Preventive Medicine xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study

Yasushi Koyama [a,*], Shinichi Kuriyama [a], Jun Aida [b], Toshimasa Sone [a], Naoki Nakaya [a], Kaori Ohmori-Matsuda [a], Atsushi Hozawa [a], Ichiro Tsuji [a]

[a] Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan
[b] Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai, Japan

ARTICLE INFO

Available online xxxx

Keywords:
Green tea
Tooth loss
Catechin

ABSTRACT

Objective. To examine the association between green tea consumption and tooth loss.

Methods. We analyzed cross-sectional data from the Ohsaki Cohort 2006 Study. Usable self-administered questionnaires about green tea consumption and tooth loss were returned from 25,078 persons (12,019 men and 13,059 women) aged 40 to 64 years in Japan. Multivariate logistic regression analysis was used to calculate odds ratios (ORs) for tooth loss using 3 cut-off points of 10, 20, and 25 teeth relative to each category of green tea consumption.

Results. Consumption of ≥1 cup/day of green tea was significantly associated with decreased odds for tooth loss, and the association appeared to fit a threshold model. In men, the multivariate-adjusted ORs for tooth loss with a cut-off point of <20 teeth associated with different frequencies of green tea consumption were 1.00 (reference) for <1 cup/day, 0.82 (95% CI, 0.74–0.91) for 1–2 cups/day, 0.82 (95% CI, 0.73–0.92) for 3–4 cups/day, and 0.77 (95% CI, 0.66–0.89) for ≥5 cups/day. The corresponding data for women and the results for cut-off points of 10 and 25 teeth were essentially the same.

Conclusions. The present findings indicate an association of green tea consumption with decreased odds for tooth loss.

Introduction

Tooth loss reduces masticatory ability, leading to detrimental changes in food selection. Restricted food selection may increase the risk of certain systemic diseases (Hung et al., 2003; Joshipura et al., 1996; Shimazaki et al., 2002; Willett, 1994). Therefore, prevention of tooth loss is important from the viewpoint of overall human health.

A number of experimental studies have shown that green tea has a profound suppressive effect on the activities of oral bacteria such as *Streptococcus mutans* and *Porphyromonas gingivalis* (Hamilton-Miller, 2001; Hirasawa et al., 2002, 2006; Otake et al., 1991; Sakanaka and Okada, 2004; Smullen et al., 2007; Socransky and Haffajee, 2002). The antibacterial effects of green tea are thought to be due to catechins (Hirasawa et al., 2002; Sakanaka and Okada, 2004; Smullen et al., 2007). Tea catechins inhibit acid production by oral bacteria such as *S. mutans* and exert bactericidal activity against *P. gingivalis* (Hirasawa et al., 2006; Sakanaka and Okada, 2004). These bacteria are strongly implicated in the development of dental caries and periodontal disease (Dietrich et al., 2004; Hamilton-Miller, 2001; Hirasawa et al., 2006; Sakanaka and Okada, 2004; Socransky and Haffajee, 2002), which are the main causes of tooth loss (Aida et al., 2006). Therefore, tea catechins may have potential oral health benefits, reducing the likelihood of tooth loss.

To date, however, there has been only one cross-sectional study of 1002 pregnant women on the association between green tea consumption and tooth loss (Tanaka et al., 2008), and the findings of that study must be verified by epidemiological observation of a large general population. Therefore, we conducted a cross-sectional study in Japan, where consumption of green tea is one of the highest in the world (Kuriyama et al., 2006a,b), to clarify the above association.

Methods

Study sample

We analyzed cross-sectional data from a baseline survey conducted for the Ohsaki Cohort 2006 study. The details of this cohort have been reported elsewhere (Kuriyama et al., 2009). In brief, we delivered a self-administered questionnaire to all 46,407 residents aged 40 to 64 years, who were included in the Residential Registry for Ohsaki City, Miyagi Prefecture, northeastern Japan, as of December 1, 2006. The survey was conducted from December 1 to 15, 2006. The questionnaire consisted of 15 items: history of diseases, family history of diseases, physical health status during the last year, smoking habit, drinking habit, dietary habits, occupation or education, body weight and height, health status during the last month, exercise, psychological distress, social support, participation in community activities, and dental status, plus reproductive history for women. The questionnaire

* Corresponding author.
E-mail address: a5mb1049-thk@umin.ac.jp (Y. Koyama).

0091-7435/$ – see front matter © 2010 Published by Elsevier Inc.
doi:10.1016/j.ypmed.2010.01.010

was distributed by the heads of individual administrative districts to individual households and collected by mail. Since 409 subjects were found to have died, moved out of the area, in hospital, or absent for a prolonged period, the questionnaire could not be distributed to them. Among 45,998 eligible individuals, 26,512 responded, giving a response rate of 57.6%. We considered the return of self-administered questionnaires signed by the subjects to imply their consent to participate in the study. The study protocol was approved by the Ethics Committee of Tohoku University Graduate School of Medicine.

Of the 26,512 individuals, we excluded 1434 who did not provide answers to the items on green tea consumption and the number of retained teeth. A final total of 25,078 persons (12,019 men and 13,059 women) were included the present analysis.

