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Research Article

Cancer Prevention Research

Examining the Association between Oral Health and Oral HPV Infection

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Abstract

Oral human papillomavirus (HPV) infection is the cause of 40% to 80% of oropharyngeal cancers; yet, no published study has examined the role of oral health in oral HPV infection, either independently or in conjunction with other risk factors. This study examined the relation between oral health and oral HPV infection and the interactive effects of oral health, smoking, and oral sex on oral HPV infection. Our analyses comprised 3,439 participants ages 30 to 69 years for whom data on oral HPV and oral health were available from the nationally representative 2009–2010 National Health and Nutrition Examination Survey. Results showed that higher unadjusted prevalence of oral HPV infection was associated with four measures of oral health, including self-rated oral health as poor-to-fair [prevalence ratio (PR) = 1.56; 95% confidence interval (CI), 1.25–1.95], indicated the possibility of gum disease (PR = 1.51; 95% CI, 1.13–2.01), reported use of mouthwash to treat dental problems in the past week (PR = 1.28; 95% CI, 1.07–1.52), and higher number of teeth lost ($P_{trend} = 0.035$). In multivariable logistic regression models, oral HPV infection had a statistically significant association with self-rated overall oral health (OR = 1.55; 95% CI, 1.15–2.09), independent of smoking and oral sex. In conclusion, poor oral health was an independent risk factor of oral HPV infection, irrespective of smoking and oral sex practices. Public health interventions may aim to promote oral hygiene and oral health as an additional measure to prevent HPV-related oral cancers. *Cancer Prev Res; 6(9); 917–24.* ©*2013 AACR.*

Introduction

Oral infection by high-risk (i.e., oncogenic) human papillomavirus (HPV) types, predominantly HPV-16, is an established cause for 40% to 80% of oropharyngeal cancers in the United States (1). Recent increases in the incidence of HPV-positive oropharyngeal cancers in the United States and worldwide (2–8), particularly among young people who neither smoke nor drink have been attributed to changes in sexual behavior such as increased oral sex, which may expose individuals to oral HPV infection (1, 3, 4, 9). The prevalence of HPV in healthy oral mucosa (10, 11) ranges from 1.3% to 9.2%, with high-risk HPV-16 the most common type (10, 12, 13). Gillison and colleagues reported an HPV prevalence of 10.1% for men and 3.7% for women in the general United States population; (12) the prevalence of HPV-16 was 1%. Overall HPV prevalence was associated with oral sex, number of lifetime sex partners, and current number of cigarettes smoked per day (10, 12–14).

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Poor oral hygiene and oral health, measured by such indicators as frequency of tooth brushing or tooth loss, are also recognized risk factors for oral and oropharyngeal cancers, both independently and synergistically with tobacco and alcohol use (4). However, it is unknown whether poor oral health may indirectly increase the risk of oropharyngeal cancers by partially elevating the odds of oral HPV infection. We found no previous study that examined the relationship between oral HPV infection and oral health. It is unclear whether poor oral health may increase the risk of oral HPV infection (e.g., by creating a facilitating environment that allows for an epithelial entry point for HPV) or whether good oral health may compensate for the risk attributable to smoking or oral sex. Addressing these questions is important because these behavioral risk factors for oral oncogenic HPV infection are modifiable and preventable. Thus, this study's aims are two-fold: to examine the relationship between oral HPV infection and oral health, and to examine the interactive effect of oral health, smoking, and oral sex on oral HPV infection.

Materials and Methods

Data

Our analyses used data from the 2009–2010 National Health and Nutrition Examination Survey (NHANES) conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention. This stratified, multistage, probability sampling survey comprised interviews,

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medical and dental examinations, and laboratory tests to monitor a variety of health topics in the United States population. Overall response rates were 79.4% for the interviewed sample and 77.3% for the examination sample. Further information is available on the NHANES website (15).

