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ORIGINAL ARTICLE

Use of nanomaterials in dentistry: covariates of risk and benefit perceptions among dentists and dental hygienists in Norway

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ABSTRACT

Objective: Focusing dentists and dental hygienists employed in the Public Dental Health Services (PDHSs) in Norway, this study set out to assess whether socio-demographic factors, familiarity with nanotechnology and social trust are associated with dental health care workers' perceived risks and benefits of use of nanomaterials in dentistry and whether those associations varied according to professional status. It was hypothesized that increased knowledge, trust in stakeholders and familiarity with nanomaterials would decrease the risk and increase benefit perceptions among dental health care workers.

Methods: Electronic questionnaires were administered to a census of 1792 dentists and dental hygienists.

Results: About 64% and 69% of respondents perceived respectively, risk and benefits associated with use of nanomaterials. Multiple variable logistic regression revealed that dentists were more likely than hygienists to perceive risks (OR = 1.9, 95% CI 1.1–3.3) and benefits (OR = 3.6, 95% CI 2.1–6.2). Having experience with dental nanomaterials (OR = 2.2, 95% CI 1.3–3.7) and feeling safe (OR = 6.6, 95% CI 3.1–14.2) increased perceived benefits. Having moderate or much correct knowledge about nanotechnology (OR = 2.3, 95% CI 1.5–3.5) increased the likelihood of perceived risk.

Conclusions: Policy makers should consider the factors that influence dental health care workers' risk and benefit perceptions associated with the use of nanomaterials in dentistry.

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Introduction

Nanotechnology has been integrated into peoples' everyday life and is considered to be known by the general public and stakeholders. However, this field is still highly innovative and new materials and technics at the nano-level continue to emerge steadily [1,2]. New applications of nanotechnology may create strong opinions from stakeholders and the public that promote or limit governmental funding for future research, as well as subsequent realization of technical advancements [3]. Therefore, consideration of stakeholders' and public's risk–benefit perceptions related to innovative nanomaterials is important at early stages of nanotechnology development.

Nanotechnology involves the manipulation of matters at the nanoscale, a size ranging from approximately 1 to 100 nm [4]. At nanoscale, particles behave differently and may display unique properties that open opportunities for the development of innovative products [5]. In dentistry, nanotechnology has a great variety of applications as components of dental materials to improve their properties. Nanoparticles are also used to improve oral hygiene products such as toothbrushes, toothpastes and mouth rinses [6,7].

Consumer products containing nanoparticles, such as new medicines, building materials and technological devices, may also display unexpected and unusual forms of toxicity [8–12]. Evidently, nanotechnology applications are associated with both benefits and risks [13]. Increasing use of nanomaterials in dentistry raises concerns about potential risks for occupational exposure to nanoparticles as well as about how to measure, communicate and manage risks for regulatory purposes. Considering agricultural applications, reviews have investigated occupational exposure to dusts containing ultrafine particles and respiratory toxicity from inhaling engineered nanomaterials [14,15]. Generally, there is a lack of toxicological data on real-life exposure to nanomaterials, exposure measurements and established occupational exposure limits, which creates concern regarding the use of nanotechnology and its potential adverse consequences for the individual and the environment.

Perceived risks and benefits of individual- and environmental consequences accruing from nano-applications have strong motivational impacts on behaviour, according to

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theoretical models [16]. In turn, information and knowledge about, as well as experience and familiarity with nanotechnology, may serve as a fundament for risk and benefit perceptions leading in the end to acceptance or opposition to this particular technology [17,18]. Moreover, attitude towards nanotechnology might be established and change over time as the public becomes familiar with its applications [17–19]. Some authors have claimed that increased knowledge about nanotechnology is associated with more optimistic views [20,21], while others did not find any association [18,22]. Van Giesen et al. [18] demonstrated in a longitudinal study that there was no change towards a positive attitude to nanotechnology over time, despite a concomitant but moderate increase in knowledge. Scientific literacy in general, rather than familiarity with nanotechnology specifically, was found to be an important predictor of positive attitudes [23]. A significant body of research demonstrated that trust in different actors is a strong predictor of peoples' risk–benefit judgements, indicating that stronger trust is associated with higher benefit and lower risk perceptions [21,23–26].

