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Relationship between orthodontic treatment and dental caries: results from a national survey

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Objectives: Orthodontic treatment has been suggested to increase the risk of dental caries. The aim of this study was to evaluate the association between orthodontic treatment and the likelihood of dental caries. **Methods:** The study included data for adults aged ≥ 19 years who participated in the Korea National Health and Nutrition Examination Survey in 2013–2015. The participants' demographic, socio-economic, and general and oral health-care data were collected by trained interviewers using a structured questionnaire. The number of decayed teeth (DT) and the decayed, missing and filled teeth (DMFT) index score on oral examinations performed by dentists were compared between subjects who underwent orthodontic treatment and those who did not, using the chi-squared test and logistic regression analysis. **Results:** All logistic regression analysis models showed a significant association between orthodontic treatment and untreated dental caries. The likelihood of having untreated dental caries was lower in subjects who had received orthodontic treatment than in those who had not, regardless of confounding factors ($P < 0.001$). After adjustment for confounding factors, the mean number of DT was lower in subjects who had received orthodontic treatment than in those who had not (0.66 *vs*. 0.94; $P < 0.001$). There was no statistically significant difference in the DMFT index score between the two groups. **Conclusions:** Orthodontic treatment was associated with a decreased likelihood of untreated dental caries. Moreover, there was no evidence indicating a link between the DMFT index score and orthodontic treatment.

Key words: *Dental caries, DMFT index, DT index, epidemiology, orthodontic treatment*

INTRODUCTION

The aims of orthodontic treatment in patients with malocclusion are to improve the aesthetics of the oral and maxillofacial area and to optimise masticatory function by changing tooth alignment[1]. However, orthodontic treatment can have undesirable consequences, including periodontal disease, root resorption, tooth devitalisation, temporomandibular disorder, caries and damage to enamel[2,3]. Dental caries that develop in patients who have received orthodontic treatment can cause inefficient mastication as well as premature tooth loss, thereby impacting quality of life[4,5]. Furthermore, caries in the anterior teeth compromise the aesthetic enhancement achieved by orthodontic treatment, even in the early demineralisation stage[6].

Although the prevalence of dental caries is decreasing globally[7], orthodontic treatment is still recognised as a strong risk factor for dental caries[8,9]. Fixed orthodontic appliances allow accumulation of dental plaque, which promotes demineralisation of enamel and results in dental caries[10,11]. One study[12] also found an increase in plaque and accumulation of bacteria in patients with fixed orthodontic appliances. In 2018, a study[13] found significant differences between the oral microbiota of individuals who did and did not receive orthodontic treatment; for example, *Pseudomonas* species were found in the normal oral microflora of patients who had received orthodontic treatment, but not in those who had not.

Dental caries is difficult to detect during orthodontic treatment because teeth are covered by orthodontic appliances such that the opportunity for timely treatment may be missed[14]. A meta-analysis, based on the results of 14 relevant studies, revealed that the incidence of newly developed dental caries lesions during orthodontic treatment was 45.8%[15]. In another review article, the authors reported orthodontic treatment to be a risk factor for dental caries, especially in

younger patients[3]. They emphasised that clinicians should educate patients about prevention of dental caries before orthodontic treatment is initiated and should not recommend orthodontic treatment to patients who are not motivated to perform good dental hygiene. However, a recent study[16] reported that orthodontic treatment is not a risk factor for dental caries if an appropriate oral-care protocol is implemented. Moreover, orthodontic treatment is indispensable in resolving malocclusion, which may be mild (such as crowding) or severe (such as impaction or abnormal tooth eruption), causing serious oral dysfunction[1]. Malocclusion in itself may also be a risk factor for dental caries[16], and it has been reported that patients who are receiving orthodontic treatment have an improved ability to manage their oral hygiene[17]. Therefore, the effect of orthodontic treatment on dental caries is unclear.

The big data studies that have recently been conducted in dentistry have the advantage of including a nationally representative sample with sufficient power for investigation[18]. However, a literature search did not reveal any studies in large cohorts in which dental caries was examined after orthodontic treatment. Therefore, the present study evaluated the relationship between dental caries and orthodontic treatment using data from a nationwide survey.

