated measures ANOVAs (see Table 1) yielded four significant interactions of the intervention by time, which indicates, as expected, that the intervention, relative to the control group, resulted in increases of perceived competence and dental behavior, and decreases in dental plaque and gingivitis, from T1a to T2. For autonomous motivation for dental home care, the hypothesis was rejected. For variables that were measured only one time, univariate ANOVAs indicated that the intervention positively predicted perceived autonomy support and autonomous motivation toward the project.

Effect sizes (see Cohen's *d*, Table 1) on variables measured only at T1, and for the Intervention x Time interaction on variables measured at T1 and T2, were estimated after analysis of covariance (ANCOVA) of absolute difference or change, respectively, on the dependent variables. For the interactions, T1 measures of the dependent variable for the two groups (both mean-adjusted to zero) were used as covariates. The effect sizes were moderate for behavior, large for autonomous motivation for the project and perceived competence, and very large for autonomy support, plaque, and gingivitis (Cohen, 1992). Thus, the first hypothesis was supported for all variables except autonomous motivation for dental home care. In this ANCOVA, it is worth noting that there was a reduction in plaque in the control group ($M_{\text{diff T2 – T1}} = -0.39$, $SE = 0.03$; $t = -13.22$, $p < .001$; Cohen's $d = -1.39$, 95% CI [−1.60, −1.18]), although not so great as in the intervention group ($M_{\text{diff T2 – T1}} = -0.79$, $SE = 0.02$; $t = -39.78$, $p < .001$; Cohen's $d = -2.83$, 95% CI [−2.97, −2.69]), but an increase in gingivitis ($M_{\text{diff T2 – T1}} = 0.04$, $SE = 0.02$; $t = 2.70$, $p < .01$; Cohen's $d = 0.29$, 95% CI [0.07, 0.50]), a paradox that will be discussed below.