Several studies have confirmed differences in attitudes towards nanotechnology between experts and the general public, with experts being more likely to perceive benefits and less likely to perceive risks as compared to laypeople [23,27]. From this perspective, dental health care workers represent a unique group since dentistry was one of the first fields to benefit from nanotechnology by introducing nanoparticles in dental materials [4]. Thus, dental health care workers (i.e. dentists and dental hygienists) have experience with dental nanomaterials, which makes them more familiar with this technology compared to the general public. At the same time, they are not expected to have as much knowledge and skills as the nanotechnology experts. Nevertheless, dental health care workers' risk–benefit perceptions might play an important role in their acceptance and use of nanomaterials in dentistry. As dental health care workers have the opportunity to communicate risks and benefits of nanotechnology to their patients and policy makers, they are placed in a separate niche between laypersons and experts. Effective regulatory decisions require that policymakers understand dental health care workers' risk–benefit perceptions related to use of nanomaterials in dentistry.

Public attitudes towards and opinions about nanotechnology have been considered in several studies in the United States and Europe, as well as in some middle-income countries [28–31]. Most studies have examined perceptions towards nanotechnology in general as opposed to perceptions towards use of various nano-products, specifically. Yet, very little research is available regarding dental health care workers' risk–benefit perceptions related to the use of nanomaterials in dentistry.

Purpose

Focusing dentists and dental hygienists employed in the Public Dental Health Services (PDHSs) in Norway, this study set out to assess whether socio-demographic factors, familiarity with nanotechnology and social trust, are associated with dental health care workers' perceived risks and benefits of the use of nanomaterials in dentistry and whether those associations varied according to the professional status. It was hypothesized that increased knowledge, trust in stakeholders and familiarity with nanomaterials would decrease risk and increase benefit perceptions associated with application of dental nanomaterials among dental health care workers'.

Material and methods

A national, cross-sectional and electronically administered survey was conducted in March–May 2017, including a census of general dentists and dental hygienists employed in the PDHS in 18 (out of 19) counties in Norway. According to the Norwegian Statistical Agency, the proportion of dentist and dental hygienists working in PDHS comprise 31.3% and 54.2% out of all (public and private) Norwegian dentists and dental hygienists, respectively. There is a difference between public dentists and the total population of dentists in terms of gender with 24.7% of men and 75.3% of women working in the public sector versus 45.5% of men and 54.5% of women among total population of dentists. Gender distribution of dental hygienists working in PDHS is similar to the distribution in total population of dental hygienists. Names and e-mail addresses were recruited from the chief PDHS in 18 participating counties. One county was not included because of lack of support from the chief PDHS in that county. A link to the questionnaire containing informed consent, general information about the study and a brief balanced description of nanotechnology was distributed to the participants by e-mail. The Ombudsman, Norwegian Center for Research Data registered and approved (51053/3/AMS) the study, and was responsible for the distribution of questionnaires and collection of data. In order to ensure a reasonable response rate, three reminders were sent and respondents were invited to participate in a lottery with two iPads as incentives. All personal information was anonymized by the Norwegian Center for Research Data and the authors did not have access to it. The original questionnaire was developed on the basis of reviewing relevant literature [20,24,27–29]. The questionnaire was constructed in Norwegian and pilot-tested among dentists and dental hygienists ($n = 7$) working at one public dental clinic in Bergen.

Independent variables

Socio-demographic characteristics were assessed in terms of age, gender, employment status, work experience, place of education and county region.

Self-reported knowledge was assessed by asking 'How much knowledge do you have about the use of nanomaterials in dentistry?' Response categories ranged from (1) not at all to (5) very much. For analysis, the item was dichotomized into (0) no/little knowledge (including the original categories 1 and 2) and (1) moderate/much/very much knowledge (including the original categories 3–5).

