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ARTICLES

Research Articles

Full Length Research Paper

Levels of prostaglandin E₂ (PGE₂) in gingival crevicular fluid from smokers and non-smokers with gingivitis and chronic periodontal disease

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The aim of this study was to evaluate the levels of prostaglandin E₂ (PGE₂) on the gingival crevicular fluid (GCF) of smokers (light and heavy) and non-smokers with gingivitis (G) and chronic periodontal disease (CPD). Forty-five patients were selected: 15 heavy smokers whose daily tobacco consumption was more than 10 cigarettes/day (HS), 15 light smokers whose daily tobacco consumption was fewer than 10 cigarettes/day (LS), and 15 non-smokers who had never smoked tobacco (NS). Clinical periodontal parameters (plaque index (PI), bleeding on probing (BOP), probing depth (PD), gingival recession (GR), and clinical attachment level (CAL)) were recorded for all groups. Each group was separated in both sites: G and CPD, and GCF samples were collected, and analyzed for PGE₂ content by enzyme-linked immunosorbent assay. The results indicated that the non-smoking group had higher PI (88.53±17.08%) and BOP (82.80±17.14%) scores than the two smoking groups. PD, GR and CAL scores did not differ significantly among the three groups. Statistically significance differences in GCF-PGE₂ were found among G versus CPD sites (P≤0.05) for the three groups. This study confirms that heavy and light smokers have less BOP and GCF-PGE₂ levels than non-smokers and that the GCF-PGE₂ was higher to CPD sites when compared with G sites.

Key words: Periodontal disease, gingival crevicular fluid, smoker, prostaglandin E₂.

INTRODUCTION

Periodontal disease is a local inflammation in the tissues that support the teeth, which leads to progressive loss of periodontal ligament tissue and bone. Periodontal destruction is directly related to smoking (Gera, 1999).

Several reports have shown that the prevalence and severity of periodontitis is significantly higher in smokers than in non-smokers (Bernzweig et al., 1998). This high risk of periodontal disease is due to systemic and local

effects of nicotine, a major component of cigarette smoke. There is evidence that nicotine may distort the clinical signs and symptoms of periodontal inflammation (e.g. periodontal bleeding, erythema and edema), indicating a suppressive influence of smoking on inflammatory responses (Bernzweig et al., 1998; Boström et al., 1998; Bergström et al., 2000). Other factors, such as the type of tobacco product, amount consumed and duration of exposure to tobacco, can exacerbate the periodontal destructive effects of tobacco (Schuller and Holst, 2001).

The relationship between tobacco and the pathogenesis of periodontal disease is less clear. Cigarette smoking is known to affect systemic and local immune responses. Prostaglandin E_2 (PGE_2), a pro-inflammatory mediator synthesized from cell membrane phospholipids by the action of cyclooxygenase enzyme, is considered a key inflammatory mediator in periodontal disease and is associated with periodontal disease progression and alveolar bone resorption (Bernzweig et al., 1998). The levels of PGE_2 in the gingival crevicular fluid (GCF) of individuals with periodontitis are elevated when compared with normal subjects, a situation believed to arise from the stimulation of PGE_2 secretion from peripheral mononuclear cells (monocytes and lymphocytes) by nicotine (Bernzweig et al., 1998). However, few studies have quantitatively analyzed the effects of cigarette smoking on PGE_2 levels in GCF or whether the daily dose of tobacco in smokers is correlated with PGE_2 secretion.

Thus, this study hypothesized that cigarette smokers have high levels of prostaglandin E_2 (GCF-PGE_2) expressed in the GCF in gingivitis and periodontitis sites. Based on this, the objective of this study was to evaluate the levels of prostaglandin E_2 (GCF-PGE_2) in the GCF of each group heavy, light and non-smokers according to gingivitis and periodontitis sites.

MATERIALS AND METHODS

Forty-five patients were recruited for this study and were distributed into three groups: 15 heavy smokers, with consumption of more than 10 cigarettes/day (HS); 15 light smokers, with consumption of less than 10 cigarettes/day (LS); and 15 non-smokers, who had never smoked (NS) (Coady et al., 2012). All subjects were recruited from the Department of Periodontology, School of Dentistry, Fluminense Federal University, Nova Friburgo, Rio de Janeiro, over a period of 6 months between 2010 and 2011. The study protocol was approved (protocol number, CAAE - 0070.0.258.000-10) by the ethics committee of the Fluminense Federal University School of Medicine. Prior to participation, the purpose and procedures were fully explained to all patients, who consequently gave written informed consent in accordance with the Helsinki Declaration. Medical and dental histories were taken and patients received clinical evaluation at prescreening visits. Inclusion criteria were: presence of periodontal disease and bleeding on probing in sites where probing depth was ≥5 mm; and radiographic bone loss ranging from 30 to 50%, diagnosis of chronic periodontal disease; however, patients had sites with gingivitis and periodontitis. Exclusion criteria were: patients with systemic diseases, diabetes, osteoporosis; pregnant lactating females; use of immune suppressive medication, phenytoin, cyclosporine, calcium channel

blockers or any use of antibiotics or nonsteroidal anti-inflammatory drugs in the past 3 months; and any medical conditions requiring immunotherapy or diagnosed as HIV+ or with AIDS that could interfere with the periodontium.

The selected patients reported the age, mean of daily tobacco consumption and the time-span over which they had been smoking (years). An experienced periodontist determined the number of sites presenting with periodontal disease and evaluated the clinical parameters using a PCP15 (PCP-UNC15, Hu-Friedy, Chicago, IL) periodontal probe at six sites per tooth for all teeth, excluding third molars. Additionally, the following parameters were recorded: plaque index (PI), bleeding on probing (BOP), probing depth (PD), gingival recession (GR), and clinical attachment level (CAL).

After one week, the collections of the samples were performed. The supragingival biofilm was removed with sterile gauze and the sites dried gently with an air syringe and isolated with cotton rolls. GCF samples were taken from two different sites from the same patient from different groups: G = gingivitis sites, the deepest PD were ≤3 mm, bleeding on probe and chronic periodontal disease (CPD) = periodontitis sites, the deepest PD were ≥5 mm, each patient had both conditions. All patients were allocated in groups: NS, LS and HS. GCF samples were obtained by placing calibrated, volumetric microcapillary pipette of internal diameter of 1.1 mm with a capacity of 5 µl. Sites which did not express appropriate volume of fluid and micropipettes which were contaminated with blood and saliva were not included in the study (Koregol et al., 2011). The GCF was immediately placed into separate tubes containing 250 µl phosphate-buffered saline. The samples were stored at -20°C for subsequent assays. The samples were analyzed by a single-blinded examiner using a commercial PGE_2-specific enzyme-linked immunosorbent assay (R&D Systems, Minneapolis, MN, USA).

Statistical analysis

The required sample size was determined by G*Power (G*Power, Franz Faul, Kiel University, Germany, Version 3.1.2, 2009) and was calculated to detect a 0.05 difference between PI (NS group) and PI (HS group) with power level of 89%. The power calculation analysis revealed that the required sample size was a minimum of 15 subjects for each study group. The primary efficacy variables were whole-mouth mean PI (NS group) and PI (HS group).

Statistical analysis was performed on data obtained from all patients who completed the trial. The decision about whether to use parametric or nonparametric tests was made based on the results of Shapiro-Wilk Normality Test for normal distribution. Statistical tests were performed using the Statistix software (Analytical Software, Tallahassee, FL, USA, Version 8.0, 2003). A two-sample T-test was performed to compare clinical parameters (PI, BOP, PD, GR and CAL) among NS, LS and HS groups. Comparison between groups was considered (NS × LS, NS × HS and LS × NS) to test variables age, total sites, number of sites with PD, daily cigarette consumption, duration of consumption, number of missing teeth, PI and BOP were considered to full mouth. PD, GR and CAL were analyzed according to G and CPD sites. All variables were normally distributed, except GCF-PGE_2. The Mann Whitney test was used to analyze differences in GCF-PGE_2 levels among G versus PD and NS, LS and HS groups. Statistical significance for all variables was defined as $p \leq 0.05$.

RESULTS

Descriptive statistics of each variable measured (mean ± standard deviation, with statistical significance assessed by two-sample T-test) are shown in Table 1. Statistically significant differences in the number of sites with

Table 1. Clinical parameters of members of the heavy smoker (HS), light smoker (LS) and non-smoker (NS) groups with gingivitis (G) and chronic periodontal disease (CPD).