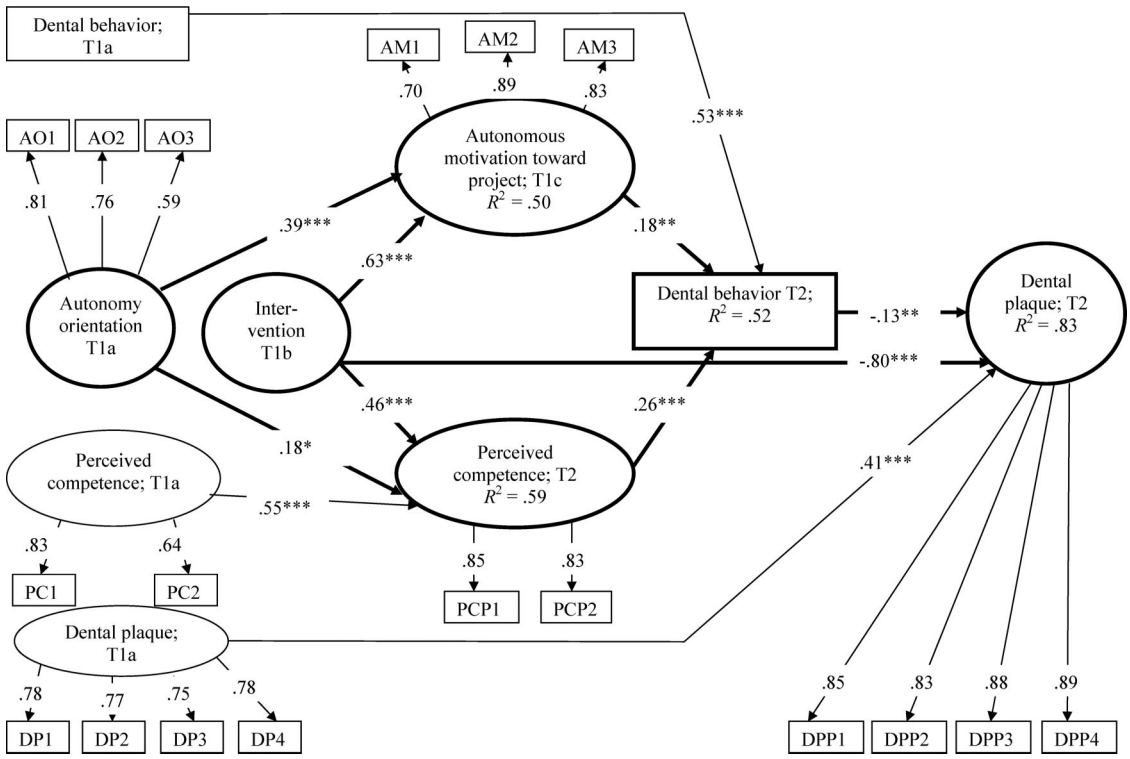

Figure 2. Standardized parameter estimates depicting the relations in the structural SDT Process Model of Dental Behavior and Dental Plaque. LISREL analysis with a combination of latent and observed variables, χ^2 (df = 171) = 267.21, $p < .001$; χ^2/df = 1.56; CFI = .95; IFI = .95; RMSEA = .06; SRMR = .063.* $p < .05$. ** $p < .01$. *** $p < .001$.

Correlations

The second hypothesis concerned expected links within the SDT-based process model. The zero order correlations in Appendix Table 2 of the online supplemental materials and the correlations among change scores in Table 2 are largely in line with the predictions. Notably, the strong correlation between the intervention relative to standard care and perceived autonomy support (r = .70; large effect size; Cohen, 1992) emphasizes the validity of the intervention content as being relatively more autonomy supportive. The correlations that were expected to be significant but were not are between autonomous motivation for dental home care and both the intervention-relative-to-standard-care variable and dental behavior, so autonomous motivation for home care did not play a role in predicting behavior and health outcomes. Thus, we explored whether the interaction of autonomous motivation toward the project and change in autonomous motivation for dental home care would be related to dental behavior. This interaction was significant, which indicated that people have to be high in autonomous motivation for the project in order for autonomous motivation for dental home care to affect behaviors (see the moderator analysis in the Moderator Analysis section). We did not include this interaction in the LISREL model (see Figure 2), instead using only autonomous motivation for the project, because the sample size was inadequate (Bollen, 1989); however, we did examine the interaction's indirect link to reduction in dental plaque through change in dental behavior by bootstrapping (see Moderator Analysis section).[1]

The Self-Determination Theory Process Model

LISREL (Version 8.72) was used to test the process model illustrated in Figure 2. Due to sample size limitations, this is a simplified model, omitting the interaction described in the previous paragraph and gingivitis. In addition, due to the number of variables and the high number of indicators per latent construct in relation to the sample size, we randomly assigned all items for each construct in 2–3 parcels, as recommended by Little, Cunningham, Shahar, and Widaman (2002). The constructs parceled were as follows: autonomy orientation (two parcels with two items each, plus one single item), autonomous motivation toward the project (one parcel with two items, plus two single items), and perceived competence at Times T1a and T2 (two parcels with four and three items, respectively, for both times). For dental plaque, four latent indicators were used both at times T1a and T2 (i.e., the sum of scores within each of the four teeth quadrants). The intervention and the 4-item formative composite measure of dental behavior were treated as observed variables, and the error variance was set to 15% of the squared standard deviation for these variables. As recommended for evaluating model fit in covariance structure analyses (Bollen,

[1] In addition, the interaction effects of autonomy orientation and the intervention on the motivation and behavior variables were tested. None of them was significant.

Table 1
ANOVA of Study Variables

Effect	*F*	Effect size Cohen's *d*[a]	95% CI Lower	95% CI Upper
Autonomy support (T1c)				
Intervention	148.98**	1.38	1.14	1.62
Autonomous project motivation (T1c)				
Intervention	52.68**	0.92	0.63	1.22
Perceived competence (T1a & T2)				
Intervention	4.30*	0.37	0.20	0.59
Time	46.11**	0.50	0.33	0.65
Intervention × Time	25.43**	0.79	0.50	1.07
Autonomous motivation for dental home care (T1a & T2)				
Intervention	0.23	−0.09	−0.26	0.10
Time	0.80	−0.08	−0.23	0.07
Intervention × Time	0.40	0.05	−0.24	0.34
Dental behavior (T1a & T2)				
Intervention	0.90	0.16	0.04	0.30
Time	35.33**	0.42	0.32	0.52
Intervention × Time	13.62**	0.45	0.22	0.68
Plaque (T1a & T2)				
Intervention	24.31**	−0.86	−0.81	−0.91
Time	628.79**	−2.01	−1.96	−2.06
Intervention × Time	81.24**	−1.44	−1.69	−1.19
Gingivitis (T1a & T2)				
Intervention	52.27**	−1.21	−1.18	−1.24
Time	110.77**	−0.71	−0.69	−0.75
Intervention × Time	210.41**	−2.26	−2.52	−2.00

Note. For autonomy support and autonomous project motivation measured at Time 1c, only the intervention effect is available. Degrees of freedom are 1, 141 for all ANOVAs.
[a] *d* = Difference or change given in *SD*; .20 = small, .50 = moderate, .80 = large (Cohen, 1992).
* $p < .05$. ** $p < .001$.