Measures

Oral HPV infection. Specimens were collected by oral rinse (16). Oral HPV results were coded as positive if any of the 19 low-risk [6, 11, 40, 42, 54, 55, 61, 62, 64, 67, 69, 70, 71, 72, 81, 82 subtype IS39, 83, 84, 89 (cp6108)] and 18 high-risk (16, 18, 26, 31, 33, 35, 39, 45, 51, 52, 53, 56, 58, 59, 66, 68, 73, 82) HPV DNA types were detected by multiplex PCR (Roche Linear Array HPV Genotyping Test). We used both high-risk and low-risk data because two of our predictors of interest (oral sex and smoking) were similar for both groups in previous reports (12).

Oral health. Four measures assessed oral health. Self-rating of overall oral health, whether participants thought they might have gum disease and use of mouthwash to treat dental problems in the past 7 days came from the oral health questionnaire, which was administered through in-home computer-assisted personal interviewing for participants ages 30 years or older. Number of teeth lost was calculated from tooth count data gathered during the oral health examination conducted by registered dental hygienists.

Sociodemographic and behavioral variables. Given that our primary outcome was oral HPV infection, we only examined covariates that could be confounders, based on the literature and a report by Gillison and colleagues (12). These included age, sex, race/ethnicity, education, income-to-poverty ratio, marital status, alcohol use, marijuana use, cigarette use, and oral sex (Tables 1, 2). Data for substance use and oral sex were collected through a self-administered

Table 1. Comparison of characteristics of included versus excluded participants in this analysis

Characteristics	Total cohort of participants who have evaluable samples for oral HPV testing Total (%)	Participants included in analysis (i.e., with available self-reported oral health data) *n* (%)	Participants excluded (i.e., without self-reported oral health data) *n* (%)	*P*
Total	4,846	3,439 (71.0)	1,407 (29.0)	
Age, y				0.001[a]
<30	1,256 (25.4)	—	1,256	
30–39	897 (19.1)	877 (26.0)	20 (14.1)	
40–49	977 (21.5)	951 (29.0)	26 (23.3)	
50–59	855 (20.2)	823 (27.1)	32 (26.5)	
60–69	861 (13.8)	788 (17.8)	73 (36.1)	
Sex				0.469
Male	2,385 (49.6)	1,713 (49.4)	672 (50.2)	
Female	2,461 (50.4)	1,726 (50.6)	735 (49.8)	
Race/ethnicity				0.000
Mexican American	1,012 (9.6)	676 (8.3)	336 (12.8)	
Other Hispanic	549 (5.5)	407 (5.3)	142 (6.0)	
White, non-Hispanic	2,073 (65.5)	1,527 (68.5)	546 (57.9)	
Black, non-Hispanic	931 (12.0)	645 (11.3)	286 (13.7)	
Other race	281 (7.4)	184 (6.6)	97 (9.6)	
Education				0.560
Less than high school	1,233 (17.6)	956 (17.5)	277 (18.1)	
High school or equivalent	1,031 (22.1)	750 (21.5)	281 (23.8)	
Some college or higher	2,291 (60.3)	1,726 (61.0)	565 (58.1)	
Income-to-poverty ratio[b]				0.000
<1.0	1,075 (15.7)	628 (11.6)	447 (26.3)	
≥1.0–<2.0	1,197 (19.2)	827 (18.0)	370 (22.1)	
≥2.0–<3.0	567 (14.0)	413 (13.7)	154 (14.9)	
≥3.0	1,549 (51.1)	1,237 (56.7)	312 (36.7)	
Marital status				0.000
Never married	953 (20.6)	408 (10.5)	545 (50.4)	
Married/living with partner	2,772 (64.3)	2,278 (71.2)	494 (43.8)	
Widowed/divorced/separated	834 (15.1)	750 (18.2)	84 (5.7)	

[a]*P* value was calculated using logistic regression, with the age group of less than 30 years excluded.
[b]Index for the ratio of family income-to-poverty threshold, specific to family size, year, and state.