Parameter	NS (n=15)	LS (n=15)	HS (n=15)
Age	48.27 ± 9.27	33.93 ± 10.53	38.53 ± 12.68
Total sites	134.0 ± 20.74	137.2 ± 27.01	133.2 ± 22.92
Number of sites with PD	40.93 ± 32.62	12.53 ± 14.6*	15.33 ± 8.34[†‡]
Mean daily cigarette consumption	N/A	7.93 ± 2.46	19.66 ± 7.02[‡]
Duration of consumption (years)	N/A	14.53 ± 10.94	20.46 ± 13.09
Mean number of missing teeth	9.66 ± 3.43	9.13 ± 4.15	9.8 ± 3.82
PI (%)	88.53 ± 17.08*	68.66 ± 33.33	91.73 ± 17.44[†]
BOP (%)	82.80 ± 17.14*	44.33 ± 30.37	42.2 ± 28.33[‡]
PD (mm)			
G	1.93 ± 0.78	2.2 ± 0.56	2.73 ± 0.46
CPD	5.13 ± 0.35	5.0 ± 0.0	5.0 ± 0.0
GR (mm)			
G	0	0	0
CPD	0.733 ± 0.96	0.86 ± 0.99	1.33 ± 1.04
CAL (mm)			
G	1.93 ± 0.78	2.2 ± 0.56	2.73 ± 0.46
CPD	6.2 ± 1.26	5.87 ± 0.99	6.47 ± 1.12

Data are means ± standard deviation. Statistical testing was by two-sample T-test. *[†‡]Statistically significant differences (p≤0.05) between the NS and LS groups, NS and HS groups, and LS and HS groups, respectively. PI: Plaque index; BOP: bleeding on probing; PD: probing depth; CAL: clinical attachment level; N/A: not applicable.

periodontal disease were observed in comparisons between the NS and LS groups (p=0.0024), the NS and HS groups (p<0.0001) and the LS and HS groups (p<0.0221). For the mean daily cigarette consumption, a statistically significant difference was observed between the LS and HS groups (p=0.0002). PI was significantly different between the NS and LS (p=0.0088) and NS and HS (p=0.0106) groups, with the highest mean PI being in the HS group (PI=91.73%), followed by the NS (88.53%) and LS (68.66%) groups, respectively. BOP was signi-ficantly different between the NS and LS (p=0.0202) and NS and HS (p=0.0202) groups, with the rank order of mean BOP values being NS (BOP=82.80%) > LS (44.33%) ≥ HS (42.2%). No significant differences among the groups were found for the PD, GR and CAL. However, significantly statistical difference was found between the G and CPD sites (p≤0.0001) to PD and CAL to NS, LS and HS sites.

GCF-PGE$_2$ production in each subject in the three groups is shown in Figure 1. Differences among groups and sites G versus CPD were assessed by Mann-Whitney test. Statistically significant difference in GCF-PGE$_2$ levels was detected when comparing NS versus LS (p=0.0576), NS was higher than LS and NS into G groups, and NS versus LS (*p*=0.0576), also NS was higher than HS group into CPD sites. Comparisons

among sites were HS/G versus HS/CPD (p=0.0002), LS/G versus LS/CPD (p=0.0158) and NS/G versus NS/CPD (p=0.0382). Periodontal disease sites showed higher levels of GCF-PGE$_2$ when they were compared to G sites.

DISCUSSION

The objective of this study was to evaluate the influence of smoking on the levels of prostaglandin E$_2$ (GCF-PGE$_2$) in the gingival crevicular fluid of heavy, light and non-smokers according to G and CPD sites. This study revealed changes in the GCF-PGE$_2$ levels between G and PD sites when comparisons were done for HS, LS and NS groups.

The samples were characterized by daily cigarette and number of consumption by years. High daily consumption of tobacco and long history of consumption have been shown to increase periodontal destruction compared with non-smokers or patients that has sporadic tobacco consumption (Bergström et al., 2000). In this study, HS group exhibited the high number of sites with probing depth higher than 5 mm in full mouth periodontal evaluations. Daily and duration consumption of cigarette were higher to HS followed by LS group to confirm the
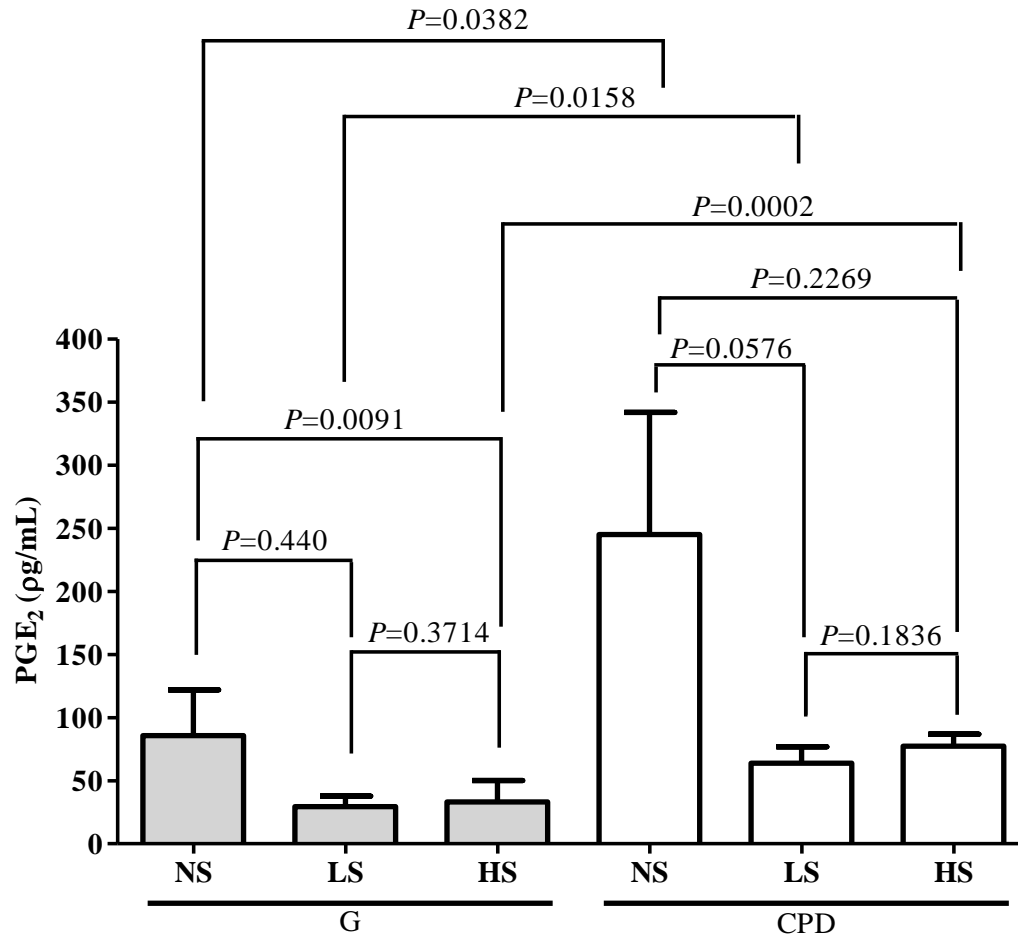
Figure 1. Levels of PGE$_2$ (pg/ml) at GCF, considering different groups: non-smokers (NS), light smokers (LS) and heavy smokers (HS) with gingivitis (G) and chronic periodontal disease (CPD). Statistically significant differences in PGE$_2$ levels were detected among any of these groups (P≤0.05, Mann-Whitney Test).

profile of the groups. However, no differences between age, PD, GR and CAL were found for the three groups (Table 1).

The smoking habit should increase teeth loss in smokers compared to non-smokers (Haffajee and Socransky, 2001; Chen et al., 2001). Previous studies have shown a high means of numbers of missing teeth to smokers (5.1) than non-smokers (2.8), respectively (Krall et al., 1999; Albandar et al., 2000). However, this study found higher means to missing teeth than previous study, but no statistically significant differences were found between the three groups (Table 1).

The comparisons for plaque index are controversial in the literature to smokers and non-smokers (Haffajee and Socransky, 2001; Chen et al., 2001). Studies have shown that cigarette smokers have more calculus and more plaque than non-smokers (Feldman et al., 1983; Luzzi et al., 2007), others reported similar plaque index between smokers and non-smokers (Gomes et al., 2007). However, this study shows that PI was different between

groups; HS had higher means than NS followed by LS groups (Table 1).

Bleeding on probe has been reported to be higher in non-smokers than in smokers (Ah et al., 1994; Bergström and Preber, 1986). Previous report showed that various symptoms of periodontal inflammation (e.g. gingival bleeding, erythema and edema) can be suppressed by smoking owing to its inhibitory action on the inflammatory response. Cytotoxic and vasoactive substances, including nicotine, are responsible for this local effect but can also cause systemic effects including the inhibition of peripheral blood and oral neutrophils and reduced antibody production (Van der Weijden et al., 2001; Matthews et al., 2011). This study according to these results, BOP was higher to NS group than HS and LS groups.

Clinical periodontal parameters were investigated in the three groups (Table 1). No difference among groups was noted for periodontal parameters PD, GR and CAL. Various studies have reported that attachment loss is

higher in smokers than non-smokers (Feldman et al., 1983; Bergström et al., 1991; Haffajee and Socransky, 2001; Kerdvongbundit and Wikesjö, 2002; Jansson and Hagström, 2002; Gonzalez et al., 2009; Guarnelli et al., 2010; Rudziński, 2010), because smoking suppressed the system of host defense against the bacterial products of the biofilm and increased the risk of suffering extensive and severe alveolar bone loss. However, in this study, no differences were found to PD and CAL for the three groups, due to the fact that all patients had previous diagnosis of chronic periodontal disease.

Despite of this fact, we decided to separate the periodontal disease sites in subgroups, gingivitis (G) and periodontitis (CPD) sites to investigate the GCF-PGE$_2$ levels per sites. Statistically significance difference confirmed the differences between PD and CAL to gingivitis (G) and periodontitis (CPD) sites (Table 1). Subgroups were characterized by sites with probing depth ≤ 3 mm, gingivitis sites or sites with periodontitis, probing depth ≥ 5 mm, all sites bleeding on probe. The level of PGE$_2$ in the GCF was measured to reveal differences among the three groups.

PGE$_2$ was selected because it is one of the most important biochemical mediators of periodontal inflammation and plays a significant role in the pathogenesis of periodontal disease. PGE$_2$ stimulates bone resorption and it is expected to increase in GCF samples from periodontal sites compared with healthy and gingivitis sites (Offenbacher et al., 1986; Preshaw and Heasman, 2002). This study is in agreement with previous reports and finds differences of GCF-PGE$_2$ levels among G versus CPD sites disease (Preshaw and Heasman, 2002; Kurtiş et al., 2007). GCF-PGE$_2$ levels of CPD sites were higher than G group. Differences were found among NS and HS for G group and NS and LS in CPD group. No differences were found among LS and HS groups. These results are similar to previous studies that found no differences in GCF-PGE levels between smokers and non-smokers in adults with periodontal disease (Preshaw and Heasman, 2002; Kurtiş et al., 2007).