1989; Hu & Bentler, 1999), a good fit should have values for the Root Mean Square Error of Approximation (RMSEA) and the Standardized Root-Mean-square Residual (SRMR) close to or lower than .06 and .08, respectively, accompanied by values for the Comparative Fit Index (CFI) and the Incremental Fit Index (IFI) close to or higher than .95 (Hu & Bentler, 1999). The a priori measurement model yielded a good fit to the data, χ^2 (df = 137) = 258.48, $p < .001$; χ^2/df = 1.88; CFI = .96; IFI = .96; RMSEA = .075; SRMR = .051.

We improved this measurement model by following the LISREL modification indices suggested, and added positive error covariances between two sum-scores for dental plaque at Times T1a and 2, and between one parcel for perceived competence at Times T1a and T2. These suggestions were evaluated as meaningful because previous SDT research has shown these parcels or items to be strongly correlated (Halvari & Halvari, 2006). By doing so, the fit indices in the final measurement model, which was used in testing the structural model, were all very good, χ^2

Table 2
*Correlations Among the Intervention, Motivation Variables at Time 1, and Change[a] in Motivation, Behavior, and Health Variables (*N = *141)*

Variables	1.	2.	3.	4.	5.	6.	7.	8.
1. Autonomous orientation (T1a)	—							
2. Intervention (T1b)	−.02	—						
3. Perceived autonomy support (T1c)	.08	.70***	—					
4. Autonomous project motivation (T1c)	.30***	.46***	.52***	—				
5. Change in perceived competence (T1a – T2)	.19*	.40***	.33***	.32***	—			
6. Change in Autonomous Motivation for Dental Home Care (T1a – T2)	.22**	.03	.01	−.04	.22**	—		
7. Change in dental behavior (T1a – T2)	.17*	.32***	.15	.29***	.38***	.16	—	
8. Change in plaque (T1a – T2)	−.16	−.69***	−.43***	−.33***	−.33***	−.16	−.34***	—
9. Change in gingivitis (T1a – T2)	.00	−.82***	−.49***	−.26***	−.35***	−.08	−.25**	.75***

[a] Change scores (standardized residuals) were created by regression of T2 measures onto T1 measures.
* $p < .05$. ** $p < .01$. *** $p < .001$.

($df = 156$) = 184.49, $p = .059$; $\chi^2/df = 1.18$; CFI = .98; IFI = .98; RMSEA = .034; SRMR = .047.

Next, we proceeded by testing the SDT structural model, which yielded good fit indices, χ^2 ($df = 171$) = 267.21, $p < .001$; $\chi^2/df = 1.56$; CFI = .95; IFI = .95; RMSEA = .06; SRMR = .063. All of the hypothesized links were supported and are illustrated in Figure 2.

Tests of indirect associations. The bootstrapping procedure (Preacher & Hayes, 2008) tested the indirect associations appearing in Figure 2. Results indicated that all six indirect links (see Table 3) were significant because the bias-corrected 95% confidence intervals (for the bands of a*b path products of coefficients after *n* resamplings) did not include zero or oppositely valued coefficients. In two of the indirect links, a full mediation was indicated (i.e., links 1–2 in Table 3), because the C′ path between the independent and the dependent variable became nonsignificant after adding the mediator into the equation. The other indirect associations indicated partial mediation, because the independent variable did still predict the dependent variable after adding the mediator into the equation (see the C′ path in Table 3). Due to the sample size limitations mentioned, we could not include change in gingivitis in the structural model tested, but we used bootstrapping separately to test the indirect link between changes in behavior and gingivitis through change in dental plaque, which fully mediated the link (see Link 7 in Table 3).