MATERIALS AND METHODS

Participants surveyed

The study was carried out using data from the 6th Korea National Health and Nutrition Examination Survey (KNHANES VI) conducted by the Korea Centers for Disease Control and Prevention (KCDC). The KNHANES is a nationwide survey conducted every 3 years, and the 6th survey was performed from 2013 to 2015. The survey selected about 11,520 households using a two-stage stratified sampling method, and surveyed their household members' health-related data. Using structured questionnaire-based interviews, the survey collected information on demographic and socio-economic characteristics, as well as data on general health, history of systemic disease, nutrition, health-related behaviours and lifestyle. Oral and physical examinations, including a blood test, were also performed. A total of 22,948 household members were surveyed, and data for the 11,732 subjects aged ≥19 years who answered all of the relevant questionnaire items were included in the present study.

Study variables

The demographic data for age and sex were collected using a questionnaire. Household income was classified as low, middle-low, middle-high or high, based on quartiles. Level of education was categorised as below elementary, middle school, high school and graduation from college. The health-related data included smoking status and alcohol consumption. The subjects were divided into smokers and non-smokers, with ex-smokers classified as non-smokers. Alcohol consumption was classified as taking <1 and ≥1 alcoholic drinks per month. The oral health care-related behaviours examined were frequency of toothbrushing, whether or not oral-care products were used and attendance for dental checkups. Frequency of toothbrushing was recorded as once or less, twice and three or more times per day. Use of oral-care products and professional oral examination at a dental clinic within the previous year were divided into 'yes' and 'no'. Orthodontic treatment was assessed by the response to a self-reported questionnaire. Dentists who were examiners for KNHANES counted the numbers of decayed teeth (DT) and decayed, missing and filled permanent teeth (DMFT).

Statistical analysis

To improve the representativeness of the sample, KNHANES uses a multistage stratified cluster sampling method, as opposed to a simple random-sample design concept. Therefore, in this study, complex sample analyses were carried out for all statistical analyses using three elements of complex sample design (i.e., weights, strata and clusters).

Statistically significant differences in mean age among study groups were evaluated using the *t*-test. The data were analysed using the chi-squared test to evaluate between-group differences in general characteristics, health-related variables and oral health-care-related variables.

Logistic regression analyses were performed to estimate odds ratios (ORs) and 95% CIs, which were used to evaluate the association between orthodontic treatment and untreated dental caries. For these analyses, the subjects were classified into two groups according to whether they did (DT ≥ 1) or did not (DT = 0) have dental caries. Adjustments for potential confounders, including age, sex, income, level of education, alcohol consumption status, smoking status and oral health-care-related behaviours, were sequentially entered into logistic regression models (models 1–5).

The mean numbers of DT and mean DMFT index scores were compared between the orthodontic and non-orthodontic treatment groups using a complex samples general linear model. The adjusted DT and DMFT mean values were also compared after adjustment for all the confounding factors used in the study. All statistical analyses were performed using SPSS for Windows (version 22.0; IBM Corp., Armonk, NY, USA). The statistical significance level was set at 0.05.

Ethical considerations

This study protocol was approved by the KCDC Institutional Review Board (2013-07CON-03-4C, 2014-12EXP-03-5C, 2015-01-02-6C) and was conducted in full accordance with the World Medical Association Declaration of Helsinki and its later amendments. All study participants provided written informed consent.

RESULTS

Demographics and oral health-care behaviours according to history of orthodontic treatment

The study population had a mean age of 44.7 years. The subjects' demographic and oral health-care behaviours, according to whether or not they had received orthodontic treatment, are shown in *Table 1*. Of 11,732 subjects included, 677 (7.1%) reported having received orthodontic treatment. The proportion of subjects receiving orthodontic treatment was higher in the following subgroups: female subjects; those with a higher income; those with a higher level of education; non-smokers; those who brushed their teeth at least three times daily; those who used oral health-care products; and those who attended for dental checkups. However, there was no statistically significant difference in alcohol consumption between subjects in the orthodontic and non-orthodontic treatment groups.