Indeed, our findings suggest that tobacco inhibit the PGE$_2$ release when G and CPD sites were compared (Figure 1). NS had higher levels of GCF-PGE$_2$ compared to HS and LS groups. Periodontitis sites (CPD) had higher PGE$_2$ levels than gingivitis sites (G). These results according to literature suggest the evidence that periodontal disease increase PGE$_2$ levels (Sánchez et al., 2013). Recent study with cell culture shows that tobacco has a detrimental effect on periodontal repair and PGE$_2$ levels are diminished in cells stimulated by cigarette smoke condensate (CSC) (Romero et al., 2014). However, further evidence of the effects of smoking on the PGE$_2$ release is necessary to demonstrate the effects of nicotine on the periodontal tissues.

Conclusion

Based on these findings, HS did not exhibit high levels of GCF-PGE$_2$ compared to LS and HS. However, non-smokers had higher levels of GCF-PGE$_2$. Indeed, this study confirmed that periodontal disease (CPD sites) exhibits higher GCF-PGE$_2$ levels compared to gingivitis (G sites), suggesting that periodontal disease can improved the GCF-PGE$_2$ levels.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Full Length Research Paper

Patients' awareness of the relationship between smoking and periodontal diseases in Kingdom of Saudi Arabia

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The aim of this study was to investigate the patients' awareness of the effects of smoking on periodontal health in Kingdom of Saudi Arabia (KSA), and to compare with similar studies in UK and Nigeria. This cross-sectional survey was conducted on a convenience sample of 600 patients attending dental clinics of Riyadh Colleges of Dentistry and Pharmacy in 2014 using anonymous, self-completed, questionnaires. The questionnaire included mainly closed-ended questions such as smoking status, duration, frequency, type, level of awareness, and demographics. Descriptive statistics and Chi-square test was performed to analyze the data. 95.7% patients were aware that smoking had a negative impact on oral health. Majority of the patients were aware that smoking causes oral cancer and stains. 11.3% (n=68) stated that smoking affected the gums. Only 4.3% (n=26) of the respondents knew specifically of the link between smoking and periodontal disease. There was a statistically significant relation between awareness of the effects of smoking on oral health with gender, nationality, and smoking status (p < 0.05). This study highlights patients' lack of awareness of the relationship between smoking and periodontal diseases, with only 4.3% of the respondents knowing of the link. This finding closely resembles those of the UK and Nigerian study.

Key words: Smoking, periodontal disease, awareness.

INTRODUCTION

Tobacco use has been associated to affect oral health from tooth staining to oral cancer (Bloom et al., 2012). Smoking is considered to be a significant risk factor for periodontal disease and its clinical effects depends on the number of cigarettes smoked daily and the duration of the habit (Ramón and Echeverría, 2002; Scabbia et al., 2001). There are substantial scientific evidence of the harmful long term effects of smoking on periodontal disease (Chang et al., 2002). Periodontal diseases can affect the function of the dentition, dental appearance, and loss of teeth (Albandar et al., 2000).

Despite several studies on the association between smoking and periodontal disease (Bergström et al., 2000; Johnson and Guthmiller, 2007; Natto et al., 2005), very

few have reported on the awareness of this among patients. A study in United Kingdom (UK) (Lung et al., 2005) highlighted patients' lack of awareness of the relationship between smoking and periodontal disease, with only 6% of respondents knowing the relationship. Another study in Nigeria (Nwhator et al., 2014) reported that the level of awareness of a link between smoking and periodontal disease was extremely low (2.2%). The level of awareness in the UK, a country with a very long history of good dental care, was also considered to be low.

Although smoking in Kingdom of Saudi Arabia (KSA) is considered socially undesirable for religious and cultural reasons, a high prevalence was seen (Al-Khashan et al., 2014). This ranged from 2.4 to 52.3%, with male ranging from 13 to 38% and female from 1 to 16% (Bassiony, 2009). Studies in the past focused on dental students and dentists' knowledge and stressed more on oral cancer than other oral health related aspects. However, no study has reported on the knowledge of the patients on the link between smoking and periodontal diseases in KSA. The aim of this study was to investigate patients' awareness of the effects of smoking on periodontal health in KSA, and to compare the findings with similar studies of UK and Nigeria.

MATERIALS AND METHODS

The ethics committee in Riyadh Colleges of Dentistry and Pharmacy approved the protocol and the questionnaire instrument for this study. This cross-sectional survey was conducted in 2014 on patients attending dental clinics of Riyadh Colleges of Dentistry and Pharmacy using self-completed questionnaires. Questionnaires were distributed to 1000 patients of whom 600 were completed and returned, giving an overall response rate of 60%. The questionnaires were distributed by the dental hygiene students to the patients attending dental clinics and were completed in the waiting room. Two pages of mainly closed-ended questions with options in simple English and Arabic were completed by these patients. The patients who completed the questionnaires represented a convenience sample.

A completed questionnaire indicated the consent to participate in the study. Anonymity and confidentiality were assured and there were no personal identifiers on the questionnaire. Information requested in the questionnaires included smoking status, duration, frequency, type of smoking, and their knowledge about how smoking affects oral health. Demographics details included were age, gender, and nationality. The quantitative data was entered onto computer for analysis using Statistical Package for Social Science (SPSS) Version 18 for Windows. Descriptive analysis was undertaken to present an overview of the findings. Univariate analysis was used to assess the association of each variable with awareness. Differences between groups were examined using the chi-square test (Pearson, Fisher's exact test). Corresponding p values from statistical tests were considered statistically significant at values of $p \leq 0.05$.

RESULTS

The mean age of the respondents was 29.9 ± 9.0 years. 67.5% (n=405) of the respondents were male and 32.5%

(n=195) were female. The mean age of the males (31.8 ± 8.7 years) were higher than the females (26 ± 8.7 years) and was statistically significant (p<0.05). There was no significant difference between age and smoking status. Almost three quarter of the respondents were Saudi nationals (74%, n=444). Just under half the respondents (46.0%, n=276) were smokers. Amongst the smokers, majority consumed cigarettes (72.5%, n=200) followed by sheesha (27.5%, n=76). 42% (n=116) of the smokers consumed more than ten cigarettes a day and 58% (n=160) consumed less than ten cigarettes a day. 72.1% (n=199) of the smokers smoked for more than five years and 27.9% (n=77) smoked for less than five years. There was a statistical significant relation between gender and smoking status, type of smoking, frequency of smoking per day, and years of smoking (p < 0.05) (Table 1).

95.7% (n=574) of the respondents were aware that smoking can affect their oral health and all the respondents were aware that smoking is not good for general health. Majority of the respondents were aware that smoking causes oral cancer (34.7%, n=208) and stains (33.5%, n=201). 11.3% (n=68) of the respondents stated that they were aware that smoking affected the gums and only 4.3% (n=26) were aware that smoking causes tooth loss (Figure 1). Chi-square test showed a statistically significant relation between awareness of the effects of smoking on oral health with gender, nationality, and smoking status (p < 0.05). Males, Saudi nationals, and smokers were more likely to be aware that smoking causes oral cancer and inflammation of gums. Whereas, females, non-Saudis, and non-smokers were more likely to be aware that smoking causes stains and bad breath (Table 2).

DISCUSSION

This cross-sectional study examined the awareness among patients on the effects of smoking on periodontal health in KSA. All the respondents in this study were aware that smoking was not good for health and 95.7% were aware that smoking can affect their oral health. Females were more aware of the association between smoking and oral health than males. Smokers constituted 46% of the study sample and majority consumed cigarettes (72.5%). 34.7% were aware that smoking causes oral cancer and only 4.3% stated that smoking caused periodontal disease. This study was conducted on a convenience sample of patients attending dental clinics of a private dental school and hence most of the subjects belonged to a selected group, including people more aware of and more likely to be able to afford dental services. The findings thus may not reflect the perceptions of the general population in KSA.

This study emphasizes patients' lack of awareness of the relationship between smoking and periodontal disease, with only 4.3% of respondents knowing the link. The findings closely resemble that of previous studies in

Table 1. Smoking habits in relation to gender.

Variable		Gender		Total	p value
		Male [% (n)]	Female [% (n)]	[% (n)]	
Smoking status (n=600)	Smokers	91.7 (253)	8.3 (23)	46.0 (276)	0.000
	Non-smokers	46.9 (152)	53.1 (172)	54.0 (324)	
Smoking type (n=276)	Cigarette	95.0 (190)	5.0 (10)	72.5 (200)	0.003
	Sheesha	82.9 (63)	17.1 (13)	27.5 (76)	
Frequency of smoking (n=276)	<10/day	87.5 (140)	12.5 (20)	58.0 (160)	0.003
	>10/day	97.4 (113)	2.6 (3)	42.0 (116)	
Years of smoking (n=276)	<5 years	84.4 (65)	15.6 (12)	27.9 (77)	0.013
	>5 years	84.4 (168)	15.6 (11)	72.1 (199)	

Table 2. Awareness on the effects of smoking on oral health in relation to gender, nationality, and smoking status.