Correct knowledge was assessed by nine statements. Three statements were assessed in terms of 'a. Nanoparticles are invisible for naked eye, b. Because of their small size, nanoparticles can penetrate cells and tissues easier compared to bigger particles of the same material, c. Nanoparticles can be more toxic compared to bigger particles of the same material'. Each statement was evaluated as (0) not correct/I don't know and (1) correct. Six statements were posed in terms of 'Nanoparticles are already used in a. toothpastes, b. mouth rinses, c. composites, d. adhesives, e. endodontic materials, f. impression materials' and evaluated as (0) no/I don't know and (1) yes. A sum score of correct knowledge was constructed (0–9) (Cronbach's alpha 0.686) and dichotomized into (0) no/little knowledge (including categories 0–4) and (1) moderate/much knowledge (including categories 5–9).

Amount of information on nanotechnology used in dentistry was assessed by asking 'How much information have you received regarding use of nanomaterials in dentistry?'. Response categories ranged from (1) no information to (5) very much information. This item was dichotomized into (0) no/little information received (including the original categories 1 and 2) and (1) moderate/much/very much information received (including the original categories 3–5).

Previous use of dental nanomaterials was assessed in response to the following question: 'Have you used dental nanomaterials for patient treatment?' (1 = yes, 2 = no, 3 = I don't know). The item was recoded into (0) no/I don't know and (1) yes for analysis.

Reading literacy was measured by two 6-point questions (1 = very often, 6 = never): (a) 'How often do you have difficulties to understand instructions following the package of dental materials?' and (b) 'How often do you need help to understand instructions following the package of dental materials?'. The items were recoded into (0) often – including originals categories 1–3 and (1) seldom – including original categories 4–6 and summed into an additive score (0–2). The final score (0–2) was dichotomized into low (0) and high (1–2) literacy.

Being worried about use of nanomaterials was assessed by the question: 'Are you worried about increasing use of dental nanomaterials?' (1 = yes, 2 = no, 3 = I don't know). The item was recoded into (1) yes and (0) no/I don't know for the analysis.

Safeness regarding use of nanomaterials was determined by one 7-point item (1 = agree very much, 7 = do not agree at all): 'It is safe to use dental nanomaterials for patient treatment'. The item was recoded into (1) safe (including original categories 1–3) and (0) not safe (including original categories 4–7) for the analysis.

Trust in stakeholders was measured using two 7-point items (1 = agree very much, 7 = do not agree at all): (a) 'Manufacturers ensure minimization of health risks associated with use of dental nanomaterials', (b) 'Politicians ensure minimization of health risks associated with use of dental nanomaterials'. The item was recoded into (1) agree (including original categories 1–3) and (0) do not agree (including original categories 4–7) and summed to an additive score (0–2), which was dichotomized into low (0) and high (1–2) trust.

Dependent variables

Benefits perception of nanotechnology was measured by an additive index of six 7-point items (1 = agree very much, 7 = do not agree at all). 'To use dental nanomaterials in the future is: a. a good idea; b. important; c. justifiable; d. reasonable with respect to treatment quality; e. valuable; f. Interesting'. Each item was dichotomized into (1) likely (original categories 1–3) and (0) unlikely (original categories 4–7) and summed to an additive index (0–6). Cronbach's alpha for this additive index was 0.912. The additive index was dichotomized to low (0) and high (1–6) risk perceptions.

Perceived risk of using nanomaterials in dentistry was measured as an additive index of six 7-point items (1 = very likely, 7 = very unlikely). 'If you use dental nanomaterials in the future, how likely is it that: a. you will cause harm to your health?; b. you increase your own risk of getting cancer?; c. you inhale nanoparticles?; d. you contribute to uncontrolled nanoparticle spreading?; e. you will cause harm to patient's health?; f. you contribute to environmental pollution?'. Each item was dichotomized into (1) likely (original categories 1–3) and (0) unlikely (original categories 4–7) and summed to an additive risk perception index (0–6). Cronbach's alpha for this additive index was 0.864. The additive index was dichotomized to low (0) and high (1–6) risk perceptions.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (IBM Corp., Released 2017, IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY). Descriptive statistics were performed in terms of frequencies with all independent and dependent variables. Bivariate analyses were conducted using cross-tabulations and Chi-square statistics. Multiple variable binary logistic regression analyses with odds ratios (ORs) and 95% confidence interval (95% CI) were conducted with the following outcome variables: (1) perceived benefits related to use of dental nanomaterials and (2) perceived risks related to use of dental nanomaterials. Two-way multiplicative interaction terms between professional status and other independent variables upon perceived risks and perceived benefits were tested for statistical significance. With respect to the large sample analysed which entails that even small differences can reach statistical significance, the significance level was set to 5%.