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Table 2. Unadjusted prevalence of oral HPV infection and overall oral health by sociodemographic and behavioral characteristics[a]

Characteristics	Total unweighted counts (unweighted counts of HPV infection)	% HPV-positive (95% CI)	Unadjusted PRs (95% CI)	Self-rated oral health as poor-to-fair, *n* (%)
Total	3,439 (296)	7.5 (6.0–9.3)		3,439
Age, y				
30–39	877 (70)	6.4 (4.5–9.0)	1	282 (25.9)
40–49	951 (64)	6.5 (4.8–8.8)	1.02 (.60–1.73)	344 (27.9)
50–59	823 (90)	9.4 (6.5–13.4)	1.47 (.84–2.56)	309 (29.8)
60–69	788 (72)	7.6 (5.4–10.6)	1.19 (.75–1.89)	267 (22.8)
P (*P* trend)		0.171 (0.174)		0.038 (0.039)
Sex				
Male	1,713 (227)	11.7 (9.0–15.1)	3.51 (2.40–5.15)	616 (28.9)
Female	1,726 (69)	3.3 (2.5–4.5)	1	586 (25.2)
P		<0.001		0.030
Race/ethnicity				
Mexican American	676 (54)	8.1 (5.9–11.0)	1.17 (.72–1.90)	335 (48.3)
Other Hispanic	407 (36)	8.7 (5.6–13.2)	1.25 (.67–2.34)	150 (34.4)
White, non-Hispanic	1,527 (115)	6.9 (4.8–9.9)	1	423 (22.4)
Black, non-Hispanic	645 (83)	11.3 (7.6–16.5)	1.64 (.94–2.85)	240 (36.1)
Other race	184 (8)	5.0 (2.1–11.0)	0.72 (.27–1.94)	54 (26.7)
P		0.201		<0.001
Education				
Less than high school	956 (94)	8.9 (7.2–10.9)	1.38 (0.87–2.19)	506 (48.6)
High school or equivalent	750 (79)	9.3 (6.9–12.5)	1.45 (1.01–2.07)	285 (34.5)
Some college or higher	1,726 (123)	6.4 (4.5–9.1)	1	409 (18.2)
P		0.088		<0.001
Income-to-poverty ratio[b]				
<1.0	628 (81)	12.2 (10.7–14.0)	1.89 (1.20–2.98)	325 (49.2)
≥1.0 to <2.0	827 (77)	8.6 (6.3–11.7)	1.23 (0.71–2.16)	363 (41.3)
≥2.0 to <3.0	413 (31)	7.0 (5.0–9.7)	1.09 (0.77–1.53)	137 (26.9)
≥3.0	1,237 (81)	6.5 (4.2–9.8)	1	251 (18.1)
P (*P* trend)		0.073 (0.062)		<0.001 (<0.001)
Marital status				
Never married	408 (41)	9.4 (5.9–14.7)	1	160 (32.6)
Married/living with partner	2,278 (176)	6.7 (5.0–8.9)	.72 (0.40–1.28)	750 (25.4)
Widowed/divorced/separated	750 (79)	9.4 (7.0–12.6)	1.00 (0.55–1.82)	291 (30.3)
P		0.241		0.031
Cigarette smoker[c]				
Never/former	1,849 (106)	5.2 (3.4–7.8)	1	554 (25.1)
Current, ≤10 cigarettes/d	446 (67)	12.1 (8.7–16.4)	2.34 (1.35–4.04)	205 (41.7)
Current, >10 cigarettes/d	343 (52)	14.7 (10.5–20.4)	2.85 (1.80–4.53)	194 (55.3)
P (*P* trend)		<0.001 (<0.001)		<0.001 (<0.001)
Alcohol use in past year, average, number of drinks/week				
0	897 (78)	8.4 (5.8–12.0)	1	362 (31.9)
<1	972 (59)	5.1 (3.8–6.9)	0.61 (.42–.88)	315 (24.7)
1–7	831 (63)	6.3 (4.9–8.1)	0.75 (.55–1.02)	252 (23.7)
>7	470 (66)	12.5 (9.3–16.7)	1.49 (1.12–1.98)	180 (29.2)
P (*P* trend)		0.002 (<0.001)		0.009 (0.009)
Marijuana use[d]				
Never	1,185 (70)	4.8 (3.6–6.2)	1	429 (28.1)
Former	944 (89)	8.3 (5.7–11.9)	1.75 (1.08–2.81)	290 (23.8)
Current	243 (36)	14.3 (10.4–19.4)	3.01 (2.21–4.10)	118 (42.7)
P (*P* trend)		<0.001 (<0.001)		0.001 (0.001)
Ever conducted oral sex[e]				
No	665 (38)	4.7 (3.0–7.2)	1	262 (31.8)
Yes	2,398 (224)	8.0 (6.2–10.4)	1.71 (0.99–2.97)	799 (25.7)