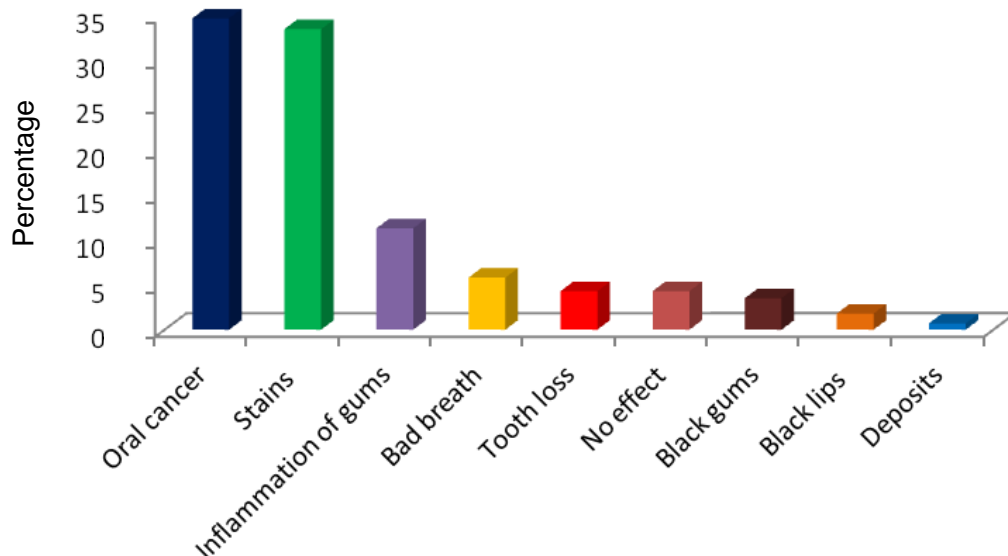| Effects of smoking on oral health	Gender		Nationality		Smoking status	
	Male [% (n)]	Female [% (n)]	Saudi [% (n)]	Non-Saudi [% (n)]	Smoker [% (n)]	Non-smoker [% (n)]
Tooth loss	4.2 (17)	4.6 (9)	4.7 (21)	3.2 (5)	3.6 (10)	4.9 (16)
Stains	27.2 (110)	46.7 (91)	29.3 (130)	45.5 (71)	33.8 (93)	33.2 (108)
Oral cancer	39.7 (161)	24.1 (47)	36.0 (160)	30.7 (48)	40.0 (110)	30.2 (98)
Inflammation of gums	13.1 (53)	7.7 (15)	13.8 (61)	4.5 (7)	12.8 (35)	10.2 (33)
Bad breath	3.2 (13)	11.3 (22)	5.6 (25)	6.4 (10)	2.5 (7)	8.6 (28)
Black lips	2.0 (8)	1.5 (3)	1.8 (8)	1.9 (3)	1.8 (5)	1.8 (6)
Black gums	4.6 (19)	1.0 (2)	3.8 (17)	2.6 (4)	3.6 (10)	3.4 (11)
Deposits	0.0 (0)	2.1 (4)	0.0 (0)	2.6 (4)	0.4 (1)	0.9 (3)
No effect	6.0 (24)	1.0 (2)	5.0 (22)	2.6 (4)	1.5 (4)	6.8 (22)
p value	0.000		0.000		0.001	

Figure 1. Awareness on the effects of smoking on oral health.

UK and Nigeria (Lung et al., 2005; Nwhator et al., 2014). Hence, the current low level of awareness of the relationship between smoking and periodontal diseases in KSA (4.3%), Nigeria (2.2%), and UK (6%) indicates a universal problem. By implication, the real situation in KSA could be worse than the already appalling picture.

In the current study, the awareness among patients about the oral cancer was good in comparison with the previous studies (Al-Shammari et al., 2006; Sood et al., 2014; Terrades et al., 2009). However, statistically, many more patients will be affected by periodontal diseases than oral cancer.

This study suggests that smoking cessation should be stressed to improve periodontal health and reduce tooth loss among smokers. Dental health campaigns must run awareness programs on the well proved association of smoking and periodontal diseases. Moreover, dental practitioners should play a crucial role in terms of advising and supporting the patients in smoking cessation during regular dentist visits. The dental team could identify the patients willing to stop smoking and guide them to specialist smoking cessation advice centers. It is recommended to conduct further surveys among the general population covering different age groups and comparative studies in other populations to determine the validity of these results.

Conflict of interest

The author declares no conflict of interest.

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Full Length Research Paper

Quality of root canal filling performed by undergraduate students in a Saudi Dental College

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The aim of this study was to evaluate the outcomes of teaching endodontics to undergraduate students at Riyadh Colleges. This study was undertaken by assessing the technical quality of root canal obturation and the presence of procedural errors in root canal treatment cases performed by the final year dental students in clinics. All of the root canal treatment cases performed by the final year dental students in the 2nd semester of 2012 to 2013 were examined, with a total of 450 root canals from 241 teeth. The quality of root canal obturation was examined in relation to the length of the root filling based on the radiographic apex, the density of the obturation according to the presence of voids, and the taper of root canal fillings. The overall acceptable quality of the evaluated root canals was 36%. Of these canals, acceptable length, density, and taper were reported in 76.6, 46.4, and 73.8%, respectively. Overall, 9.3% of the treated root canals had procedural errors, and majority of these errors were found in canals of posterior mandibular teeth. Apical transportation was the most encountered error; it was found in 3.1% of the treated canals. The technical quality of the root canal treatments conducted by the students in this study was comparable to other studies. However, introducing new techniques and armamentaria might improve this quality.

Key words: Technical quality of obturation, undergraduate education, evaluation, education development.

INTRODUCTION

Endodontic treatment is an essential component of comprehensive dental therapy; it acts as a foundation for other successive treatments such as post and core. Additionally, the interrelationship between pulpal and periodontal tissues is well known, and failure in endodontic therapy can lead to significant damage of the surrounding periodontal tissues (Dugas et al., 2003). The success of endodontic therapy is remarkably affected by the radiographic technical quality of the canal(s) obturation (Boucher et al., 2002).

The technical quality of root canal therapy is best assessed by radiograph (Tsuneishi et al., 2005). The European Society of Endodontology (2006) considered root canal therapy to be acceptable when it shows a root canal filling of 0 to 2 mm shorter than the radiographic apex, dense without voids, and consistently tapered. Furthermore, this society expected graduating students to be competent at doing safe root canal therapy on single and multi-rooted teeth, in addition to thoroughly understanding the iatrogenic mishaps that might happen

and the way to manage and prevent such accidents. Yet, internationally, in "Competencies for the New General Dentist" by the American Dental Education Association (ADEA, 2011), and in "Profile and Competencies for the Graduating European Dentist: Update 2009" (Cowpe et al., 2010), and also nationally in "Learning Outcomes for Bachelor Degree Programs in Dentistry" by the National Commission for Academic Accreditation and Assessment (NCAAA, 2011), the set expectation is that dentists strive to achieve the total health of their patients through oral health management without supervision. Those skills should be taught to students during their undergraduate studies.

Learning outcomes should be evaluated to determine whether the graduates of dental institutes meet those expected competencies. Several models of evaluation have been used in the educational context to evaluate the final outcomes of learners. Among them is Stufflebeam's CIPP model, which stands for evaluations of an entity's context, inputs, processes, and products. The purpose of product evaluation is to identify and assess the outcomes, either intended or unintended (Stufflebeam and Shinkfield, 2007).

Evaluation of the technical quality of root canal obturation, which is the outcome of teaching endodontics in the undergraduate stage, has been done in several countries for both undergraduate students and general practitioners. The results in most studies have shown inadequate quality of root canal obturation (Tables 1 and 2). In Saudi Arabia, three studies were conducted to evaluate the quality of root canal treatments done by undergraduate students (Al-Yahya, 1990; Al-Kahtani, 2009; Balto et al., 2010).

At Riyadh Colleges of Dentistry and Pharmacy, Saudi Arabian undergraduate students take the pre-clinical training of endodontics in two courses through two semesters, one course in level 6 and the other in level 7. At this stage, the students are requested to complete root canal treatment on extracted teeth for two anterior teeth, two premolars, and two molars. The primary technique of root canal instrumentation is the step-back technique using hand files with Gates Glidden to provide a straight line access, and the cold lateral condensation technique for obturation. Thereafter, students start clinical practice of root canal therapy for a variety of teeth for five successive semesters.

The aim of this study was to evaluate the outcomes of teaching endodontics to the undergraduate students at Riyadh Colleges. This study was undertaken by assessing the technical quality of root canal obturation and presence of procedural errors in root canal treatment cases performed by the final year dental students (levels 11 and 12) in clinics.

MATERIALS AND METHODS

All of the root canal treatment cases performed by the final year dental students in the 2nd semester of 2012/2013 were examined,

except the following: cases with incompletely formed roots; cases with previous root canal treatment; and cases that had poor quality of treatment radiographs.

Treatment was done under rubber dam using the same instrumentation and obturation techniques of the pre-clinical training which are step-back with hand files for instrumentation and lateral condensation for obturation. Working length was determined using Apex locator (Root ZX, J. Morita USA, Inc.) and confirmed radiographically. After obturation, each tooth was temporarily restored, then a post-operative digital X-ray was taken using a paralleling approach. All cases were done under direct supervision of endodontists or Advanced Restorative Dentistry specialists with an average staff to student ratio of 1:6.

Evaluation criteria

Evaluating the technical quality of root canal obturation was based on examining the pre-operative and post-operative radiographs. The radiographs were independently evaluated by two senior endodontists; the results were compared till agreement was reached. The radiographs were taken digitally using Kodak RVG 6100 machines and were shown on 17-inch flat screens; the evaluators magnified the images as needed. The quality of root canal obturation was assessed based on the length, density, and taper of the root canal filling. This criteria was adopted from Barrieshi-Nusair et al. (2004) (Table 3). The root canal filling was considered "acceptable" when all parameters were marked as acceptable.