Results

The 2017 census of dental health care workers employed in the Norwegian PDHSs amounted to 1792 participants, of which 851 (570 dentists and 228 dental hygienists) responded to the present survey, providing a response rate of 47.5%. Table 1 depicts the socio-demographic characteristics of dental health care workers by professional status. As shown, all socio-demographic factors, except county region, discriminated significantly between dentists and dental hygienists. Of the respondents, 18.6% were males, 71.0% were dentists, 39.5% belonged to younger age group

Table 1. Sociodemographic factors by employment status in the total sample ($N = 851$).

	Dentists % (*n*) $n = 570$	Dental hygienists % (*n*) $n = 228$	Total % (*n*) $n = 798$[a]
Gender			
Male	25.6 (139)	1.4 (3)	18.6 (142)
Female	74.4 (404)	98.6 (218)**	81.4 (622)[a]
Age group			
22–35 years	44.8 (238)	26.6 (58)	39.5 (296)
36–55 years	36.0 (191)	37.6 (82)	36.4 (273)
56–70 years	19.2 (102)	35.8 (78)**	24.0 (180)[a]
Work experience			
≤5 years	28.2 (161)	19.3 (44)	25.7 (205)
6–20 years	44.7 (255)	43.4 (99)	44.4 (354)
>20 years	27.0 (154)	37.3 (85)*	29.9 (239)[a]
Place of education			
University of Olso	31.1 (176)	41.2 (94)	34 (270)
University of Bergen	28.3 (160)	35.1 (80)	30.2 (240)
University of Tromsø	9.2 (52)	14.5 (33)	10.7 (85)
Highschool in Norway	0.2 (1)	5.7 (13)	1.8 (14)
Foreign institution[b]	31.3 (177)	3.5 (8)**	23.3 (185)[a]
County region			
South-East	40.9 (233)	42.7 (97)	41.4 (330)
West	30.2 (172)	24.7 (56)	28.6 (228)
Middle-North	28.9 (165)	32.6 (74)[ns]	30.0 (239)[a]

*$p < .05$.
**$p < .001$.
ns: not significant
[a]Number of subjects do not comprise 851 in each question due to missing values.
[b]Foreign dentists who studied abroad and has gotten license to work in Norway.

(22–35 years) and 44.4% had work experience between 6 and 20 years. The distribution of dentists/dental hygienist (71.4% dentists/28.6% dental hygienists) among survey participants in this study corresponds to the distribution in the census of PDHS (71.1% dentists/28.9% dental hygienists). Moreover, the gender distribution among the participants (25.6% males/74.4% females among dentists and 1.4% males/98.6% females among dental hygienists) corresponds to the gender distribution in the census of PDHS (24.7% males/75.3% females among dentists and 1.9% males/98.1% females among dental hygienists).

Table 2 depicts the percentage distribution of independent and dependent variables by dental health care workers' professional status. Most variables, except for being worried about increasing use of nanomaterials and having interest in information about nanomaterials, differed statistically significantly according to professional status. Above half of the participants, 64.0% reported high perceptions of risk (69.1% dentists versus 50.6% dental hygienists, $p < .001$) and high perceived benefits, 68.5% (77.3% dentists versus 44.0% dental hygienists, $p < .001$). About half of the participants reported moderate/much/very much self-reported knowledge (60.4% dentists versus 23.3% dental hygienists, $p < .001$) and moderate/much correct knowledge (62.2% dentists versus 38.0% dental hygienists, $p < .001$). Moderate proportions of all participants confirmed previous use of dental nanomaterials (63.7% dentists versus 28.7% dental hygienists, $p < .001$). Minor proportions of dental health care workers reported to have high trust in stakeholders (39.3%), feeling safe to use (35.8%) and worry about increasing use of dental nanomaterials (20.5%).