Distribution according to untreated dental caries

The prevalence of dental caries in the study population was 30.8% (*Table 2*). The prevalence of dental caries was significantly lower in the group of subjects who had received orthodontic treatment than in the group of subjects who had not (21.5% *vs.* 31.5%; $P < 0.001$) and significantly higher in male subjects and in those with a low income ($P < 0.001$). The prevalence of dental caries was also significantly higher in high school graduates and in smokers (both $P < 0.001$) as well as in those who consumed one or more alcohol-containing drinks per month ($P < 0.01$). Furthermore, the subjects who brushed their teeth no more than once daily and did not use oral health-care products had a higher prevalence of dental caries ($P < 0.001$). A higher prevalence of dental caries was also found in subjects who did not attend annually for a dental checkup ($P < 0.001$).

Association between history of orthodontic treatment and untreated dental caries

The ORs and 95% CIs for the logistic regression models that were used to evaluate the association between orthodontic treatment and dental caries are shown in *Table 3*. All models (1–5) were statistically significant ($P < 0.001$). The OR for the unadjusted model 1 was 0.597, meaning that the risk of dental caries was lower in subjects with a history of orthodontic treatment than in those without. The adjusted ORs for the remaining models were 0.538 (model 2), 0.577 (model 3), 0.589 (model 4) and 0.616 (model 5), implying that the risk of having untreated dental caries was lower in the orthodontic treatment group, even after adjustment for demographic, socio-economic, general health-related and oral health-care-related factors.

DT and DMFT scores according to history of orthodontic treatment

Table 4 shows the mean DT and mean DMFT scores in the study population. Individuals who had had orthodontic treatment had a lower mean DT score than those who had not (0.43 *vs.* 0.74; $P < 0.001$). To reduce confounding effects, the mean DT scores were adjusted for age, sex, income, education, smoking status, alcohol consumption, frequency of toothbrushing, use of oral health-care products and attendance for professional oral examinations, using a complex samples general linear model. The adjusted mean DT scores in the orthodontic and non-orthodontic groups were 0.66 and 0.94, respectively ($P < 0.001$).

The mean DMFT score was lower in subjects with a history of orthodontic treatment than in those without (6.58 *vs.* 6.82); however, the difference was not statistically significant ($P = 0.212$). After adjustment for potential confounders, the group with orthodontic treatment showed a higher mean DMFT score than did the group without (7.55 *vs.* 7.27); however, the difference was not statistically significant ($P = 0.167$).

DISCUSSION

Dental caries is one of the most common chronic diseases[19]. It is a multifactorial disease that results in demineralisation of dental hard tissues as a result of the action of acidic byproducts produced by several species of microorganism[20]. The initial stage of dental caries is reversible as remineralisation can occur spontaneously via deposition of minerals in the saliva. However, without appropriate treatment, most cases of dental caries remain as permanent defects, causing aesthetic and functional impairment and, if severe, lead to tooth loss[21].

Dental caries is also one of the most common adverse consequences of orthodontic treatment[5]. Early dental caries, called white spot lesions, is the best known form of caries associated with orthodontic treatment[22]. Although the reported prevalence rates of

Table 1 Comparison of demographic and oral health-care-related variables between the groups that did and did not receive orthodontic treatment