In addition, the presence of procedural errors was recorded. The criteria for the detection of procedural errors were as follows:

(1) Ledge formation was diagnosed when the root filling was at least 1 mm shorter than the working length and deviated from the original canal shape in teeth where root canal curvature occurred.
(2) Apical transportation was diagnosed when the filling material was located on the outside curve of the canal at the apical third.
(3) Apical perforation was diagnosed when the apical termination of the filled canal was different from the original canal terminus or when the filling material was extruding through the apical foramen.
(4) Gouging was diagnosed when there was overextension of the access cavity undermining the enamel walls, as shown by the radiographs.
(5) Root perforation was diagnosed when extrusion of filling material was detected in any other area of a root except the furcation area, the inner wall of the root, and through the apical foramen.
(6) Strip perforation was diagnosed when extrusion of filling material was detected in the lateral (inner) wall of the root canal.
(7) Missed canal was diagnosed (with mesial and distal angulated radiographs) when the canal filling was not centered in the root and there was a radiolucent space indicating presence of another canal.
(8) Presence of fractured instrument was diagnosed when a fractured instrument was detected inside a root canal or when its tip extended into the periapical area.
(9) Zipping was diagnosed when the apical termination of the filled canal appeared as an elliptical shape transported to the outer wall.
(10) Furcation perforation was diagnosed when extrusion of filling material through the furcation area was detected in multi-rooted teeth.

Ethical considerations

This research has been conducted in full accordance with the World Medical Association Declaration of Helsinki. Before conducting the research, an approval has been taken from the "Ethical Committee of the Research Centre at Riyadh Colleges". This was a retrospective study in which patient information was anonymized and de-identified prior to analysis.

Table 1. Quality of root canal fillings performed by undergraduate students.

Authors	Country	Sample	Acceptable fillings	
			Number	Percentage
Hayes et al. (2001)	United Kingdom	157 Teeth	27	13
Barrieshi-Nusair et al. (2004)	Jordan	912 Root canals	432	47.4
Eleftheriadis and Lambrianidis (2005)	Greece	620 Root canals	343	55.3
Er et al. (2006)	Turkey	1893 Teeth	624	33
Lynch and Burke (2006)	Ireland	100 Single rooted teeth	63	63
Moussa-Badran et al. (2008)	France	304 Teeth	92	30.3
Balto et al. (2010)	Saudi Arabia	125 Teeth	550	23
Elsayed et al. (2010)	Sudan	265 Root canals	64	24.2
Khabbaz et al. (2010)	Greece	1109 Root canals	608	54.8
Rafeek et al. (2012)	India	460 Root canals	50	10.9

Table 2. Quality of root canal fillings performed by general dental practitioners.

Authors	Country	Sample	Acceptable fillings	
			Number	Percentage
Weiger et al. (1997)	Germany	215 Teeth	30	14
De Moor et al. (2000)	Belgium	312 Teeth	135	43.3
Boucher et al. (2002)	France	1982 Root canals	412	20.8
Chueh et al. (2003)	Taiwan	1867 Root canals	650	34.8
Boltacz-Rzepkowska and Pawlicka (2003)	Poland	282 Teeth	138	48.9
Segura-Egea et al. (2004)	Spain	93 Teeth	32	34.4
Loftus et al. (2005)	Ireland	152 Teeth	72	47.4
Siqueira et al. (2005)	Brazil	2051 Teeth	1167	56.9
Ridell et al. (2006)	Sweden	153 Teeth	75	49
Sunay et al. (2007)	Turkey	470 Teeth	188	40
Chen et al. (2007)	USA	169 Teeth	44	26
Toure et al. (2008)	Senegal	344 Root canals	61	17.7

Table 3. Radiographic evaluation criteria.

Parameter	Criteria	Definition
Length of root canal filling	Acceptable	Root filling ending from 0 to 2 mm short of radiographic apex
	Overfill	Root filling ending beyond the radiographic apex
	Underfill	Root filling ending more than 2 mm short of radiographic apex
Density of root canal filling	Acceptable	Density of root filling uniform without voids and canal space not visible
	Poor	Density of root filling not uniform with clear presence of voids and canal space is visible
Taper of root canal filling	Acceptable	Consistent taper from the coronal to the apical part of the filling, with good canal shape
	Poor	Inconsistent taper from the coronal to the apical part of the filling

RESULTS

The results were analyzed using SPSS© V17.0 software. In total, this study included 450 root canals from 241 teeth. Of these, 220 (48.9%) were located in the maxillary arch and 230 (51.1%) were in the mandibular arch. Majority (85.1%) of the canals were located in posterior teeth and to a lesser extent (14.9%) in anterior teeth.

Table 4 shows the quality of the root canal fillings according to length, density, and taper. Acceptable length, density, and taper were reported in 76.6, 46.4, and 73.8% of the evaluated root canals, respectively, with an overall acceptable quality of 36%. Although the acceptable quality of individual parameters was higher when the "whole tooth" was used as the measuring unit, the overall quality of teeth with filled root canals was lower (26.1%) than that of

Table 4. Quality of root canal fillings by tooth and root canal.

Criteria	Sample	Length			Density		Taper		Overall	
		Acceptable	Underfill	Overfill	Acceptable	Poor	Acceptable	Poor	Acceptable	Unacceptable
By canal	450	349 (77.6)	53 (11.8)	48 (10.7)	209 (46.4)	241 (53.6)	332 (73.8)	118 (26.2)	162 (36.0)	288 (64.0)
By tooth	241	199 (82.6)	20 (8.3)	22 (9.1)	111(46.1)	130 (53.9)	185 (76.8)	56 (23.2)	63 (26.1)	178 (73.9)

Table 5. Quality of root canal fillings by canal location and type.

Criteria	Sample	Length			Density		Taper		Overall	
		Acceptable	Underfill	Overfill	Acceptable	Poor	Acceptable	Poor	Acceptable	Unacceptable
Canal location										
Maxillary	220	181 (82.3)[a]	17 (7.7)	22 (10)	106 (48.2)	114 (51.8)	174 (79.1)[a]	46 (20.9)	85 (38.6)	135 (61.4)
Mandibular	230	168 (73)[b]	36 (15.7)	26 (11.3)	103 (44.8)	127 (55.2)	158 (68.7)[b]	72 (31.3)	77 (33.5)	153 (66.5)
Canal type										
Anterior	67	57 (85.1)	4 (6)	6 (9)	27 (40.3)	40 (59.7)	53 (79.1)	14 (20.9)	20 (29.9)	47 (70.1)
Posterior	383	292 (76.2)	49 (12.8)	42 (11)	182 (47.5)	201 (52.5)	279 (72.8)	104 (27.2)	142 (37.1)	241 (62.9)

Figures with different symbols are statistically different.

individual root canals.

Table 5 shows the technical quality of root canal fillings by canal position and type. In general, the maxillary root canals had a better quality of individual parameters than the mandibular canals; the difference was statistically significant for the length and taper parameters (P<0.05). Similarly, canals located in anterior teeth had better length and taper than their posterior counterparts, while the latter had a better density. However, no significant differences were noted for all of the three parameters (P>0.05). Overall, root canals in maxillary and posterior teeth had a better quality than those in mandibular and anterior teeth without reaching a significant level.

The incidence of procedural errors by the students during treatment is shown in Table 6. Overall, 42 (9.3%) of the treated root canals had procedural errors, and the majority of these errors were found in canals of posterior mandibular teeth.

DISCUSSION

The quality of root canal treatment carried out by general practitioners has been reported to be inadequate in many countries (Table 2). Some authors attributed this inadequacy to under-graduate endodontic training. Because it has been suggested that dentists continue to use the techniques they were taught during under-graduate training, it is important to regularly evaluate the outcomes of clinical undergraduate endodontic training.

The aims of this study were to evaluate the technical quality of root canal fillings performed by final year undergraduate students at the Riyadh Colleges of Dentistry and Pharmacy and to compare the results with the findings reported in other dental schools. To accomplish this goal, the digital periapical radiographs of 241 endodontically treated teeth containing 450 root canals were evaluated according to the guidelines suggested by international endodontic organizations. According to these guidelines, the root canal fillings should end (0 to 2 mm) from the radiographic apex, have a uniform taper from the canal end to the orifice, and have a uniform density without voids (European Endodontic Society, 2006).

This study revealed that the overall quality was acceptable in 36% of the root canals and 26.1% of teeth. Previously published studies reported that

Table 6. Incidence of procedural errors observed in the study by canal type location and type (*n*=450).

Procedural error	Overall (%)	By canal location (%)		By canal type (%)	
		Maxillary	Mandibular	Anterior	Posterior
Ledge	11 (2.4)	0 (0)	11 (100)	0 (0)	11 (100)
Transportation	14 (3.1)	3 (21.4)	11 (78.6)	1 (7.1)	13 (92.9)
Gouging	5 (1.1)	1 (20)	4 (80)	1 (20)	4 (80)
Apical perforation	5 (1.1)	1 (20)	4 (80)	2 (40)	3 (60)
Root perforation	1 (0.2)	0 (0)	1 (100)	0 (0)	1 (100)
Stripping perforation	1 (0.2)	0 (0)	1 (100)	0 (0)	1 (100)
Fractured instruments	5 (1.1)	3 (60)	2 (40)	0 (0)	5 (100)

10.1 to 63% of root canal-filled teeth (Hayes et al., 2001; Er et al., 2006; Moussa-Badran et al., 2008; Balto et al., 2010; Elsayed et al., 2011; Rafeek et al., 2012) and 10.9 to 63% of individual root canals (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Khabbaz et al., 2010; Rafeek et al., 2012) had an acceptable technical quality. The differences between these studies can be attributed to the differences in the study design and the evaluation criteria. Nevertheless, majority of these studies concluded that the quality of root canal fillings performed by undergraduate students is poor and that there is a need to improve the teaching of endodontics at the pre-clinical and clinical levels.