Measurement

Dietary intake was assessed using a self-administered food frequency questionnaire (FFQ). In this questionnaire, we asked participants to report their frequency of recent consumption of 40 food and beverage items. The questionnaire provided 5 categories of response to describe the participant's frequency of green tea consumption: never, occasionally, 1–2 cups/day, 3–4 cups/day, and ≥5 cups/day. The volume of a typical cup of green tea was 100 ml in the study region (Kuriyama et al., 2006a). We conducted a validation study of the FFQ, in which 113 participants provided four 3-day dietary records within a period of 1 year and subsequently responded to the questionnaire (Ogawa et al., 2003). The results showed that the Spearman rank coefficient for the correlation between the amounts of green tea consumed according to the questionnaire and the amounts consumed according to the records was 0.71 for men and 0.53 for women; the correlation between consumption measured by the 2 questionnaires administered 1 year apart was 0.63 for men and 0.64 for women. Since only 5.2% of the participants said they never drank green tea, data from participants who never and occasionally drank green tea were collapsed into the single category of <1 cup/day for the purpose of our analysis.

We assessed the number of teeth using the self-administered questionnaire, which was structured with categorical responses: none (zero teeth), few (1–9 teeth), nearly half (10–19 teeth), most (20–24 teeth), almost all (25–27 teeth), or all (28 teeth). We did not take third molars into account. Because there are no specific markers for tooth loss, we used 3 cut-off points to conduct our analyses. The initial cut-off point was <10 teeth, a category including 0–9 teeth, the second was <20 teeth, a category including 0–19 teeth, and the third was <25 teeth, a category including 0–24 teeth.

Statistical analyses

To determine the relationship between green tea consumption and tooth loss, we used logistic regression analyses to derive adjusted odds ratios (ORs). The main independent variables were the levels of green tea consumption. Odds for tooth loss were calculated by dividing the number of persons with a low number of teeth by the number of persons with a high number of teeth. The ORs were computed as the odds among subjects in each green tea consumption category divided by the odds among subjects in the "<1 cup/day" category. The ORs and 95% confidence intervals (CIs) were estimated using SAS Version 9.1 (SAS Institute Inc., 2004). All statistical tests are two-sided. Differences at $P<0.05$ were accepted as statistically significant.

We considered the following variables as potential confounders: age (40–44, 45–49, 50–54, 55–59, or 60–64 years), the number of times teeth were brushed per day (<2, 2, or >2 times/day), years of education (<10, 10–12, or ≥13 years), body mass index calculated with self-reported weight and height (<18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0 kg/m^2), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19 cigarettes/day, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, or current), weekly consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily dietary consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), oolong tea, black tea, and coffee (for each beverage, <1, 1–2, 3–4, or ≥5 cups/day), daily consumption of total fish, which was categorized into quartile by sex, daily consumption of total calories, which was also categorized into quartiles by sex, and the details were given as follows: the intake of total calories was calculated from daily rice consumption, daily *miso* soup consumption, daily consumption of green tea, oolong tea, black tea, or coffee, alcohol consumption, and FFQ using the *Standard Tables of Food Composition* published by the Science and Technology Agency of Japan. The confounders were selected for their relationship to green tea consumption and tooth loss (Bahekar et al., 2007; Elter et al., 2003; Hanioka et al., 2007; Heitmann and Gamborg, 2008; Klein et al., 2004; Okamoto et al., 2006; Pischon et al., 2007; Pitiphat et al., 2003; Susin et al., 2005; Tu et al., 2007).

We also estimated ORs for tooth loss for other beverages such as oolong tea and coffee for the cut-off point of <20 teeth, since the results for green tea consumption revealed that ORs for tooth loss were similar at each cut-off point. We calculated ORs for tooth loss stratified by coffee consumption with or without sugar or syrup since adding sugar or syrup to coffee is widespread in Japan. In the stratified analyses we excluded participants who never consumed coffee, since they were included in each reference group. We did not estimate ORs for black tea consumption since the number of persons who consumed black tea was extremely small.

Results

Baseline characteristics of the participants are shown in Tables 1 and 2 for men and women, respectively. Men consuming more cups of green tea tended to be older, brush their teeth more often, have a higher calorie intake, and consume more sweets, *miso* soup, and soybean products, but they were less likely to consume coffee. They showed a higher prevalence of chronic diseases such as stroke, myocardial infarction, or cancer. Women consuming green tea more often tended to be older, have a higher calorie intake, and consume more *miso* soup, soybean products, and total fish, but they were less likely to consume coffee. They also showed a higher prevalence of chronic diseases such as myocardial infarction, diabetes mellitus, or cancer. Women who drank no alcohol were less likely to consume a higher number of cups of green tea.

Table 3 shows the ORs of tooth loss with the 95% CIs. We found that consumption of ≥1 cup/day of green tea was significantly associated with decreased odds for tooth loss in both the age-adjusted and multivariate-adjusted ORs. The association appeared to fit a threshold model. In men, the multivariate-adjusted ORs for tooth loss at the <20 teeth cut-off point associated with different frequencies of green tea consumption were 1.00 (reference) for <1 cup/day, 0.82 (95% CI, 0.74–0.91) for 1–2 cups/day, 0.82 (95% CI, 0.73–0.92) for 3–4 cups/day, and 0.77 (95% CI, 0.66–0.89) for ≥5 cups/day (P for trend <0.0001). The corresponding data for women were 1.00, 0.87 (95% CI, 0.78–0.97), 0.87 (95% CI, 0.77–0.98), and 0.89 (95% CI, 0.78–1.01), respectively (P for trend = 0.011). The results for the cut-off points of <10 teeth and <25 teeth were essentially the same as those for the <20 teeth cut-off point. Since we found a threshold association, we conducted additional analysis at the <20 teeth cut-off point, categorizing the green tea consumption level into two groups (<1 cup/day versus ≥1 cup/day). The multivariate-adjusted ORs for men and women were 0.81 (95% CI, 0.74–0.89) and 0.87 (95% CI, 0.79–0.96), respectively.