(Continued on the following page)

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Table 2. Unadjusted prevalence of oral HPV infection and overall oral health by sociodemographic and behavioral characteristics[a] (Cont'd)

Characteristics	Total unweighted counts (unweighted counts of HPV infection)	% HPV-positive (95% CI)	Unadjusted PRs (95% CI)	Self-rated oral health as poor-to-fair, *n* (%)
P		0.040		0.011
Number of lifetime oral sex partners[e,f]				
0	665 (38)	4.7 (3.0–7.2)	1	262 (31.8)
1	487 (21)	3.5 (1.9–6.4)	0.77 (0.34–1.76)	172 (28.3)
2–5	925 (68)	5.6 (4.2–7.5)	1.20 (0.80–1.79)	308 (25.5)
6–10	259 (30)	10.5 (6.7–16.2)	2.24 (1.06–4.73)	84 (25.9)
11–20	154 (23)	13.3 (7.6–22.3)	2.84 (1.48–5.44)	50 (26.8)
≥21	135 (37)	25.7 (14.6–41.3)	5.50 (2.49–12.12)	54 (33.7)
P (*P* trend)		<.001 (<.001)		0.353 (.355)
Number of oral sex partners in past year[e,f]				
0	1,205 (73)	4.8 (3.7–6.1)	1	462 (30.2)
1	1,168 (103)	8.3 (6.4–10.8)	1.75 (1.34–2.30)	354 (23.5)
≥2	245 (38)	13.0 (7.8–20.8)	2.73 (1.52–4.90)	111 (40.1)
P (*P* trend)		0.001 (<0.001)		0.010
Barrier use during oral sex in past year[e,g]				
No oral sex in previous year	622 (42)	4.8 (3.2–7.1)	0.53 (0.36–0.76)	—
Never/rarely	1,251 (127)	9.2 (7.3–11.5)	1	—
Usually/always	109 (13)	14.2 (6.9–26.8)	1.55 (0.84–2.9)	—
P		0.005		—
Overall oral health[h]				
Poor—fair	1,202 (128)	10.1 (8.2–12.4)	1.56 (1.25–1.95)	—
Good—excellent	2,233 (167)	6.5 (5.0–8.4)	1	—
P		<0.001		—
Think might have gum disease[i]				
No	2,750 (227)	6.9 (5.4–8.7)	1	704 (18.8)
Yes	641 (66)	10.4 (7.6–14.1)	1.51 (1.13–2.01)	461 (63.3)
P		0.012		<0.001
Used mouthwash to treat dental problems in the past 7 days [j]				
No	1,477 (116)	6.5 (5.1–8.2)	1	457 (23.5)
Yes	1,958 (179)	8.3 (6.6–10.4)	1.28 (1.07–1.52)	744 (30.2)
P		0.010		<0.001
Number of teeth lost[k]				
0	197 (19)	8.1 (5.7–11.3)	1	42 (16.5)
1–2	318 (27)	6.6 (4.3–9.9)	0.82 (0.46–1.45)	92 (25.5)
3–5	1,189 (72)	6.2 (3.6–10.4)	0.77 (0.38–1.60)	261 (15.6)
6–10	837 (71)	6.7 (5.1–8.9)	0.84 (0.51–1.37)	306 (29.6)
≥11	766 (97)	12.2 (9.4–15.7)	1.51 (0.95–2.42)	391 (54.8)
P (*P* trend)		0.045 (0.035)		<0.000 (<0.000)

[a]Analyses were restricted to NHANES 2009–2010 surveyed participants ages 30 to 69 years whose data on oral HPV results and oral health (interview or examination sections) were available ($n = 3,439$).

[b]Index for the ratio of family income-to-poverty threshold, specific to family size, year, and state. A value of 1 or less denotes a family income below the poverty threshold.

[c]Current smokers included those who had smoked a cigarette in the prior 30 days.