Moderator Analysis

In a regression of change in dental behavior, the results yielded an additional explanatory power of 5% from entering the interaction of autonomous motivation toward the project and change in autonomous motivation for dental home care, F_{Change} (1,137) = 8.12, $p < .01$. This indicates that autonomous motivation for the project moderates the relation between autonomous motivation for home care and change in dental behavior (Cohen, Cohen, West, & Aikin, 2003). The estimated regression lines are illustrated in Figure 3. Change in autonomous motivation for dental home care strongly predicted positive change in behavior for participants whose autonomous motivation for the project was high, but not for participants whose autonomous motivation for the project was low. In bootstrapping, this interaction predicted change in dental behavior (point estimate = .04, $SE = .01$, $p < .01$), which predicted change in dental plaque (point estimate = −.32, $SE = .08$, $p < .001$). In addition, the indirect effect of this interaction on change in plaque through change in behavior was significant (point estimate = −.01, $SE = .006$, $Z = -2.04$, $p < .05$; 95% CI [−.03 to −.004]).

Discussion

The experimental test of the autonomy-supportive competence-enhancing intervention, relative to autonomy-supportive standard care, and the SEM test of the SDT process model of changes in dental behaviors and dental plaque received strong support. The intervention positively affected autonomous motivation for the project, as well as prompting increases in perceived dental competence and dental behaviors, and decreases in plaque and gingivitis, over a 5.5-month period. The intervention also led to higher perceived autonomy support at the visit relative to the standard care condition. The effect sizes (Cohen, 1992) were large or very large for all dependent measures, except for dental behaviors, which was moderate.

Regarding the SDT process model, both autonomy orientation and the intervention positively predicted autonomous motivation for the project and change in perceived dental competence, both of which increased dental behaviors and, in turn, reduced dental plaque. Separate analyses showed that change in dental plaque did fully mediate the negative link between change in dental behaviors and change in gingivitis. Correlation analyses also revealed that autonomy orientation predicted change in autonomous motivation for dental home care, which interacted with autonomous motivation for the project, in turn predicting change in dental behaviors and indirectly reducing plaque.

In Figure 2, full mediations were indicated in two out of the six indirect links tested: the links from autonomy orientation to dental behavior through both autonomous motivation toward the project

Table 3
Tests of Indirect Associations

Independent Variable (IV)	Mediator (M)	Dependent Variable (DV)	Point Estimate	*SE*	A*B-Path *Z*	Bootstrapping BC 95% CI Lower	Bootstrapping BC 95% CI Upper	C Path	C′ Path
Indirect associations emerging in Figure 2									
1. Autonomous orientation	→ Autonomous motivation	→ Change in behavior	.08	.04	2.37*	.03	.18	.18*	.10
2. Autonomous orientation	→ Change in competence	→ Change in behavior	.07	.04	1.97*	.02	.15	.22*	.15
3. Intervention	→ Autonomous motivation	→ Change in behavior	.16	.08	2.06*	.02	.36	.63***	.47***
4. Intervention	→ Change in competence	→ Change in behavior	.24	.08	2.98**	.12	.44	.58***	.34***
5. Autonomous motivation	→ Change in behavior	→ Change in plaque	−.06	.03	−2.41*	−.13	−.02	−.28***	−.22**
6. Change in competence	→ Change in behavior	→ Change in plaque	−.08	.04	−2.20*	−.16	−.02	−.32***	−.24**
Additional indirect link tested									
7. Change in behavior	→ Change in plaque	→ Change in gingivitis	−.25	.06	−3.99***	−.38	−.14	−.25**	.00

Note. Indirect pair of links with the same independent and dependent variables but different mediators were contrasted (i.e., the indirect links 1 – 2 and 3 – 4). None of these contrasts were significant. BC = bias corrected; 5000 bootstrap samples. A path = IV → M; B path = M → DV; C path = total effect of IV → DV; C′ path = IV → DV controlled for mediator.
* $p < .05$. ** $p < .01$. *** $p < .001$.

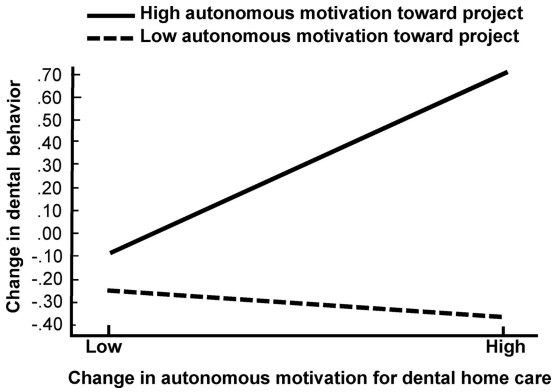

Figure 3. Simple regression lines depicting the relationship between autonomous motivation toward the project and change in dental behavior at specified values of change in autonomous motivation for dental home care.

and change in perceived dental competence. In addition, change in dental plaque did fully mediate the link from change in dental behavior to change in gingivitis (see Table 3).