Table 4 presents the ORs of tooth loss for oolong tea. We found an inverse dose–response relationship, rather than a threshold relationship, for oolong tea consumption with tooth loss.

Table 5 shows the ORs of tooth loss for coffee consumption. We found that higher coffee consumption was significantly associated with increased odds for tooth loss in both age-adjusted and multivariate-adjusted ORs. In women, analyses stratified by addition of sugar or syrup exhibited a pronounced increase of ORs for tooth loss due to sugar or syrup, while ORs for coffee consumption in men were almost unchanged, irrespective of addition of sugar or syrup.

Discussion

Our findings showed that green tea consumption was significantly associated with decreased odds for tooth loss.

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010

Table 1
Baseline characteristics of men according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).[a]

Characteristics	Green tea consumption, cups/day				
	<1 ($n=4108$)	1–2 ($n=4180$)	3–4 ($n=2395$)	≥5 ($n=1336$)	*P*-value[b]
Total number of teeth					
0–9	428 (10.4)	356 (8.5)	223 (9.3)	154 (11.5)	<0.0001
10–19	894 (21.8)	770 (18.4)	477 (19.9)	263 (19.7)	
20–24	1283 (31.2)	1352 (32.3)	797 (33.3)	425 (31.8)	
≥25	1503 (36.6)	1702 (40.7)	898 (37.5)	494 (37.0)	
Age, mean (SD), years	52.2 (6.7)	52.7 (6.5)	54.7 (6.5)	56.0 (6.3)	<0.0001
Daily tooth brushing					
<2 times/day	1925 (47.4)	1745 (42.0)	955 (40.2)	574 (43.5)	<0.0001
2 times/day	1716 (42.2)	1826 (44.0)	1066 (44.9)	533 (40.4)	
>2 times/day	424 (10.4)	582 (14.0)	356 (15.0)	213 (16.1)	
Years of education					
<10	442 (11.1)	342 (8.4)	252 (10.8)	181 (14.0)	<0.0001
10–12	2388 (59.9)	2473 (60.6)	1356 (58.1)	748 (57.7)	
≥13	1158 (29.0)	1265 (31.0)	727 (31.1)	367 (28.3)	
Body mass index, kg/m^2					
<18.5	108 (2.7)	78 (1.9)	49 (2.1)	30 (2.3)	0.0001
18.5–22.9	1554 (38.2)	1502 (36.2)	897 (37.7)	492 (37.2)	
23.0–24.9	1009 (24.8)	1115 (26.9)	641 (26.9)	394 (29.8)	
25.0–29.9	1220 (30.0)	1299 (31.3)	734 (30.8)	372 (28.1)	
≥30.0	176 (4.3)	156 (3.8)	61 (2.6)	36 (2.7)	
Time spent walking, h/day					
<1	2689 (66.5)	2881 (69.9)	1632 (69.4)	843 (64.7)	0.0002
≥1	1355 (33.5)	1238 (30.1)	721 (30.6)	461 (35.4)	
History of chronic disease					
Stroke	55 (1.3)	60 (1.4)	36 (1.5)	25 (1.9)	0.57
Myocardial infarction	51 (1.2)	55 (1.3)	33 (1.4)	27 (2.0)	0.19
Diabetes mellitus	323 (7.9)	338 (8.1)	223 (9.3)	121 (9.1)	0.14
Cancer	85 (2.1)	99 (2.4)	71 (3.0)	50 (3.7)	0.0033
Smoking status					
Never	617 (15.3)	757 (18.3)	449 (19.1)	248 (19.0)	<0.0001
Former	1205 (29.8)	1419 (34.4)	842 (35.7)	437 (33.5)	
Current, 1–19 cigarettes/day	586 (14.5)	535 (13.0)	289 (12.3)	151 (11.6)	
Current, ≥20 cigarettes/day	1633 (40.4)	1418 (34.3)	776 (32.9)	469 (35.9)	
Alcohol drinking					
Never	596 (14.7)	494 (11.9)	310 (13.1)	206 (15.6)	<0.0001
Former	287 (7.1)	232 (5.6)	138 (5.8)	104 (7.9)	
Current	3182 (78.3)	3418 (82.5)	1924 (81.1)	1007 (76.5)	
Consumption of sweets (such as *manju*[c], *yokan*[d] or cake)					
<3 times/week	3240 (80.5)	3234 (79.1)	1790 (76.2)	925 (71.3)	<0.0001
≥3 times/week	785 (19.5)	854 (20.9)	558 (23.8)	373 (28.7)	
Daily consumption					
Miso (soybean paste) soup[e]	2875 (70.0)	3227 (77.2)	1937 (80.9)	1102 (82.6)	<0.0001
Soybean products[e]	1182 (29.4)	1470 (35.9)	1035 (43.8)	658 (50.0)	<0.0001
Milk[e]	1163 (28.8)	1286 (31.2)	753 (31.9)	440 (33.8)	0.0018
Total fish, mean (SD), g	40.4 (28.4)	44.1 (29.1)	48.3 (29.1)	54.1 (32.0)	<0.0001
Oolong tea, ≥3cups/day	126 (3.2)	91 (2.4)	69 (3.2)	47 (4.0)	0.025
Black tea, ≥3 cups/day	25 (0.6)	17 (0.5)	28 (1.3)	19 (1.6)	<0.0001
Coffee, ≥3 cups/day	1541 (37.9)	1271 (31.0)	720 (31.0)	359 (28.1)	<0.0001
Total calories, mean (SD), kcal	1590.1 (509.3)	1627.7 (494.0)	1702.6 (515.0)	1734.2 (510.0)	<0.0001

[a] Data were expressed as No. (%) unless otherwise indicated.
[b] *P*-values calculated by analysis of variance or χ^2 test.
[c] A steamed bean-jam bun.
[d] Sweetened and jellied bean paste.
[e] Almost everyday.