[d]Current marijuana users included those who had used it at least once in the prior 30 days.

[e]Analyses were restricted to individuals ages 30- to 59 years, for whom data on oral HPV, oral health, and oral sex were available.

[f]Included partners of both sexes.

[g]Original responses on a 4-point Likert scale were dichotomized.

[h]Self-rating overall oral health was measured by the question, "Overall, how would you rate the health of your teeth and gums?" Original responses on a 5-point Likert scale, from 1 = excellent to 5 = poor, were dichotomized into poor–fair and good–excellent.

[i]Respondents were asked if they thought they might have a gum disease (based on signs of swollen gums, receding gums, sore or infected gums or loose teeth).

[j]Respondents were coded as "yes" if they reported more than 1 day of use.

[k]Analysis was restricted to participants ages 30 to 69 years who underwent oral examination ($n = 3,375$) by registered dental hygienists. A tooth was counted as lost if it was recorded as "dental implant," "tooth not present," or "permanent dental root fragment present."

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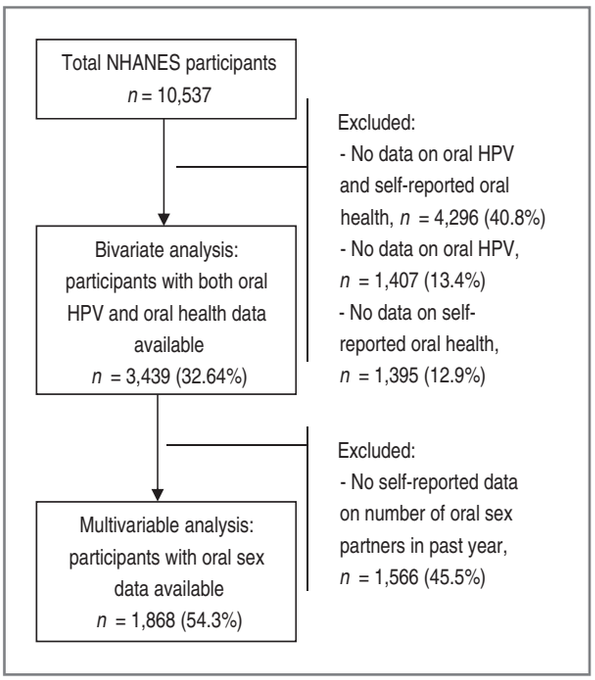

Figure 1. Selection of NHANES participants for this analysis.

audio computer assisted self interview system in a private room in the NHANES mobile examination center (MEC).

Statistical analysis. Bivariate analyses were restricted to surveyed participants ages 30 to 69 years, for whom data on oral HPV and self-reported oral health were available (n = 3,439). Figure 1 displays the selection and restriction process. Table 1 displays comparisons of sociodemographic characteristics of participants who were included in these analyses versus those who had available oral HPV data but were excluded because of lack of self-reported oral health data. Significant sociodemographic differences between these two subgroups may be due to differences in age (i.e., included participants were $\geq$ 30 years old and hence were more likely to be married and had higher household income). Multivariable analyses using logistic regression were further restricted to individuals ages 30 to 59 years for whom data on oral sex were available. To account for the complex survey design, sampling-design parameters (strata and primary sampling units) were specified and MEC sample weights were used in all analyses, aided by complex samples procedures in SPSS 20.0 (17). Univariable and multivariable associations with oral HPV infection were assessed using the adjusted F test. To assess for potential confounders, we first stratified the association of self-rated overall oral health and oral HPV infection by sociodemographic and behavioral factors which were known *a priori* or suspected risk factors of oral HPV infection and/or overall oral health. Variables which altered the OR point estimate by 10% or more in stratified analysis were included in the final multivariable logistic regression model for the adjusted OR estimation. Separate models with product terms between overall oral health and each covariate were conducted to evaluate interaction effects of overall oral health and other risk factors on the likelihood of oral HPV infection.