Table 3 depicts the percentage distribution of participants reporting high benefit perceptions of using nanomaterials by socio-demographic and individual characteristics. Bivariate cross-tabulation analyses revealed that all independent variables, except being worried about increasing use of nanomaterials, were statistically significantly associated with perceived benefits. A multiple variable logistic regression model regressing high benefit perceptions on socio-demographic characteristics, knowledge, oral literacy, previous use of nanomaterials, worry, social trust and safety revealed ORs and 95% CI that ranged from 2.2 (95% CI 1.3–3.7) regarding previous use of dental nanomaterials to 6.6 (95% CI 3.0–14.2) regarding safety. Being a dentist, having previous experience with dental nanomaterials, high trust in stakeholders and feeling safe increased the odds of having high benefit perceptions related to use of nanomaterials in dentistry. The corresponding ORs (95% CI) were 3.6 (2.1–6.2), 2.2 (1.3–3.7), 2.6 (1.4–4.6) and 6.6 (3.1–14.2), respectively. Compared to participants with less than 5 years of work experience, those who reported 6–20 years of work experience were 0.3 times less likely, whereas those who had more than 20 years of experience were 0.4 times less likely to report benefit perceptions. No two-way interaction terms between professional status and independent variables were statistically significantly associated with perceived benefits in the multiple variable logistic regression model. Nagelkerke's R^2 was 0.423, implying that the final model including all independent variables explained 42.3% of the variance in benefit perceptions.

Table 4 depicts percentage distribution of participants reporting high perceived risk of using nanomaterials by socio-demographic and individual characteristics. Bivariate cross-tabulation analysis revealed that a number of independent variables, except for gender, work experience, reading literacy and safety to use nanomaterials, were statistically significantly associated with high risk perceptions. Regressing perceived risk of using nanomaterials on socio-demographic and individual characteristics of the participants revealed ORs and 95% CI in the range from 1.9 (95% CI 1.1–3.2) regarding employment status to 9.3 (95% CI 4.5–19.3) with respect to being worried about use of nanomaterials. Being a dentist, confirming to be worried about increasing use of nanomaterials and having high trust in stakeholders increased the likelihood for risk perceptions. The corresponding ORs were 1.9, 9.3 and 2.1, respectively. No two-way interaction terms between professional status and other predictors were statistically significantly associated with perceived risks in the multiple variable logistic regression model. Nagelkerke's R^2 was 0.266, implying that the final model with all independent variables explained 26.6% of the variance in risk perceptions.

Discussion

This study is among the first to provide evidence of risk–benefit perceptions related to the use of dental nanomaterials among dental health care professionals at a national level. The study aimed to gain information about covariates of risk–benefit perceptions, in terms of socio-demographic and individual characteristics of dentists and dental hygienists,

Table 2. Descriptive data on independent and dependent variables by professional status ($N = 851$).