The association appeared to fit a threshold model, such that persons who consume at least one cup of green tea per day might receive some benefit in terms of tooth retention. The catechin content of green tea might be able to explain the threshold association. Dental caries and periodontal disease are the main causes of tooth loss in persons aged over 45 years in Japan (Aida et al., 2006). These diseases are mainly due to the actions of oral bacteria. A number of experimental studies have shown that green tea catechins inhibit oral bacteria (Hirasawa et al., 2002; Sakanaka and Okada, 2004; Smullen et al., 2007), while some experiments have indicated that the concentration of tea catechin conferring the above effect should be more than 100 mg/100 ml (Hirasawa et al., 2002; Otake et al., 1991; Sakanaka and Okada, 2004). A typical preparation of green tea contains a catechin concentration of 50–150 mg/100 ml (Sakanaka and Okada, 2004). Therefore, this amount of catechin contained in one cup of green tea might be sufficient to aid tooth retention.

An inverse dose–response relationship should be observed for any beverage with a weaker catechin concentration, for instance oolong tea (Ooshima et al., 1994). Indeed, we found that ORs for oolong tea indicated an inverse dose–response relationship. Shimada et al. reported that oolong tea contained about 13 mg/100 ml catechin, which was far weaker than that in green tea (Shimada et al., 2004). Because of the low catechin concentration, the amount of catechin contained in one cup of oolong tea is insufficient to reach a level that will inhibit oral bacteria. Hence, in order to be exposed to a level of catechins necessary to prevent tooth loss, many more cups of oolong tea might have to be consumed. Therefore, the results for oolong tea might explain the apparent threshold association for green tea consumption from the viewpoint of the amount of catechin.

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010

Table 2
Baseline characteristics of women according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).[a]

Characteristics	Green tea consumption, cups/day				
	<1 ($n=3693$)	1–2 ($n=4070$)	3–4 ($n=3026$)	≥5 ($n=2270$)	*P*-value[b]
Total number of teeth					
0–9	369 (10.0)	355 (8.7)	301 (10.0)	256 (11.3)	<0.0001
10–19	668 (18.1)	708 (17.4)	599 (19.8)	516 (22.7)	
20–24	1107 (30.0)	1184 (29.1)	940 (31.1)	669 (29.5)	
≥25	1549 (41.9)	1823 (44.8)	1186 (39.2)	829 (36.5)	
Age, mean (SD), years	51.3 (6.6)	52.5 (6.7)	54.9 (6.4)	56.7 (5.9)	<0.0001
Daily tooth brushing					
<2 times/day	771 (21.0)	625 (15.4)	443 (14.7)	372 (16.5)	<0.0001
2 times/day	2081 (56.7)	2287 (56.3)	1597 (53.0)	1213 (53.7)	
>2 times/day	821 (22.4)	1150 (28.3)	971 (32.3)	674 (29.8)	
Years of education					
<10	316 (8.9)	298 (7.6)	243 (8.4)	226 (10.4)	0.0015
10–12	1991 (55.8)	2219 (56.3)	1580 (54.3)	1230 (56.5)	
≥13	1262 (35.4)	1428 (36.2)	1087 (37.4)	723 (33.2)	
Body mass index, kg/m^2					
<18.5	208 (5.7)	189 (4.7)	135 (4.5)	104 (4.6)	<0.0001
18.5–22.9	1739 (47.7)	1961 (48.7)	1369 (45.7)	982 (43.6)	
23.0–24.9	729 (20.0)	875 (21.7)	690 (23.1)	484 (21.5)	
25.0–29.9	795 (21.8)	858 (21.3)	679 (22.7)	589 (26.1)	
≥30.0	173 (4.8)	148 (3.7)	120 (4.0)	95 (4.2	
Time spent walking, h/day					
<1	2566 (71.1)	2866 (71.9)	2170 (73.4)	1554 (70.7)	0.12
≥1	1044 (28.9)	1122 (28.1)	788 (26.6)	644 (29.3)	
History of chronic disease					
Stroke	24 (0.7)	20 (0.5)	16 (0.5)	6 (0.3)	0.24
Myocardial infarction	9 (0.2)	11 (0.3)	14 (0.5)	15 (0.7)	0.037
Diabetes mellitus	145 (3.9)	162 (4.0)	137 (4.5)	133 (5.9)	0.0016
Cancer	133 (3.6)	156 (3.8)	136 (4.5)	142 (6.3)	<0.0001
Smoking status					
Never	2645 (75.0)	3184 (82.6)	2465 (86.6)	1813 (86.3)	<0.0001
Former	297 (8.4)	254 (6.6)	152 (5.3)	110 (5.2)	
Current, 1–19 cigarettes/day	399 (11.3)	296 (7.7)	155 (5.5)	109 (5.2)	
Current, ≥20 cigarettes/day	185 (5.3)	120 (3.1)	73 (2.6)	69 (3.3)	
Alcohol drinking					
Never	1734 (48.4)	1986 (50.3)	1621 (55.9)	1291 (59.9)	<0.0001
Former	271 (7.6)	224 (5.7)	165 (5.7)	143 (6.6)	
Current	1577 (44.0)	1737 (44.0)	1114 (38.4)	720 (33.4)	
Consumption of sweets (such as *manju*[c], *yokan*[d] or cake)					
<3 times/week	2278 (62.6)	2389 (59.5)	1655 (55.7)	1265 (56.7)	<0.0001
≥3 times/week	1364 (37.5)	1628 (40.5)	1314 (44.3)	966 (43.3)	
Daily consumption					
Miso (soybean paste) soup[e]	2469 (67.0)	3068 (75.5)	2401 (79.6)	1808 (79.8)	<0.0001
Soybean products[e]	1698 (46.8)	2194 (54.7)	1839 (61.9)	1491 (67.0)	<0.0001
Milk[e]	1351 (37.0)	1622 (40.2)	1271 (42.6)	946 (42.4)	<0.0001
Total fish, mean (SD), g	37.8 (24.3)	42.0 (24.9)	46.8 (25.5)	51.2 (26.7)	<0.0001
Oolong tea, ≥3 cups/day	198 (5.6)	119 (3.1)	105 (3.7)	91 (4.3)	<0.0001
Black tea, ≥3 cups/day	47 (1.3)	38 (1.0)	46 (1.6)	38 (1.8)	0.035
Coffee, ≥3 cups/day	1538 (42.0)	1360 (33.8)	847 (28.4)	515 (23.4)	<0.0001
Total calories, mean (SD), kcal	1177.2 (299.0)	1231.1 (299.0)	1279.2 (294.9)	1299.0 (303.1)	<0.0001