Variable	Division	Orthodontic treatment		*P*-value†
		Yes	No	
All		677 (7.1)	11,055 (92.9)	
Age (years)		30.9 ± 0.404	45.8 ± 0.238	<0.001***
Sex	Male	222 (5.5)	5,107 (94.5)	<0.001***
	Female	455 (8.8)	5,948 (91.2)	
Household income	Low	27 (2.4)	2,002 (97.6)	<0.001***
	Middle-low	144 (5.9)	2,885 (94.1)	
	Middle-high	227 (7.7)	3,113 (92.3)	
	High	279 (9.6)	3,055 (90.4)	
Education	≤Elementary school	7 (0.4)	2,088 (99.6)	<0.001***
	Middle school	11 (0.9)	1,325 (99.1)	
	High school	115 (3.7)	3,452 (96.3)	
	≥University or college	544 (12.3)	4,190 (87.7)	
Smoking	Yes	118 (5.5)	2,306 (94.5)	0.002**
	No	559 (7.6)	8,749 (92.4)	
Alcohol consumption	<1 alcoholic drink per month	248 (7.0)	4,347 (93.0)	0.742
	≥1 alcoholic drink per month	429 (7.2)	6,708 (92.8)	
Frequency of toothbrushing per day	≤1	23 (2.5)	1,355 (97.5)	<0.001***
	2	205 (5.8)	4,244 (94.2)	
	≥3	449 (8.9)	5,456 (91.1)	
Use of oral health-care products	Yes	444 (8.7)	5,544 (91.3)	<0.001***
	No	233 (5.4)	5,511 (94.6)	
Annual professional oral examination	Yes	267 (9.1)	3,163 (90.9)	<0.001***
	No	410 (6.3)	7,892 (93.7)	

Values are given as *n* (%) or mean ± standard error.
**$P < 0.01$; ***$P < 0.001$; †*P*-value calculated using complex samples *t*-test and chi-squared test.

dental caries in patients who receive orthodontic treatment vary widely[8,14,23], younger patients are more likely to develop dental caries because of their immature tooth enamel and lack of appropriate oral hygiene[3,22]. A previous study[24] found that the prevalence of orthodontic treatment-related dental caries was higher in male patients than in female patients, while another study[22] found no significant sex-related difference.

Fixed orthodontic devices increase the surface area to which plaque can attach and, because of their irregular shape, make it almost impossible to remove plaque completely[10,11]. Therefore, orthodontic treatment is considered a risk factor for dental caries. A previous study[8] diagnosed dental caries in 350 patients before and after orthodontic treatment, and found that 72.9% of subjects developed new dental caries during treatment. Moreover, using digital photographs and the records of 385 patients who underwent orthodontic treatment, another study[25] found that 23.4% of these patients developed dental caries on their anterior teeth.

Although orthodontic treatment is a risk factor for dental caries, it should be remembered that orthodontic treatment also alleviates malocclusion, which is another risk factor for caries. Irregular tooth alignment makes toothbrushing difficult, and the accumulated dental plaque can promote demineralisation of the enamel, resulting in dental caries[26,27]. In addition to dental crowding, other types of malocclusion, such as spacing, midline shift, an Angle class II/III molar relationship and an open bite, have also been linked to dental caries[28]. In a recent systematic review[29], 15 studies in subjects with malocclusion and dental caries were selected and analysed; all but one reported a relationship between dental caries and malocclusion. According to that meta-analysis, individuals with malocclusion had a higher DMFT score. Therefore, the probability of dental caries decreases after completion of orthodontic treatment, but increases during treatment.

In the present study, 30.8% of all participants had untreated dental caries, a proportion similar to the 35% reported in a previous study[30]. The prevalence of untreated dental caries was lower in subjects who had undergone orthodontic treatment than in those who had not (21.5% *vs.* 31.5%). Furthermore, the logistic regression analyses in this study showed that the likelihood of having untreated dental caries was lower in subjects who had received orthodontic treatment than in those who had not (OR = 0.597). Other logistic regression analysis models that were sequentially adjusted for various confounders (age, sex, income, educational level, smoking status, alcohol consumption, frequency of toothbrushing, use of oral health-care products and attendance for professional oral examinations) were statistically significant, with adjusted ORs ranging from 0.538 to 0.616. These