	Dentists % (*n*) $n = 570$	Dental hygienists % (*n*) $n = 228$	Total % (*n*) $n = 798$[a]
Independent variables			
Self-reported knowledge			
Not at all/little	39.6 (223)	76.7 (165)	49.9 (388)
Moderate/much/very much	60.4 (340)	23.3 (50)**	50.1 (390)[a]
Correct knowledge			
Not at all/little	37.8 (170)	62.0 (111)	44.7 (281)
Moderate/much	62.2 (280)	38.0 (68)**	55.3 (348)[a]
Amount of received Information about nanotechnology in dentistry			
Not at all/little	63.9 (359)	85.7 (186)	70.0 (545)
Moderate/much/very much	36.1 (203)	14.3 (31)**	30.0 (234)[a]
Source of information			
University	83.6 (321)	68.6 (59)**	80.9 (380)
Books	61.9 (180)	43.3 (26)**	58.7 (206)
Journals	91.4 (352)	77.8 (70)**	88.8 (422)
Newspapers	16.6 (40)	14.3 (8)	16.2 (48)
Internet	70.8 (221)	70 (56)	70.7 (277)
TV	9.2 (21)	14.5 (8)	10.2 (29)
Radio	1.8 (4)	3.9 (2)	2.2 (6)
Colleagues	61.6 (186)	87 (80)**	67.5 (266)
Sales representative	68.1 (226)	64.7 (55)	67.4 (281)
Other	22.2 (53)	19.6 (10)	21.7 (63)
Reading literacy			
High	58.5 (330)	37.5 (81)	52.7 (411)
Low	41.5 (234)	62.5 (135)**	47.3 (369)[a]
Previous use of dental nanomaterials			
No/I do not know	36.3 (177)	71.3 (134)	46.0 (311)
Yes	63.7 (311)	28.7 (54)**	54.0 (365)[a]
Being worried about use of dental nanomaterials			
Yes	18.9 (85)	24.9 (42)	20.5 (127)
No/I don't know	81.1 (365)	75.1 (127)[ns]	79.5 (492)[a]
Safety to use nanomaterials			
Not safe	57.7 (256)	81.5 (137)	64.2 (393)
Safe	42.3 (188)	18.5 (31)**	35.8 (219)[a]
Trust in stakeholders			
Low	56.2 (246)	72.7 (120)	60.7 (366)
High	43.8 (192)	27.3 (45)**	39.3 (237[a]
Interest in information about nanomaterials			
Low	9.2 (40)	10.7 (18)	9.6 (58)
High	90.8 (397)	89.3 (150)[ns]	90.4 (547)[a]
Dependent variables			
Perceived benefits			
Low	22.7 (110)	56.0 (98)	31.5 (208)
High	77.3 (375)	44.0 (77)**	68.5 (452)[a]
Perceived risks			
Low	30.9 (135)	49.4 (83)	36.0 (218)
High	69.1 (302)	50.6 (85)**	64.0 (387)[a]

**$p < .001$.
ns: not significant
[a]Number of subjects do not comprise 851 in each question due to missing values.

such as knowledge, trust and experience related to the topic of nanotechnology. Overall, Norwegian dental health care workers appeared to have critically constructed and balanced risk- and benefit perceptions regarding the use of dental nanomaterials. About two-thirds of the participants targeted in this study, reported high-perceived benefits as well as high-perceived risks. The present findings confirmed that previous experience with nanomaterials, feeling safe to use such materials and having trust in stakeholders increased, whereas work experience decreased the likelihood of reporting benefit perceptions. Having correct knowledge about nanomaterials, being worried about the increasing use of nanomaterials and having high trust in stakeholders increased the likelihood of dental health care workers' risk perceptions. Surprisingly, dentists were more likely than dental hygienists to perceive both benefits and risks, also after adjusting for other demographic and individual characteristics in multiple variable regression models.

A major strength of this study is the use of a robust and nationally representative group of dental health care workers employed in the PDHS in Norway. This increases the likelihood that the present findings are generalizable to the targeted study population. A census of dentists and hygienists provided a response rate of 47% which was considered reasonable when compared to similar surveys in the field of nanotechnology, reporting response rates between 25% and 76% [18,25–27,32]. Questionnaires about nanotechnology have shown to be of lower interest to the general public mainly because people consider to have low knowledge to answer the questions. This leads to lower response rate than scientists could expect from an online survey. In accordance with the demography of PDHS employed dentists and dental

Table 3. Unadjusted and adjusted associations of benefit perceptions with socio-demographic and individual factors. Chi-square test and odds ratios (ORs) and 95% confidence interval (CI) (N = 851).