[a] Data were expressed as No. (%) unless otherwise indicated.
[b] *P*-values calculated by analysis of variance or χ^2 test.
[c] A steamed bean-jam bun.
[d] Sweetened and jellied bean paste.
[e] Almost everyday.

The ORs for coffee consumption (Table 5) showed that persons who consumed more cups of coffee had a lower number of teeth. Tooth loss in the case of coffee consumption might be due to exacerbation of dental caries by addition of sugar or syrup (Jones et al., 1999), since 44.2% of men and 30.7% of women in this study added sugar or syrup to their coffee. Our analyses stratified by addition of sugar or syrup showed that the effects attributable to sugar or syrup were remarkable for women but almost negligible for men. Therefore, addition of sugar or syrup might be one possible explanation for the remarkable reduction of ORs in women. Furthermore, the non-decreasing ORs of tooth loss for those consuming coffee without sugar or syrup might be explained by the absence of catechin in coffee.

The effects of mouth rinses on tooth retention should be taken into account. If mouth rinsing itself prevents tooth loss, other beverages lacking catechin such as coffee without sugar or syrup might produce effects similar to the result of green tea consumption. However, we did not observe any decrease in ORs for tooth loss among subjects consuming coffee. Hence, mouth rinsing might have no effect on tooth retention.

Study strengths

Our study had several methodological strengths. First, this was a population-based study with a large sample size of 25,078 subjects from the general population in Japan. Second, the validity and reproducibility of green tea consumption among subjects in our previous validation study were reasonably high (Ogawa et al., 2003). Third, many of the subjects drank green tea and were distributed nearly evenly among the four categories of consumption frequency.

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010

Table 3
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to green tea consumption (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Green tea consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
Cut-off point: <10 teeth					
Men					
Number of cases/number of participants	428/4108	356/4180	223/2395	154/1336	
Age-adjusted OR (95% CI)	1.00	0.76 (0.65, 0.88)	0.69 (0.58, 0.83)	0.79 (0.64, 0.96)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.74, 1.02)	0.81 (0.68, 0.97)	0.82 (0.66, 1.01)	0.0063
Women					
Number of cases/number of participants	369/3693	355/4070	301/3026	256/2270	
Age-adjusted OR (95% CI)	1.00	0.74 (0.63, 0.87)	0.67 (0.57, 0.79)	0.66 (0.55, 0.79)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.74, 1.02)	0.81 (0.68, 0.97)	0.75 (0.62, 0.91)	0.0006
Cut-off point: <20 teeth					
Men					
Number of cases/number of participants	1322/4108	1126/4180	700/2395	417/1336	
Age-adjusted OR (95% CI)	1.00	0.73 (0.67, 0.81)	0.72 (0.64, 0.80)	0.72 (0.63, 0.83)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.82 (0.74, 0.91)	0.82 (0.73, 0.92)	0.77 (0.66, 0.89)	<0.0001
Women					
Number of cases/number of participants	1037/3693	1063/4070	900/3026	772/2270	
Age-adjusted OR (95% CI)	1.00	0.79 (0.71-0.88)	0.76 (0.68-0.85)	0.81 (0.71-0.91)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.87 (0.78-0.97)	0.87 (0.77-0.98)	0.89 (0.78-1.01)	0.011
Cut-off point: <25 teeth					
Men					
Number of cases/number of participants	2605/4108	2478/4180	1497/2395	842/1336	
Age-adjusted OR (95% CI)	1.00	0.80 (0.73, 0.87)	0.81 (0.73, 0.90)	0.76 (0.67, 0.87)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.89 (0.81, 0.98)	0.94 (0.84, 1.05)	0.85 (0.74, 0.97)	0.011
Women					
Number of cases/number of participants	2144/3693	2247/4070	1840/3026	1441/2270	
Age-adjusted OR (95% CI)	1.00	0.80 (0.72, 0.87)	0.83 (0.74, 0.92)	0.80 (0.72, 0.90)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.86 (0.78, 0.95)	0.94 (0.84, 1.04)	0.89 (0.79, 1.00)	0.083