In the current study, the quality of the root canal fillings was evaluated using three criteria: the length, density, and taper. Epidemiological studies have shown that the length of the root canal fillings had a significant influence on treatment outcome, with fillings ending (0 to 2 mm) from the radiographic apex having the best prognosis (Sjogren et al., 1990; Saunders et al., 1997; Chugal et al., 2003). In the current study, 76.6% of the individual root canals had an acceptable length. This finding is higher than the results of other studies (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Khabbaz et al., 2010; Rafeek et al., 2012). At the institution (Riyadh Colleges of Dentistry and Pharmacy), the students determine the working length using electronic apex locators and confirm it radiographically, and this may account for the relatively high percentages of acceptable length canal fillings. This result is in line with the findings of a recent study (Tchorz et al., 2014) that concluded that the early introduction of electronic apex locators during pre-clinical training improves the quality of root canals performed by undergraduate students in the clinical setting.

About 73.8% of the evaluated root canals had acceptable taper. This result is generally higher than the findings of previous studies (Er et al., 2006; Al-Qahtani, 2009; Balto et al., 2010; Rafeek et al., 2012) but comparable to the findings of Barrieshi-Nusair et al. (2004). A tapered root canal is essential to facilitate the introduction of obturation materials and instruments inside the root canal system, creates a resistance form for obturation materials, and reduces the potential for overextensions (Schilder, 1974).

Additionally, the quality of each root filling was assessed by its radiodensity and the presence of voids within the filling or between the filling and canal walls. Eriksen and Bjertness (1991) found that the incidence of apical periodontitis is higher in root-filled teeth with inadequate densities. Inadequate density of root canal obturation may lead to failure of root canal treatment because of microleakage along the root filling (Kirkevang et al., 2000). In contrast to the high percentage of acceptable length and taper of the root canal fillings noted in the current study, only 46.6% of the root canal fillings had an acceptable density. This finding is comparable to findings of previous studies (Er et al., 2006; Moussa-Badran et al., 2008; Balto et al., 2010; Rafeek et al., 2012). The high incidence of unacceptable density among undergraduate students could be in part due to the inexperience of the students in applying sufficient force when using hand or finger spreaders in non-flared or minimally-flared canals. Furthermore, the high incidence of unacceptable fill density may be due to an insufficient number of accessory gutta-percha points being used during the lateral condensation process (Khabbaz et al., 2010).

The statistical analysis demonstrated no significant differences in the overall number of acceptable root canal fillings according to canal location (maxillary versus mandibular) or type (anterior versus posterior). The findings of previous studies generally agree that although the location has little effect on the overall quality of root fillings, the posterior teeth (particularly molars) have poorer quality fillings than anterior teeth (Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Lynch and Burke, 2006; Balto et al., 2010; Khabbaz et al., 2010; Rafeek et al., 2012). This may be in part attributed to the more complex anatomy of these teeth, which are usually associated with narrow and curved canals that require a lot of time and patience in order to properly clean, shape and obturate.

In addition to the aforementioned variables that may affect the quality of root canal fillings, the overall quality can be influenced by the type of instrumentation and the obturation technique used during root canal treatment. In majority of the previous studies (Hayes et al., 2001; Barrieshi-Nusair et al., 2004; Eleftheriadis and Lambrianidis, 2005; Er et al., 2006; Lynch and Burke, 2006; Balto et al., 2010; Elsayed et al., 2010; Khabbaz et al., 2010; Rafeek et al., 2012), the undergraduate students instrumented the root canals with stainless steel files using the step-back technique and obturated the canal spaces with cold lateral condensation. Both techniques are widely taught for undergraduate students and are indicated for canals with mild or moderate curvature. The step-back technique, when used by inexperienced students, may produce procedural errors such as ledges, blocking, and transportation of the root canal, which may lead to incomplete cleaning and underfilling (Gambarini, 1999; Kfir et al., 2004). Moreover, the use of stainless steel instruments may produce a high incidence of procedural errors, which may reduce the prognosis (Cheung and Liu, 2009). On the other hand, the cold lateral condensation technique in a non-flared or minimally flared root canal may create voids (Khabbaz et al., 2010). Recently, Silvani et al. (2013) investigated the quality of root canal fillings performed by undergraduate students using rotary nickel-titanium files (WaveOne) and preheated gutta-percha (Thermafil) in the clinical setting. The authors of that study found that 26 of the 28 (92.9%) root canal fillings had adequate length, and none of them had voids. Further studies are required to compare the quality of the root canal fillings made using conventional and contemporary techniques.

In the light of the findings of the current study, there is a need to revise the endodontic curricula in order to improve the technical quality of root canal treatment performed by undergraduate dental students. Such revision may include extending the training time in the pre-clinical and clinical sessions as well as the gradual introduction of new technology, such as nickel-titanium rotary systems and heated gutta-percha techniques, into the curricula. Finally, it will be of great interest to repeat the same research in the future to ensure the predictability of the new educational measures.

Conclusions

The technical quality of root canal fillings performed by undergraduate dental students was acceptable in 36.6% of cases. To improve the quality of treatment performed by these students, the endodontic curricula must be revised to increase the training time at the pre-clinical and clinical levels and to introduce new techniques and armamentaria into the curricula.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Full Length Research Paper

Low dietary diversity among older Japanese adults with impaired dentition

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The aim of this cross-sectional study was to investigate the relationship of dentition status, defined by the number of occluding pairs of natural teeth (OPNT) and removable denture fit, to food diversity among older Japanese adults. The study participants were 268 Japanese (mean age: 81.7 years) classified into four groups: (i) good dentition ($n = 91$; ≥5 OPNT), (ii) compromised dentition ($n = 43$; <5 OPNT), (iii) well-fitting dentures ($n = 104$; self-reported), and (iv) ill-fitting denture ($n = 30$; self-reported). Food diversity was assessed as a measure of dietary quality using the 11-item Food Diversity Score Kyoto (FDSK-11), which evaluates frequency of consumption of 11 main food groups (grains, potatoes, beans and soybean products, meat, fish and shellfish, eggs, milk and dairy products, vegetables, seaweed, nuts and fruits). Multivariable analysis of the differences in FDSK-11 score ranging from 0 to 11, with a higher score indicating greater food diversity, among the four groups was conducted using linear regression models with robust standard errors. The compromised dentition and self-perceived ill-fitting denture groups had significantly lower FDSK-11 scores than the good dentition group after adjusting for confounders ($P < 0.05$). A less-varied diet, as indicated by low FDSK-11 score, was observed in participants with fewer OPNT or ill-fitting dentures. Impaired dentition was associated with poor diet quality among older Japanese.

Key words: Epidemiology, elderly, diet, dental health.

INTRODUCTION

Food diversity is an important dietary factor reflecting
dietary quality. Dietary variety has previously been found

to be associated with better energy intake, nutrient intake and biochemical measures of nutritional status in the elderly (Mirmiran et al., 2006). The overall nutritional quality of the diet was improved by a diverse diet. Diversity in the diet is a simple tool for screening and identifying people at nutritional risk (Oldewage-Theron and Kruger, 2008). In addition, previous studies have reported that intake of a variety of foods is significantly associated with lower risk of mortality in elderly individuals (Huang et al., 2014).

Older adults are especially at increased risk of dietary deficiencies due to age-related physiologic changes, loss of appetite associated with sensitivity decline in taste and smell, economic limitations, illnesses, and medications (Ahmed and Haboubi, 2010). Oral health is significantly associated with geriatric nutrition, and impaired dentition and chewing ability can limit the type and quantity of food consumed (Samnieng et al., 2011; Yoshida et al., 2011). Previous research suggested that the location and function of the teeth is more related to masticatory ability than merely the total number of teeth (Moriya et al., 2012). Furthermore, the quality of fit of dentures was also reported to be associated with dietary intake. Well-fitting dentures can correct nutritional problems, whereas ill-fitting dentures cannot (Iwasaki et al., 2014; Sahyoun and Krall, 2003).

To date, epidemiological evidence has accumulated to support the association of dentition status with specific food, nutrient or energy intakes among older adults (Ervin and Dye, 2012). However, little is known about the association of functional dentition status with overall diet quality among community-based older adults, especially in Asian populations. Therefore, this study was planned with the purpose of assessing whether dentition status, defined as the number of functional occluding pairs of teeth and self-reported adequacy of fit of removable dentures, was related to food diversity among older Japanese adults.

MATERIALS AND METHODS

Study design

This study is a cross-sectional study carried out to investigate the relationship of dentition status, defined by the number of occluding pairs of natural teeth (OPNT) and removable denture fit, to food diversity among older Japanese adults

Selection of study participants

In April 2011, all 994 individuals aged ≥75 years currently residing in the town of Tosa, Kochi Prefecture, Japan, except for 128 individuals living in hospitals or nursing homes, were sent a written request to participate in a geriatric health survey. Subsequently, 305

responded positively to participating in the survey. In August 2011, study participants underwent dental examination, dietary assessment, interview and anthropometric evaluation at a community center. Thirty-seven individuals did not submit complete data. Data were, therefore, available from 268 participants (95 men and 173 women, mean age = 81.7 years).

This study was conducted in accordance with the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Ethical Committee of the Faculty of Medicine, Kyoto University, Kyoto, Japan (E-514). Written informed consent was obtained from all study participants.