	% (*n*) Unadjusted	OR (95% CI) Adjusted Benefit perception
Gender		
Male	81.2 (108)	1
Female	65.5 (347)**	1.001 (0.508–1.971)
Employment status		
Dental hygienist	44.0 (77)	1
Dentist	77.3 (375)**	3.628 (2.102–6.260)**
Work experience		
≤5 years	78.5 (150)	1
6–20 years	64.5 (191)	0.315 (0.169–0.588)**
>20 years	63.8 (132)**	0.390 (0.196–0.775)*
Self-reported knowledge		
Not at all/little	56.6 (196)	1
Moderate/much/very much	79.5 (275)**	0.754 (0.430–1.323)
Correct knowledge		
Not at all/little	57.6 (152)	1
Moderate/much	77.7 (261)**	1.418 (0.849–2.367)
Previous use of dental nanomaterials		
No/I do not know	51.1 (155)	1
Yes	81.6 (307)**	2.166 (1.267–3.701)*
Reading literacy		
Low	42.3 (199)	1
High	57.7 (271)**	1.137 (0.695–1.862)
Being worried about use of dental nanomaterials		
No/I don't know	62.6 (82)	1
Yes	70.5 (347)	1.302 (0.745–2.276)
Safety to use nanomaterials		
Not safe	54.6 (215)	1
Safe	93.3 (208)**	6.606 (3.063–14.248)**
Trust in stakeholders		
Low	54.6 (202)	1
High	89.4 (210)**	2.575 (1.433–4.629)*
R^2		0.423

*$p < .05$.
**$p < .001$.

hygienists in Norway, larger proportions of females and younger aged individuals participated in the present study. Moreover, a larger proportion of females were present among dental hygienists than among dentists. This is consistent with the corresponding sex distribution of dental health care workers in the PDHS in Norway and support the external validity of this study. Evidence suggests that relying on single item measures might lead to invalid inference of public risk–benefit perceptions related to potentially unfamiliar technologies [33]. A strength of this study is the use of multi-item measures of risk–benefit perceptions theoretically derived from the dentistry context. Multiple indicators of risk benefit perceptions showed satisfactory internal consistency reliability and might overcome validity shortcomings associated with single item measures.

Some weaknesses of the present findings need to be addressed. First, the data utilized are based on self-administered questionnaires and the study included dental health care workers who volunteered to participate. Thus, the findings might be subject to measurement and selection bias. It might be argued, however, that anonymous self-reports are more reliable than personal interview data, as respondents are less prone to pressure of social demand emanating from face-to-face conversation with research assistants [34]. Thus, self-administered questionnaires are valid means of obtaining information about cognitions and health behaviours and thus are common in epidemiological surveys. Second, although the data were collected through individually distributed questionnaires to dentists and dental hygienists, they might have discussed their opinion with their peers and consulted leaders for guidance [22]. This might have influenced the risk–benefit perceptions of the participants employed in the same clinic. That said, the present findings await corroboration from those of future studies of dental health care workers' risk–benefit perceptions conducted in different settings. Finally, the present study is limited by its cross-sectional design, assessing risk–benefit perceptions and its presumed socio-demographic and individual antecedents at the same time. This makes it difficult to determine the direction of associations between variables. Studies of risk- and benefit perceptions related to nanotechnology with a prospective design represent a promising direction for future research in this field.

Professional status was associated significantly with both risk and benefit perceptions, being the most important socio-demographic covariate identified in this study. Thus, dentists were most likely to perceive both high risks and benefits accruing from use of dental nanomaterials. A possible explanation could be that dentists and dental hygienists are using different materials, with dental hygienists handling a significantly narrower range of dental materials compared to dentists. Additionally, there is a difference in the length of education with dentists having 5-years master and dental hygienists a 3-years bachelor degree. Although demographic

Table 4. Unadjusted and adjusted associations of risk perceptions with socio-demographic and individual factors. Chi-square test and odds ratios (ORs) and 95% confidence interval (CI) (N = 851).