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2, or >2 times/day), years of education (>10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), oolong tea, black tea, and coffee (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day), and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

Study limitations

Several methodological limitations should also be considered when interpreting our results. First, our study had a cross-sectional design and no temporal relationship between green tea consumption and tooth loss can be inferred. However, teeth are not considered to play an indispensable role in drinking green tea, since green tea is a liquid. Therefore, we can reasonably speculate that teeth are retained as a result of consuming green tea. Second, we had no information on the validity of the self-reported number of residual teeth. However, previous studies had shown that the general population was able to provide reasonably accurate estimates of the self-reported number of teeth present (Axelsson and Helgadóttir, 1995; Douglass et al., 1991; Pitiphat et al., 2002). If a large proportion of the subjects gave vague answers in the questionnaires as to the number of their remaining teeth, misclassification regarding green tea consumption would occur. If data containing misclassifications were used for estimation of ORs, the general results would probably have been distorted, and any effect of green tea consumption in decreasing the odds for tooth loss might have been attenuated. Third, we had no information about dental

Table 4
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to oolong tea consumption; cut-off point: <20 teeth (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Oolong tea consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
Men					
Number of cases/number of participants	2966/10,031	171/700	56/231	29/115	
Age-adjusted OR (95% CI)	1.00	0.90 (0.75, 1.08)	0.84 (0.61, 1.14)	0.85 (0.54, 1.30)	0.0019
Multivariate-adjusted OR (95% CI)[a]	1.00	0.93 (0.77, 1.12)	0.87 (0.63, 1.20)	0.85 (0.54, 1.33)	0.042
Women					
Number of cases/number of participants	3116/10,988	208/815	80/344	54/187	
Age-adjusted OR (95% CI)	1.00	0.99 (0.83, 1.17)	0.77 (0.59, 1.00)	1.07 (0.76, 1.48)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	0.99 (0.83, 1.18)	0.72 (0.55, 0.94)	0.85 (0.60, 1.20)	<0.0001

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2, or >2 times/day), years of education (>10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), green tea, black tea, and coffee (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day), and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010

Table 5
Odds ratios (ORs) and 95% confidence intervals (CIs) of tooth loss according to coffee consumption with or without sugar or syrup; cut-off point: <20 teeth (December 2006, Ohsaki City, Miyagi Prefecture, Northeastern Japan).

	Coffee consumption, cups/day				
	<1	1–2	3–4	≥5	*P*-values for trend
Coffee consumption					
	Men				
Number of cases/number of participants	887/3003	1521/5206	953/3142	335/972	
Age-adjusted OR (95% CI)	1.00	1.12 (1.01, 1.24)	1.30 (1.16, 1.45)	1.58 (1.34, 1.85)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.06 (0.96, 1.18)	1.16 (1.03, 1.31)	1.30 (1.10, 1.54)	0.0003
	Women				
Number of cases/number of participants	855/2766	1731/6041	939/3384	313/1025	
Age-adjusted OR (95% CI)	1.00	1.06 (0.96, 1.18)	1.18 (1.05, 1.33)	1.40 (1.19, 1.65)	0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.11 (1.00, 1.24)	1.18 (1.04, 1.33)	1.28 (1.07, 1.52)	0.0034
Coffee consumption excluding participants who never drink coffee					
	Men				
Number of cases/number of participants	670/2222	1521/5206	953/3142	335/972	
Age-adjusted OR (95% CI)	1.00	1.08 (0.96, 1.21)	1.25 (1.11, 1.42)	1.52 (1.29, 1.80)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.02 (0.91, 1.15)	1.12 (0.98, 1.27)	1.25 (1.05, 1.49)	0.0055
	Women				
Number of cases/number of participants	636/2079	1731/6041	939/3384	313/1025	
Age-adjusted OR (95% CI)	1.00	1.10 (0.98, 1.23)	1.23 (1.08, 1.39)	1.45 (1.22, 1.72)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.14 (1.01, 1.28)	1.21 (1.06, 1.39)	1.32 (1.10, 1.58)	0.0010
Coffee consumption with sugar or syrup excluding participants who never drink coffee					
	Men				
Number of cases/number of participants	403/1140	871/2463	464/1219	139/322	
Age-adjusted OR (95% CI	1.00	1.12 (0.97, 1.31)	1.39 (1.16, 1.65)	1.70 (1.31, 2.20)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.04 (0.89, 1.22)	1.17 (0.97, 1.41)	1.31 (0.99, 1.72)	0.024
	Women				
Number of cases/number of participants	310/907	710/1940	279/804	98/222	
Age-adjusted OR (95% CI)	1.00	1.33 (1.12, 1.58)	1.42 (1.15, 1.75)	2.11 (1.54, 2.89)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.34 (1.11, 1.60)	1.35 (1.08, 1.69)	1.88 (1.35, 2.63)	0.0002
Coffee consumption without sugar or syrup excluding participants who never drink coffee					
	Men				
Number of cases	267/1082	650/2743	489/1923	196/650	
Age-adjusted OR (95% CI)	1.00	1.06 (0.90, 1.26)	1.27 (1.06, 1.52)	1.63 (1.30, 2.04)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.02 (0.86, 1.22)	1.16 (0.97, 1.41)	1.35 (1.06, 1.72)	0.0041
	Women				
Number of cases	326/1172	1021/4101	660/2580	215/803	
Age-adjusted OR (95% CI)	1.00	1.02 (0.88, 1.19)	1.23 (1.05, 1.45)	1.37 (1.11, 1.69)	<0.0001
Multivariate-adjusted OR (95% CI)[a]	1.00	1.06 (0.90, 1.24)	1.22 (1.03, 1.45)	1.24 (0.99, 1.56)	0.0063