Results

In the analyzed sample, the prevalence of those who reported overall oral health as poor-to-fair was 27.8% (95% CI, 25.6%–30.1%), of those possibly having gum disease was 17.5% (95% CI, 15.4%–19.8%), and of those

Table 3. Associations between self-rated overall oral health as poor-fair and oral HPV infection stratified by sociodemographic and behavioral characteristics

Characteristics	Total unweighted counts (unweighted counts of HPV infection)	OR (95% CI)	*P*
Age, y	3,435 (295)	1.62 (1.28–2.06)	0.001
30–39	876 (70)	1.83 (1.04–3.25)	0.039
40–49	951 (64)	1.81 (1.22–2.68)	0.006
50–59	822 (90)	1.87 (0.97–3.59)	0.059
60–69	786 (71)	0.74 (0.33–1.64)	0.434
Sex, all	3,435 (295)	1.62 (1.28–2.06)	0.001
Male	1,711 (226)	1.52 (1.09–2.13)	0.017
Female	1,724 (69)	1.64 (0.91–2.97)	0.094
Cigarette smoker, all	2,634 (224)	1.87 (1.44–2.41)	0.006
Never/former	1,846 (106)	1.39 (0.97–2.07)	0.056
Current, $\leq$10 cigarettes/d	445 (66)	1.20 (0.61–2.35)	0.581
Current, >10 cigarettes/d	343 (52)	1.75 (0.79–3.91)	0.157
Number of oral sex partners in past year, all	2,616 (214)	1.92 (1.40–2.64)	0.001
0	1,203 (73)	1.87 (0.78–4.45)	0.148
1	1,168 (103)	2.04 (1.28–3.26)	0.005
$\geq$2	245 (38)	1.73 (0.65–4.59)	0.252

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using mouthwash to treat dental problems in the past week was 53.9% (95% CI, 49.8%–58.0%). The prevalence of numbers of teeth lost was 6.3% (95% CI, 5.0%–8.0%) for no teeth lost, 9.5% (95% CI, 7.4%–12.1%) for 1 or 2 teeth lost, 47.1% (95% CI, 42.2%–52.1%) for 3 to 5 teeth lost, 24.4% (95% CI, 21.6%–27.5%) for 6 to 10 teeth lost, and 12.6% (95% CI, 9.9%–15.9%) for 11 or more teeth lost. Table 2 shows bivariate associations between participants' characteristics and oral HPV infection and self-rated overall oral health. Being male, smoking, drinking alcohol, using marijuana, having lifetime experience of oral sex and having multiple lifetime and past year oral sex partners were significantly associated with increased likelihood of oral HPV infection. Higher prevalence of oral HPV infection was also associated with all four oral health measures, including self-rated oral health as poor-to-fair [prevalence ratio (PR) = 1.56; 95% confidence interval (CI), 1.25–1.95], possible gum disease (PR = 1.51; 95% CI, 1.13–2.01), using mouthwash to treat dental problems in the past week (PR = 1.28; 95% CI, 1.07–1.52), and higher number of teeth lost (P_{trend} = 0.035). Most sociodemographic and behavioral characteristics were associated with overall oral health. Each of the three specific oral health measures was also associated with overall oral health. When examination of the bivariate association between self-rated oral health and oral HPV infection was restricted to males who identified themselves as gay or bisexual (n = 39, data not shown), oral HPV infection among the poor-to-fair oral health group was higher than that among the good-to-excellent group (20% vs. 11%); however, this association was not statistically significant (P = 0.26), which was probably due to the small sample size.

Table 3 displays stratified analyses for the association of overall oral health and oral HPV infection by some important known risk factors for oral HPV infection. In the final multivariable model, the likelihood of oral HPV infection remained significantly associated with being male, being a current cigarette smoker, having multiple oral sex partners in the previous year, and rating one's oral health as poor-to-fair (Table 4). No interaction terms between overall oral health and other risk factors were significant.