One puzzling result of the ANCOVA indicated that control group participants showed a decrease in plaque but an increase in gingivitis. It is possible that the plaque decrease may be related to a phenomenon observed in the dental clinic field, namely, that patients exert extra effort in cleaning their teeth right before their clinic visit, which would remove plaque. If, at follow-up, these control group participants, who showed only a small increase in dental behaviors (Cohen's $d = .19$; 95% CI [.02 to .35]) relative to a large increase in the experimental group (Cohen's $d = .64$; CI [.48 to .80]), exerted extra effort they would have removed plaque without affecting the gingivitis that resulted from inadequate dental behaviors for the prior 5.5 months. If this were true, it would emphasize the importance of having a competence-enhancing intervention, such as the one in this trial, because it would indicate that just standard care, even if autonomy supportive, was not adequate to yield the desired outcome. Future research could shed further light on this.

An additional unexpected result was that the current intervention did not yield a change in autonomous motivation for dental home care, which, in turn, did not relate to change in dental behavior. Although we expected these to be significant, based on extrapolating from a previous study (Halvari & Halvari, 2006), it is worth noting that, in the previous study, the finding linked an autonomy-supportive intervention to autonomous motivation for treatment, which is essentially what was found here (viz, autonomous motivation for the project). Further, it is worth noting that the intervention did affect the interaction of the two types of autonomous motivation (for the project and for home care), such that the intervention affected autonomous motivation for home care in those participants who were high in autonomous motivation for the project but not those who were low in the latter. In turn, this interaction affected dental home behaviors. In short, this conveys that patients had to be autonomously involved with the project for it to affect their autonomous motivation for home care and, in turn, to change their home behaviors.

The links from the intervention to motivation, behaviors, dental plaque, and oral health variables were considered causal because the study was designed as a randomized controlled trial. This is very important in light of clinical experimental evidence concluding that effective plaque removal is causally linked to lifelong dental and periodontal health (see literature review by Löe, 2000). However, changes in motivation, behavior, plaque, and gingivitis were assessed at the same time, so we cannot conclude that the motivation variables produced the changes in dental behavior, plaque, and gingivitis.

The Relation of This Trial to a Previous One

The present randomized trial differed from a previous one (Halvari & Halvari, 2006) in that the previous one compared an autonomy-supportive intervention with usual care and found that the autonomy-supportive intervention led to improvements in motivation, oral health behaviors, and oral health. The fact that the autonomy-supportive intervention improved oral health relative to the usual type of standard care made it no longer ethical to use this standard care as a control group, so the current trial compared the competence-enhancing intervention administered in an autonomy-supportive way to standard care administered in an autonomy-supportive way. As such, the present trial added the important results that the competence-enhancing aspect of the intervention did in fact lead to more positive outcomes, relative to usual care, assuming that both were done in an autonomy-supportive way.

The idea of enhancing perceived competence for dental care bears some relation to increasing patients' self-efficacy for dental care, which focuses on strengthening efficacy expectations for targeted behaviors. However, in self-efficacy theory, the concept of supporting patients' autonomy is not included; indeed, Bandura (1989) claimed that autonomy is not important for behavior change. Yet in the current study, we found that autonomy support provided the backdrop for the competence-enhancing intervention to function effectively.

It is worth noting that the competence-enhancing intervention in the current trial was done during a 45-min period added on to the dental visit, relative to that received by the control group. Accordingly, this implies that the extra time devoted to competence enhancement was important for optimal motivation, because just making standard care more autonomy supportive led to less positive outcomes than adding the autonomy-supportive competence enhancement. The current study also indicated that the larger dose of autonomy support that accompanied the competence-enhancing intervention led to greater perceived autonomy support, relative to the control group, which would have received a smaller dose of autonomy support in the standard care.

That the competence-enhancing intervention, carried out in an autonomy-supportive way, increased motivation, behavior, and health is theoretically important because this field experiment confirms the results of a lab experiment showing that, for competence enhancement to increase autonomous motivation, an autonomy-supportive interpersonal context was necessary (Ryan, 1982).