[a] The multivariate OR has been adjusted for age (40–44, 45–49, 50–54, 55–59, or 60–64 years), daily tooth brushing (<2, 2,or >2 times/day), years of education (>10, 10–12, or ≥13), body mass index (calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5–22.9, 23.0–24.9, 25.0–29.9, or ≥30.0), time spent walking (<1 or ≥1 h/day), history of stroke, myocardial infarction, diabetes mellitus, and cancer (for each disease, yes or no), smoking status (never, former, currently smoking 1–19, or currently smoking ≥20 cigarettes/day), alcohol drinking (never, former, current), consumption of sweets such as *manju* (a steamed bean-jam bun), *yokan* (sweetened and jellied bean paste), or cake (<3 or ≥3 times/week), daily consumption of *miso* (soybean paste) soup, soybean products, milk (for each food, almost everyday or not), total fish (categorized into quartiles: <21.7, 21.7–47.5, 47.5–53.4, or ≥53.4 g/day for men; <22.8, 22.8–41.3, 41.3–53.4, or ≥53.4 g/day for women), green tea, oolong tea, and black tea (for each beverage, never or occasionally, 1–2, 3–4, or ≥5 cups/day) and total intake of calories (categorized into quartiles: <1265.8, 1265.8–1603.4, 1603.4–1933.2, or ≥1933.2 kcal/day for men; <1027.3, 1027.3–1242.8, 1242.8–1439.0, or ≥1439.0 kcal/day for women).

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010

caries and periodontal disease. However, as these diseases represent an intermediate state leading to tooth loss, we consider that absence of information about them did not largely modify our results. Finally, since the response rate was not high (57.6%), the respondents might not have been a representative sample of the source population of Ohsaki City residents. The relatively low response rates should be kept in mind when interpreting the results.

Conclusions

The present findings indicate that green tea consumption is associated with decreased odds of tooth loss.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Acknowledgments

This study was supported by Health Sciences Research Grants (H19-Seisaku-Ippan-026, H18-Choju-Ippan-014, H21-Choju-Ippan-001) from the Ministry of Health, Labour and Welfare, Japan, and a Grant-in-Aid for Scientific Research (B) (21390200) from the Japan Society for the Promotion of Science. No other potential conflict of interest relevant to this article was reported.

The authors thank Ms. Yoshiko Nakata, Ms. Mika Wagatsuma, Ms. Naoko Sato, and Ms. Yuki Takeda, Division of Epidemiology, Department of Public Health and Forensic Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan, for their technical assistance.

References

Aida, J., Ando, Y., Akhter, R., Aoyama, H., Masui, M., Morita, M., 2006. Reasons for permanent tooth extractions in Japan. J. Epidemiol. 16, 214–219.

Axelsson, G., Helgadóttir, S., 1995. Comparison of oral health data from self-administered questionnaire and clinical examination. Community Dent. Oral Epidemiol. 23, 365–368.

Bahekar, A.A., Singh, S., Saha, S., Molnar, J., Arora, R., 2007. The prevalence and incidence of coronary heart disease is significantly increased in periodontitis: a meta-analysis. Am. Heart J. 154, 830–837.

Dietrich, T., Joshipura, K.J., Dawson-Hughes, B., Bischoff-Ferrari, H.A., 2004. Association between serum concentrations of 25-hydroxyvitamin D3 and periodontal disease in the US population. Am. J. Clin. Nutr. 80, 108–113.

Douglass, C.W., Berlin, J., Tennstedt, S., 1991. The validity of self-reported oral health status in the elderly. J. Public Health Dent. 51, 220–222.

Elter, J.R., Offenbacher, S., Toole, J.F., Beck, J.D., 2003. Relationship of periodontal disease and edentulism to stroke/TIA. J. Dent. Res. 82, 998–1001.

Hamilton-Miller, J.M.T., 2001. Anti-cariogenic properties of tea (*Camellia sinensis*). J. Med. Microbiol. 50, 299–302.

Hanioka, T., Ojima, M., Tanaka, K., Aoyama, H., 2007. Relationship between smoking status and tooth loss: findings from national databases in Japan. J. Epidemiol. 17, 125–132.

Heitmann, B.L., Gamborg, M., 2008. Remaining teeth, cardiovascular morbidity and death among adult Danes. Prev. Med. 47, 156–160.

Hirasawa, M., Takada, K., Makimura, M., Otake, M., 2002. Improvement of periodontal status by green tea catechin using a local delivery system: a clinical pilot study. J. Periodontal Res. 37, 433–438.