Table 4. Adjusted odds ratios for oral HPV infection by sociodemographic and behavioral characteristics[a]

Variables	OR (95 CI)	$P_{interaction}$ with overall oral health[b]
Age, y		
30–39	1	
40–49	0.91 (0.43–1.92)	
50–59	1.66 (0.93–2.96)	
P	0.106	0.759
Sex		
Male	3.33 (2.05–5.42)	
Female	1	
P	<0.001	0.753
Cigarette smoker		
Never/former	1	
Current, ≤10 cigarettes/d	2.08 (1.06–4.07)	
Current, >10 cigarettes/d	2.42 (1.30–4.51)	
P	0.014	0.635
Marijuana use		
Never	1	
Former	1.70 (0.87–3.28)	
Current	1.92 (1.07–3.44)	
P	0.155	0.491
Number of oral sex partners in past year		
0	1	
1	1.90 (1.26–2.87)	
≥2	2.08 (1.12–3.84)	
P	0.009	0.520
Overall oral health		
Poor–fair	1.55 (1.15–2.09)	
Good–excellent	1	
P	0.007	

[a]Analyses were further restricted to individuals ages 30 to 59 years, for whom data on oral HPV, oral health, and oral sex were available (valid unweighted observations, n = 1,868). Dependent variable: oral HPV infection (reference category = No).

[b]Separate models were conducted to evaluate interactions, with each product term included in turn.

Discussion

Although our analyses were restricted to a subgroup of participants whose oral health data were available, the results about factors associated with oral HPV infection resemble those of Gillison and colleagues (12). Specifically, smoking and having multiple oral sex partners were independent behavioral risk factors for oral HPV infection with comparable ORs. Our findings suggest that poor oral health is an additional risk factor for oral HPV infection, given the associations between all four measures of oral health and oral HPV infection in univariable analyses. The independent association between oral health and oral HPV infection in the multivariable model imply that oral health is a risk factor over and above smoking and having multiple oral sex partners. To infect the oral cavity, HPV enters the basal layer of epithelium through epithelial wounds (18). Poor oral health, which may include ulcers, mucosal disruption, or chronic inflammation, may increase susceptibility to and infectiousness of HPV. Further research is needed to explore the pathologic mechanisms of oral health and oral HPV infection.

Given Gillison and colleagues' findings of a bimodal pattern of oral HPV prevalence for older and younger age and a significantly higher prevalence among men (12), we hypothesized possible alternative risk factors by age or sex, for example, multiple oral sex partners for younger

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individuals and poorer oral health for older individuals. However, the nonsignificant interactions between age or sex and overall self-rated oral health suggest that poor oral health is not a distinct risk factor by age or sex. The association between overall oral health and oral HPV infection in the multivariable model remained significant ($P < 0.01$) even when lifetime number of any sex partners was used for adjustment in lieu of number of oral sex partners in the past year (data not shown).

This study has some limitations. Because of the cross-sectional nature of the data, temporal relationships between variables cannot be established. However, oral HPV infection is usually asymptomatic (18, 19), thus, it is unlikely to affect self-reported oral health. The primary behavioral variables were based on self-reports and hence might be subject to recall bias or under-reporting. Despite the large number of NHANES participants, the low oral HPV prevalence limited statistical power to evaluate associations and interactions. For example, the wide ranges of 95% CI of ORs when stratified by smoking or number of oral sex partners in the past year might be due to small sample sizes in each stratum. Because we have used secondary data, we could not examine associations between specific hygienic oral sex behaviors (e.g., mouth-washing before or after oral sex), or other oral bacterial infections, with oral HPV infection. The association between oral health and oral HPV prevalence in this study could not be investigated specifically with regard to newly infected HPV, persistent HPV, or HPV reinfection. Additional research is needed to investigate these topics.

Overall, this study indicates that poor oral health is an independent risk factor for oral HPV infection, irrespective of smoking status and oral sex behavior. Given that oral hygiene is fundamental for oral health and that it is modifiable, public health interventions may aim to promote oral hygiene and oral health as additional preventive measures for HPV-related oral cancers. Our results also contribute to the knowledge of oral and oropharyngeal cancer pathogenesis attributable to poor oral health, by suggesting its indirect relationship through oral HPV infection.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

Disclaimer

The content of the article is solely the responsibility of the authors and does not necessarily represent the official views of the National Center for Health Statistics (NCHS) or the Cancer Prevention and Research Institute of Texas (CPRIT). T.C. Bui had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Conception and design: T.C. Bui, C.M. Markham, P.D. Mullen
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Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis): T.C. Bui, C.M. Markham, M.W. Ross, P.D. Mullen
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