Also different from the previous trial (Halvari & Halvari, 2006), this is the first dental study that examined the autonomy orientation (as well as autonomy support), and it significantly predicted autonomous motivation for the project and changes in perceived dental competence, and indirectly predicted changes in dental behaviors, which, in turn, predicted reduced dental plaque. Auton-

omy orientation is conceived as a relatively stable individual difference in which people's orientation toward a broad specter of dental health problems or dilemmas can be described by personal responsibility, proactive involvement, and effective coping. Thus, theoretically, patients are themselves active change agents who causally influence their autonomous motivation for treatment and home care, dental competence, and oral behaviors, and, consequently, their dental health. It is likely to be much easier for dental professionals to interact with patients who are high in autonomy orientation than with those who are low in this orientation.

The Trial's Clinical Relevance

The clinical relevance of this study derives from the fact that the 45-min competence-enhancing intervention, delivered in an autonomy-supportive way (see Appendix B of the online supplemental materials), produced reductions in plague and gingivitis, with very large effect sizes, over a 5.5-month period, relative to standard dental care carried out in an autonomy-supportive way. It thus has important implications for dental treatment and promotion of dental home care behaviors, as will be discussed below. As well, because it successfully promoted change in mundane health behaviors, it may also have implications for promoting other such behaviors including, for example, mammogram exams, blood sugar testing, blood pressure monitoring, and taking medications.

Traditionally, dental professionals have applied the biomedical model to patient care, an approach to individual oral health education based on paternalistic or expert information giving that has been largely ineffective (Yevlahova & Satur, 2009). In contrast, the biopsychosocial model and approach to patient care (Engel, 1977), when applied to dentistry, would involve dental professionals being emphatic, patient centered, and sensitive to patients' psychological and social needs. Such an approach is highly consistent with creating an autonomy-supportive health care context that is specified in SDT (Williams & Deci, 1996) and that, in the current and previous trials (Halvari & Halvari, 2006), yielded large positive effects on oral health.

From the SDT perspective, the important elements in the conversation between a dental professional and the patient to create the autonomy-supportive context are (a) listen to patients' perceived problems, encourage and be responsive to their questions, acknowledge their feelings and perspectives, and ask them what they want to achieve; (b) propose clear recommendations regarding patient-perceived problems and goals, but acknowledge that the patient does not have to accept the recommended changes; (c) explain, in a noncontrolling way that uses behavior-health contingencies, why recommendations or prescribed activities may be effective in solving perceived problems or attaining personal goals (i.e., provide meaningful rationales); (d) offer supervised exercises to master activities and achieve their goals; and (e) encourage patients to consider the different options and make their own choices about whether or not to endorse them.

Dental research has recently called for developing an effective model for chairside oral health promotion, because traditional approaches to such education have been shown to be largely ineffective (Yevlahova & Satur, 2009). The autonomy-supportive approach to competence enhancement, as examined in this study, seems to represent such an alternative.

Such intervention content could be offered to new patients, and some elements of it could be adapted to individuals' perceived oral health problems and repeated at regular intervals according to the individuals' wants and needs. Dental hygienists are licensed professionals specialized in oral disease prevention and oral health promotion and they normally use 30–45 min on a patients' visit. The approach tested in the present study could easily be integrated in the work of dental hygienists, perhaps by adding some time to the visit in order to give patients the opportunity to understand their oral health challenges. It could also give patients thorough information about how to relate to their own goals and strategies, thus helping to motivate and train them to develop disease-preventive and health-promoting behaviors.

Further, it seems that if dentists, who are specialized in technical skills and are normally procedure-oriented toward treatment of oral diseases, were 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 (Williams & Deci, 1996). In sum, then, the study suggests that if dental hygienists were to perform the intervention by adding some additional time, it would likely improve patients' oral health, and if dentists learned to be more autonomy supportive without increasing the length of visits, it might also help.

Conclusions

The current randomized clinical trial clearly showed that a competence-enhancing intervention, delivered in an autonomy-supportive manner, improved motivation, perceived competence, dental health behaviors, plaque, and gingivitis relative to standard-care treatment carried out in an autonomy-supportive way. Combined with a previous trial by Halvari and Halvari (2006), this emphasizes the importance of dental professionals relating to their patients in autonomy-supportive and competence-enhancing ways for patients' improved oral health.

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