Hirasawa, M., Takada, K., Otake, S., 2006. Inhibition of acid production in dental plaque bacteria by green tea catechins. Caries Res. 40, 265–270.

Hung, H.-C., Willett, W., Ascherio, A., Rosner, B.A., Rimm, E., Joshipura, K.J., 2003. Tooth loss and dietary intake. JADA 134, 1185–1192.

Jones, C., Woods, K., Whittle, G., Worthington, H., Taylor, G., 1999. Sugar, drinks, deprivation and dental caries in 14-year-old children in the north west of England in 1995. Community Dent. Health 16, 68–71.

Joshipura, K.J., Willett, W., Douglass, C.W., 1996. The impact of edentulousness on food and nutrient intake. JADA 127, 459–467.

Klein, B.E., Klein, R., Knudtson, M.D., 2004. Life-style correlates of tooth loss in an adult midwestern population. J. Public Health Dent. 64, 145–150.

Kuriyama, S., Shimazu, T., Ohmori, K., et al., 2006a. Green tea consumption and mortality due to cardiovascular disease, cancer, and all causes in Japan: the Ohsaki study. JAMA 296, 1255–1265.

Kuriyama, S., Hozawa, A., Ohmori, K., et al., 2006b. Green tea consumption and cognitive function: a cross-sectional study from the Tsurugaya Project. Am. J. Clin. Nutr. 83, 355–361.

Kuriyama, S., Nakaya, N., Ohmori, K., et al., 2009. Factor associated with psychological distress as measured by the K6 scale in a community-dwelling population: a cross-sectional study from the Ohsaki Cohort 2006 Study. J. Epidemiol. 19, 294–302.

Ogawa, K., Tsubono, Y., Nishino, Y., et al., 2003. Validation of a food-frequency questionnaire for cohort studies in rural Japan. Public Health Nutr. 6, 147–157.

Okamoto, Y., Tsuboi, S., Suzuki, S., et al., 2006. Effects of smoking and drinking habits on the incidence of periodontal disease and tooth loss among Japanese males: a 4-yr longitudinal study. J. Periodontal Res. 41, 560–566.

Ooshima, T., Minami, T., Aono, W., Tamura, Y., Hamada, S., 1994. Reduction of dental plaque deposition in humans by oolong tea extract. Caries Res. 28, 146–149.

Otake, S., Makimura, M., Kuroki, T., Nishihara, Y., Hirasawa, M., 1991. Anticaries effects of polyphenolic compounds from Japanese green tea. Caries Res. 25, 438–443.

Pischon, N., Heng, N., Bernimoulin, J.-P., Kleber, B.-M., Willich, S.N., Pishon, T., 2007. Obesity, inflammation, and periodontal disease. J. Dent. Res. 86, 400–409.

Pitiphat, W., Garcia, R.I., Douglass, C.W., Joshipura, K.J., 2002. Validation of self-reported oral health measures. J. Public Health Dent. 62, 122–128.

Pitiphat, W., Merchant, A.T., Rimm, E.B., Joshipura, K.J., 2003. Alcohol consumption increases periodontitis risk. J. Dent. Res. 82, 509–513.

Sakanaka, S., Okada, Y., 2004. Inhibitory effects of green tea polyphenols on the production of a virulence factor of the periodontal-disease-causing anaerobic bacterium *Porphyromonas gingivalis*. J. Agric. Food Chem. 52, 1688–1692.

SAS Institute Inc., 2004. SAS/STAT User's Guide, release 9.1 edition. SAS Institute Inc, Cary, NC.

Shimada, K., Kawarabayashi, T., Tanaka, A., et al., 2004. Oolong tea increases plasma adiponectin levels and low-density lipoprotein particle size in patients with coronary artery disease. Diabetes Res. Clin. Pract. 65, 227–234.

Shimazaki, Y., Soh, I., Saito, T., et al., 2002. Influence of dentition status on physical disability, mental impairment, and mortality in institutionalized elderly people. J. Dent. Res. 80, 340–345.

Smullen, J., Koutsou, G.A., Foster, H.A., Zumbe, A., Storey, D.M., 2007. The antibacterial activity of plant extracts containing polyphenols against *Streptococcus mutans*. Caries Res. 41, 342–349.

Socransky, S.S., Haffajee, A.D., 2002. Dental biofilms: difficult therapeutic targets. Periodontology 2000 28, 12-55.

Susin, C., Oppermann, R.V., Haugejorden, O., Albandar, J.M., 2005. Tooth loss and associated risk indicators in an adult urban population from south Brazil. Acta Odontol. Scand. 63, 85–93.

Tanaka, K., Miyake, Y., Sasaki, S., et al., 2008. Beverage consumption and the prevalence of tooth loss in pregnant Japanese women: the Osaka Maternal and Child Health Study. Fukuoka Acta Medica 99, 80–89.

Tu, Y.-K., Galobardes, B., Smith, G.D., McCarron, P., Jeffreys, M., Gilthorpe, M.S., 2007. Associations between tooth loss and mortality patterns in Glasgow alumni cohort. Heart 93, 1098–1103.

Willett, W., 1994. Diet and health: what should we eat? Science 264, 532–537.

Please cite this article as: Koyama, Y., et al., Association between green tea consumption and tooth loss: Cross-sectional results from the Ohsaki Cohort 2006 Study, Prev. Med. (2010), doi:10.1016/j.ypmed.2010.01.010