	% (*n*) Unadjusted	OR (95% CI) Adjusted Risk perception
Gender		
Male	64.8 (122)	1
Female	63.9 (308)	1.276 (0.731–2.229)
Employment status		
Dental hygienist	50.6 (85)	1
Dentist	69.1 (302)**	1.947 (1.116–3.251)*
Work experience		
≤5 years	64.3 (108)	1
6–20 years	65.5 (182)	1.091 (0.660–1.803)
>20 years	63.3 (119)	0.818 (0.457–1.465)
Self-reported knowledge		
Not at all/little	59.7 (197)	1
Moderate/much/very much	70.3 (213)*	1.018 (0.622–1.665)
Correct knowledge		
Not at all/little	52.4 (131)	1
Moderate/much	75.3 (226)**	2.272 (1.469–3.515)**
Previous use of dental nanomaterials		
No/I do not know	53.6 (156)	1
Yes	73.8 (253)**	1.533 (0.935–2.513)
Reading literacy		
Low	48.9 (200)	1
High	51.1 (209)	0.820 (0.531–1.269)
Being worried about use of dental nanomaterials		
No/I don't know	91.0 (122)	1
Yes	57.4 (286)**	9.315 (4.507–19.254)**
Safety to use nanomaterials		
Not safe	62.4 (252)	1
Safe	68.6 (153)	0.741 (0.435–1.261)
Trust in stakeholders		
Low	59.3 (224)	1
High	73.1 (174)**	2.061 (1.262–3.368)*
R^2		0.266

*$p < .05$.
**$p < .001$.

characteristics have not been among the key predictors of nanotechnology perceptions, previous studies have shown that people with higher level of education tend to have the most positive opinions about nanotechnology [21,23]. Similarly, Anderson et al. [35] demonstrated that laypeople with higher-level science degree reported more support for nanotechnology compared to respondents with lower education. As shown in Table 1, dental hygienists were older than the dentists, had longer work experience and less knowledge about the topic of nanotechnology. According to the present findings, dental health care workers with less work experience were most likely to report benefit perceptions. We assumed that participants with less work experience are also those who have newly graduated and might have become familiar with dental nanomaterials during their education both theoretically and practically. Inconsistent with the present findings, previous studies have shown that older respondents tend to have more positive attitudes towards nanotechnology than the younger ones although the association is not always strong [21,23,27]. Also, at odds with previous studies reporting women to consider dental nanomaterials as being more hazardous than men do, the present study did not reveal any strong effect of gender on dental health care workers' risk–benefit perceptions [23,24,26,36].

Only half of the respondents, and dentists more frequently than dental hygienists, confirmed moderate/much knowledge about the use of nanomaterials in dentistry as assessed by a global single-item and a multi-item knowledge test. This is consistent with a review of Satterfield et al. [21], synthesizing surveys regarding the publics' self-reported awareness and showing that half of the respondents in the reported studies had no familiarity with nanotechnology. Consistent with some previous surveys but at odds with others, this study did not support the idea that increased knowledge about dental nanomaterials is associated with more benefit and less risk perceptions [21,37]. Thus, whereas some authors claim that greater familiarity with nanotechnology has a positive association with benefits perceptions and negative association with risk perceptions; others suggest that better knowledge does not have an effect on risk–benefit judgement or may lead to polarized opinions [21,22,37]. This study indicated that dental health care workers with more correct knowledge were more likely to have high risk perceptions, whereas health care workers confirming previous use of dental materials were most likely to confirm high benefit perceptions. A positive association between previous use of nanomaterials and benefit perceptions might reflect that dental health care workers did benefit from previous use of nanomaterials and thus were more supportive compared to those who had not or did not know if they had used nanomaterials previously.

Evidence suggests that public responses to emerging technologies, such as nanomaterials in dentistry, are mostly

driven by affect (emotions) and less by cognition (beliefs) [18]. This study supports this hypothesis since benefit perception was strongly associated with feeling safe to use nanomaterials while high risk perception was associated with high level of worry. The present study also adds to the previous ones demonstrating that trust in stakeholders was an important covariate of benefit perceptions. Numerous studies have shown that higher trust in different parties, such as scientists, business leaders, manufacturers, politicians and journalists, is associated with higher benefit- and lower risk perception [21,23–26,37].

Conclusions

About half of the Norwegian dental health care workers investigated in this study had high risk and benefit perceptions related to the use of nanomaterials. Feeling safe to use nanomaterials and being worried about increasing use were the strongest covariates of perceived benefits and perceived risks, independent of professional status. Policy makers should consider socio-demographic and individual covariates of dental health care workers' risk–benefit perceptions in order to provide reliable and balanced information about the current status of nanotechnology.

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Disclosure statement

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