Dental examination

Two trained dentists, under sufficient illumination using artificial light, determined the number of OPNT (range 0 to 7, excluding the third molar) (Morita et al., 2007) and the use of dentures for each participant. No study participant had dental implants. Participants who wore at least a complete denture in the upper or lower jaw were classified as denture wearers (Sahyoun and Krall, 2003). Subjective sense of denture fit was assessed by asking denture wearers to respond to the question, "In general, would you say the fit of your denture is excellent, good, poor, or very poor?" The answer was treated as a dichotomous variable with good fit encompassing the first two responses and poor fit, the last two responses.

Dietary assessment

Food diversity was assessed as a measure of dietary quality using the 11-item Food Diversity Score Kyoto (FDSK-11) (Kimura et al., 2013). This validated retrospective method of dietary diversity assessment evaluates frequency of consumption of 11 main food groups (grains, potatoes, beans and soybean products, meat, fish and shellfish, eggs, milk and dairy products, vegetables, seaweed, nuts and fruits) during the previous 6 months. After the participants had rated their frequency of consumption of each group with a score of 1 (consumption once or more per week) or 0 (consumption less than once per week), the individual scores were summed to obtain a FDSK-11 score ranging from 0 to 11, with a higher score indicating greater food diversity. A more precise assessment of the frequency of food intake was carried out by asking the participants the question "How often do you eat these foods each week?", using the same 11 food groups, to which they responded by assigning a score of 4 (every day), 3 (often or 3 to 5 days/week), 2 (sometimes or 1 to 2 days/week) or 1 (hardly ever) (Kimura et al., 2013).

Geriatric assessment and anthropometric evaluation

Activity of daily living (ADL) was assessed using the Tokyo Metropolitan Institute of Gerontology index (TMIG index; range 0 to 13) with low scores indicating disability (Koyano et al., 1991). Decreased ADL was defined as the lowest quartile of TMIG index (TMIG index <11). The presence of depressive symptoms was assessed using the Japanese version of the 15-item Geriatric Depression Scale (GDS-15; range 0 to 15) with higher scores indicating more severe depression. Depression was defined by a GDS-15 score of 6 or greater (Wada et al., 2003). An interview was conducted to obtain data on age, years of education, smoking status, drinking frequency and current medical treatment of

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hypertension, diabetes, dyslipidemia, stroke, coronary heart disease, bone and joint disease, and cancer. Anthropometric evaluation included measurements of height and weight to calculate body mass index (BMI).

Description of main exposure variable

The principal exposure variable included functional dentition status, which was defined by the number of OPNT and self-reported adequacy of complete denture fit. First, participants were classified into two groups based on the presence of complete dentures. Participants with complete dentures were then further divided into two groups based on the self-perceived quality of fit of their dentures, as either well-fitting or ill-fitting. Participants without full dentures were divided into two groups based on the number of OPNT; ≥5 OPNT (good dentition) and <5 OPNT (compromised dentition). Less than 5 OPNTs was defined as compromised dentition because it was reported to be associated with chewing difficulty (Hildebrandt et al., 1997). Overall, four groups used to specify the main exposure variable for this study were: (i) good dentition (n = 91, 34%), (ii) compromised dentition (n = 43, 16%) (iii) well-fitting dentures (n = 104, 39%), and (iv) ill-fitting dentures (n = 30, 11%).

Description of outcome variables

FDSK-11 score and its components (that is, food frequency scores) were used as outcome variables.

Furthermore, to compare nutritional status among the four dentition groups, underweight was included as secondary outcome measure. Participants with a BMI lower than 20 kg/m^2 were defined as underweight, because this value was reported to be an independent predictive factor of mortality in older adults (Tamakoshi et al., 2010).

Statistical analyses

Initially, analysis of variance for continuous variables and Chi-square test for categorical variables were used to test differences in the means and percentages of selected characteristics among the four different study groups. Post-hoc tests were conducted using Pairwise comparisons with Bonferonni's correction for continuous variables and Pairwise comparisons of marginal linear predictions, which were calculated subsequent to the regression model, for categorical variables.

Because outcome variables were not normally distributed, robust statistical procedures were conducted. Multivariable analysis of differences in FDSK-11 score and its components among the four dentition status groups (referent category = good dentition) was conducted using linear regression models with robust standard errors. Multivariable models were adjusted for potential confounders based on previous studies: age (continuous), gender (categories: men or women), education (categories: school attendance: ≥7 or <7 years), decreased ADL (categories: yes or no), depression (categories: yes or no), number of present illness (continuous), smoking status (categories: never, former or current smoker), alcohol use (categories: never or rarely, sometimes, usually or always), and BMI (continuous). Effect modification was evaluated using interaction terms. Least-square means (LSMs) of FDSK-11 score and its components were obtained across categories of dentition status.

Univariable and multivariable Poisson regression models with robust error variance assessed the association of dentition status with underweight status. Crude and adjusted relative risks (RRs) with 95% confidence intervals (CIs) were calculated. Age, gender, education, ADL, depression, present illness, smoking status, and

alcohol use were tested as potential confounders in the multivariable model.

The level of significance was set at $\alpha = 0.05$. All calculations and statistical analyses were performed using the statistical software package STATA (version 13) (Stata Corp., TX, USA).

RESULTS

Table 1 shows study participants' characteristics by dentition status. Significant differences were observed in age, BMI, ADL, depression and number of natural teeth. Full denture users were older and had fewer natural teeth than participants with good dentition (P < 0.05). The compromised dentition and ill-fitting denture group had lower BMI than the good dentition group (P < 0.05). Compared with good dentition group, higher percentages of decreased ADL and depression were found among compromised dentition and ill-fitting denture groups (P < 0.05). The compromised dentition group had fewer natural teeth than the good dentition group (P < 0.05), although they had a greater number of natural teeth than full denture users (P < 0.05).

Table 2 shows the estimated LSMs and 95% CIs of the FDSK-11 score and its components by dentition status. There were no interactions of the dentition status with covariates. The compromised dentition and self-perceived ill-fitting denture groups had significantly lower FDSK-11 scores than the good dentition group after adjusting for confounders (P < 0.05). Furthermore, food frequency scores of meat, fish and shellfish, milk and dairy products, and vegetables for the compromised dentition group were significantly lower than those for the good dentition group (P < 0.05). Food frequency scores for potatoes, beans and soybean products, meat, fish and shellfish, vegetables, seaweed, and fruits for the self-perceived ill-fitting denture group were significantly lower than for the good dentition group (P < 0.05). The food frequency score of milk and dairy products tended to be lower in individuals with self-perceived ill-fitting dentures than those with good dentition (P = 0.05).

Table 3 shows the results of the Poisson regression analyses for the associations of dentition status with underweight status. There were no interactions of dentition status with any third variable. In the crude model, the compromised dentition and self-perceived ill-fitting denture groups were at significantly higher risk of being underweight compared with the reference group (good dentition). The crude RR was 2.8 (95% CI = 1.3 to 6.2) for the compromised dentition group and 4.0 (95% CI = 1.9 to 8.7) for the ill-fitting denture group. This association remained significant after multivariable adjustment (adjusted RR = 2.5, 95% CI = 1.1 to 5.3 for the compromised dentition group and adjusted RR = 3.6, 95% CI = 1.7 to 7.6 for the ill-fitting denture group).

DISCUSSION

To the best of our knowledge, this is the first study to

Table 1. Selected characteristics of study participants by dentition status.

Demographic and socio-economic status	All participants (n = 268)	Good dentition (n = 91)	Compromised dentition (n = 43)	Well-fitting denture (n = 104)	Ill-fitting denture (n = 30)	P[†]
Age, mean (SD)	81.7 (4.8)	79.6 (3.7)[a]	81.7 (4.4)	83.2 (5.2)[b]	83.0 (5.0)[b]	<0.01
Gender, n. (%)						
Men	95 (35.5)	34 (37.4)	21 (48.8)	32 (30.8)	8 (26.7)	0.14
Women	173 (64.5)	57 (62.6)	22 (51.2)	72 (69.2)	22 (73.3)	
School attendance years<7 years, n (%)	38 (14.2)	6 (6.6)	8 (18.6)	17 (16.4)	7 (23.3)	0.06
Health status and health behavior						
BMI, mean (SD), (kg/m^2)	23.0 (3.3)	23.7 (3.2)[a]	22.1 (2.9)[b]	23.2 (3.3)	21.9 (3.3)[b]	<0.01
Decreased ADL, n (%)	66 (24.6)	16 (17.6)[a]	16 (37.2)[b]	23 (22.1)	11 (36.7)[b]	0.03
Depression, n (%)	83 (31.0)	21 (23.1)[a]	19 (44.2)[b]	29 (27.9)	14 (46.7)[b]	0.02
Number of present illness, mean (SD)	1.7 (1.3)	1.7 (1.3)	1.6 (1.2)	1.6 (1.4)	1.9 (0.9)	0.75
Smoking status, n (%)						
Never smoked	190 (70.9)	66 (72.5)	31 (72.1)	71 (68.3)	22 (73.3)	0.90
Previous or current smoker	68 (26.1)	25 (27.5)	12 (27.9)	33 (31.7)	8 (26.7)	
Drinking behavior, n (%)						
Never or rarely	160 (59.7)	51 (56.0)	23 (53.5)	64 (61.5)	22 (73.4)	0.30
Sometimes, usually or always	108 (40.3)	40 (44.0)	20 (46.5)	40 (38.5)	8 (26.7)	
Oral health status						
Number of natural teeth, mean (SD)	10.1 (10.0)	22.7 (3.5)[a]	9.8 (4.2)[b]	1.6 (2.8)[c]	2.3 (3.7)[c]	<0.01

SD: Standard deviation, BMI: body mass index. [†]P value for the comparison of selected characteristics among different study groups.
[a-c]Values in a row without a common superscript letter significantly differ as detected by multiple comparison tests.

investigate the association between functional dentition status and food diversity among older adults in Japan. A less-varied diet, which was indicated by low FDSK-11 score, was observed in participants with fewer OPNT or ill-fitting dentures after controlling for other important characteristics. Furthermore, these participants tended to have a higher risk of being underweight.

A previous study indicated that dentition status was associated with overall diet quality among US populations. Savoca et al. (2011) investigated the association between dental status and Healthy Eating Index (HEI) score, a measure of the overall quality of an individual's diet, among adults aged ≥60 years in the rural United States. They observed that individuals with fewer than 11 teeth present without dentures, and individuals with complete dentures in one or both jaws had significantly lower HEI scores than all other groups. Sahyoun and Krall (2003) reported, in a cross-sectional study of the third National Health and Nutrition Examination Survey participants, that the HEI score was significantly lower in the group with self-perceived ill-fitting dentures. Our results were consistent with these findings and further confirmed that: (1) the association

between dentition status and diet quality existed in a Japanese older population as well after adjusting for relevant confounders including ADL and depression, and (2) impaired dentition status was associated with malnutrition indicated by low BMI in older adults.

When the components of FDSK were examined separately, the results suggested that lower FDSK score in the current study population was attributed to less frequent intake of certain food groups including potatoes, beans and soybean products, meat, fish and shellfish, milk and dairy products, vegetables, seaweed, and fruits. Potatoes, vegetables, seaweed, and fruits are one of the important sources of many vitamins, minerals, and fiber. Beans, meat, fish, and milk are recognized as foods with plenty of protein. Fish and shellfish are rich sources of polyunsaturated fatty acids as well. An inverse association was found between the consumption of these food groups and the development of systemic diseases such as cardiovascular disease (He et al., 2006), diabetes (Mahoney and Loprinzi, 2014), and others. In addition, a low BMI was found to be associated with increased risk of mortality, even among those with a lower normal BMI range (BMI = 18.5 to 19.9) (Tamakoshi et al., 2010). Thus,

Table 2. Associations between dentition status and food diversity score[†].

FDSK-11 component (range 1 to 4)	Good dentition (Referent) (n = 91)		Compromised dentition (n = 43)			Well-fitting denture (n = 104)			Ill-fitting denture (n = 30)		
	LSM	95% CI	LSM	95% CI	P[‡]	LSM	95% CI	P[‡]	LSM	95% CI	P[‡]
Grains	3.9	3.8 - 4.0	3.8	3.6 - 3.9	0.10	3.9	3.7 - 4.0	0.22	3.8	3.7 - 4.0	0.22
Potatoes	2.7	2.5 - 2.9	2.5	2.2 - 2.7	0.13	2.7	2.5 - 2.9	0.65	2.2	2.0 - 2.5	<0.01
Beans and soybean products	3.1	2.9 - 3.3	3.0	2.7 - 3.2	0.29	3.1	2.8 - 3.3	0.71	2.7	2.3 - 3.0	0.012
Meat	2.7	2.5 - 2.9	2.3	2.0 - 2.5	<0.01	2.5	2.3 - 2.7	0.22	2.2	1.9 - 2.4	<0.01
Fish and shellfish	3.0	2.8 - 3.2	2.6	2.4 - 2.9	<0.01	3.0	2.8 - 3.2	0.69	2.5	2.2 - 2.8	<0.01
Egg	3.0	2.7 - 3.2	2.8	2.4 - 3.1	0.23	2.8	2.6 - 3.1	0.27	2.6	2.2 - 3.0	0.08
Milk and dairy products	2.9	2.6 - 3.2	2.4	2.0 - 2.8	0.03	2.8	2.5 - 3.1	0.70	2.4	1.9 - 2.8	0.05
Vegetables	3.5	3.3 - 3.7	3.2	2.9 - 3.5	<0.01	3.5	3.4 - 3.7	0.99	3.2	2.8 - 3.5	0.02
Seaweed	2.9	2.7 - 3.1	2.7	2.5 - 3.0	0.22	2.8	2.6 - 3.0	0.38	2.5	2.2 - 2.8	0.02
Nuts	2.4	2.2 - 2.6	2.1	1.9 - 2.4	0.05	2.3	2.1 - 2.5	0.28	2.1	1.8 - 2.4	0.07
Fruits	2.8	2.6 - 3.0	2.5	2.1 - 2.8	0.05	2.7	2.5 - 2.9	0.56	2.4	2.0 - 2.7	0.02
FDSK-11 (range 0 to 11)	10.7	10.5 - 11.0	9.9	9.4 - 10.4	<0.01	10.6	10.4 - 10.8	0.10	9.6	9.1 - 10.1	<0.01

FDSK-11: 11-item food diversity score Kyoto; LSM: least square mean; CI: confidence interval. [†]Adjusted for age, gender, education, activity of daily living, depression, present illness, smoking status, alcohol use, and body mass index. [‡]Comparison to referent category. Bold text highlights statistically significant findings (P<0.05).

oral functional limitations associated with lower OPNTs and self-perceived ill-fitting dentures might lead to the avoidance of certain foods, which can lead to decreased dietary diversity and ultimately, lead to an increased risk of systemic diseases, malnutrition and mortality among older Japanese.

In contrast, dietary diversity in individuals with well-fitting dentures was not significantly different from individuals with good dentition. Therefore, regular dental care to maintain intact dentition, as well as dental treatment to replace missing teeth and ensure adequate denture fit and function, may be important for the dietary diversity of older Japanese.

The FDSK-11 is a useful and validated tool to assess dietary quality among the Japanese population. In addition, the FDSK-11 is associated with ADL and quality of life (QOL) (Kimura et al., 2013, 2012). The FDSK-11 was used to examine the association of food diversity with ADL and QOL in highlanders in Qinghai, China, as well (Kimura et al., 2009). However, it should be noted that it is not an international index. The dietary questionnaire used in the current study is specially designed for FDSK-11 and does not allow us to estimate other international criteria such as HEI and oral nutritional supplements (Volkert et al., 2006) to assess dietary quality and malnutrition in older adults. This may limit the generalizability of the current study results. Additional well-controlled studies are needed to elucidate whether there may be a possible association of other international criteria with FDSK-11 and dental/oral health.

Our findings suggest that oral health status can influence an individual's food choice and food diversity; however, it is important to note that there are several other factors that influence food choice, such as food preferences, dietary habits, nutritional knowledge, cooking skills and available food sources (Hildebrandt et al., 1997). The current study does not include data to address such factors; consequently, was not include them in the analyses.

Although this study provides a novel finding that an association between functional dentition status and food diversity was observed in an Asian (Japanese) older population, there is potential that our final sample analyzed may not be representative of the target study population, community-based older Japanese. Only 268 participants of all the 994 individuals aged ≥75 years currently residing in the town of Tosa in 2011 were analyzed. Because there was no information on the food diversity and dental health of the older general population in the town of Tosa, the characteristics between the current study population and the general population were not compared.

Table 3. Poisson regression models of the effect of dentition status on underweight.

Good dentition (reference)	Outcome = Underweight					
	Crude model			Multivariable adjusted model[†]		
	RR	95% CI	P[‡]	RR	95% CI	P[‡]
Compromised dentition	2.8	1.3 to 6.2	0.01	2.5	1.1 to 5.3	0.02
Well-fitting denture	1.8	0.9 to 3.9	0.11	1.3	0.6 to 2.6	0.52
Ill-fitting denture	4.0	1.9 to 8.7	<0.01	3.6	1.7 to 7.6	<0.01

RR: Relative risk; CI: confidence interval. [†]Adjusted for age, gender, education, activity of daily living, depression, present illness, smoking status, and alcohol use. [‡]Comparison to referent category.

The mean number of teeth present was 10.1 (standard deviation [SD] = 10.0) among study population. In the national dental survey, mean number of teeth present in adults aged ≥80 years was 11.1 (The Ministry of Health, Labour, and Welfare, 2011). Although, no great gap was observed in dental characteristics, it can be assumed that those who declined to participate in the survey or who did not submit complete data might be more likely to be less concerned with their diet and overall health. In this context, the results based on this single study should be interpreted with some caution, because selection bias may lead to over- or under-estimation of the true association. There are several other limitations to the present study. First, this study had a cross-sectional design, which prevented the assessment of a temporal relationship and establishing causality. Second, information on fixed dental prostheses was not available; therefore, we could not determine whether the partially edentulous space was restored by pontics, artificial teeth in partial dentures, or no replacement. Information on present natural teeth and complete denture status were included in the current analyses. One large population-based survey evaluating the association between dental status and diet (Nowjack-Raymer and Sheiham, 2007) also does not include dental prostheses information. Third, information on participants' serum nutritional biomarkers such as albumin and vitamin levels was not available to the investigators; therefore, we were unable to fully assess participants' nutritional status. Finally, swallowing difficulties can influence dietary outcomes in older adults (Mann et al., 2013); however, information on participants' swallowing function was not collected, hence this potentially important factor could not be assessed in the analyses. Future work with larger, more diverse samples and more complete information would be necessary to substantiate our findings.

Conclusion

Conclusively, in this older Japanese population, poor dietary diversity and underweight were observed in impaired dentition. Accumulating evidence by cohort, intervention, and other highly reliable studies is an important future task to further elucidate the associations between dental/oral health and nutrition.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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