Table 2 Demographic characteristics according to presence of dental caries

Variable	Division	Dental caries		*P*-value†
		Yes (DT ≥ 1)	No (DT = 0)	
All		3,404 (30.8)	8,328 (69.2)	
Age (years)		43.3 ± 0.369	45.3 ± 0.267	<0.001***
Sex	Male	1,768 (34.8)	3,561 (65.2)	<0.001***
	Female	1,636 (26.4)	4,767 (73.6)	
Household income	Low	677 (36.3)	1,352 (63.7)	<0.001***
	Middle-low	941 (34.2)	2,088 (65.8)	
	Middle-high	937 (29.7)	2,403 (70.3)	
	High	849 (26.5)	2,485 (73.5)	
Education	≤Elementary school	653 (32.5)	1,442 (67.5)	<0.001***
	Middle school	372 (30.0)	964 (70.0)	
	High school	1,127 (34.2)	2,440 (65.8)	
	≥University or College	1,252 (28.2)	3,482 (71.8)	
Smoking	Yes	976 (42.9)	1,448 (57.1)	<0.001***
	No	2,428 (26.8)	6,880 (73.2)	
Alcohol consumption	<1 alcoholic drink per month	1,254 (28.7)	3,341 (71.3)	0.001**
	≥1 alcoholic drink per month	2,150 (31.9)	4,987 (68.1)	
Frequency of toothbrushing per day	≤1	466 (37.4)	912 (62.6)	<0.001***
	2	1,360 (32.4)	3,089 (67.6)	
	≥3	1,578 (28.2)	4,327 (71.8)	
Use of oral health-care product	Yes	1,480 (26.6)	4,508 (73.4)	<0.001***
	No	1,924 (35.2)	3,820 (64.8)	
Annual professional oral examination	Yes	722 (23.0)	2,708 (77.0)	<0.001***
	No	2,682 (34.0)	5,620 (66.0)	
Orthodontic treatment	Yes	144 (21.5)	533 (78.5)	<0.001***
	No	3,260 (31.5)	7,795 (68.5)	

Values are given as *n* (%) or mean ± SE, standard error.DT, decayed teeth.
**$P < 0.01$; ***$P < 0.001$; †*P*-value calculated using complex samples *t*-test and chi-squared test.

Table 3 Association between orthodontic treatment and dental caries

Variable*	Models†	Adjusted factors	OR	95% CI	*P*-value‡
Orthodontic treatment (ref. no)	Model 1	Unadjusted model	0.597	0.482–0.739	<0.001
	Model 2	Model 1 + demographic factor	0.538	0.432–0.669	<0.001
	Model 3	Model 2 + socio-economic factor	0.577	0.462–0.721	<0.001
	Model 4	Model 3 + health-related factor	0.589	0.471–0.735	<0.001
	Model 5	Model 4 + oral health-care-related factor	0.616	0.492–0.771	<0.001

OR, odds ratio.
*Dependent variable: untreated dental caries (ref. no).
†Model 1 was unadjusted; model 2 was adjusted for demographic factors (age, sex); model 3 was adjusted for age, sex and socio-economic factors (income, education); model 4 was adjusted for age, sex, income, education and health-related factors (smoking, alcohol consumption); and model 5 was adjusted for age, sex, income, education, smoking, alcohol consumption and oral health-care-related factors (toothbrushing frequency, oral-care product use and professional oral examination).
‡*P*-value calculated using complex samples logistic regression analysis.

results indicate a significant association between orthodontic treatment and untreated dental caries, consistent with the results of previous studies[27–29].

The mean DT was also lower in the orthodontic treatment group than in the non-orthodontic treatment group (0.43 *vs*. 0.74), which is again similar to a previous finding[31]. The mean DT value after adjustment for confounders was 0.66 in the orthodontic group and 0.94 in the non-orthodontic group. However, there was no statistically significant between-group difference in the DMFT score, whether adjusted or not. A recent Australian cohort study also reported no significant difference in the DMFT score between a group with orthodontic treatment and a control group, consistent with the results of the present study[32].

The varying results for the DT and DMFT scores in this study may reflect the malocclusion before treatment and use of orthodontic appliances during treatment, both of which may lead to difficulties with toothbrushing. Therefore, it is possible that the subjects in the orthodontic treatment group already had developed dental caries in multiple teeth before orthodontic treatment. Furthermore, dental caries was less likely to develop after completion of treatment because the malocclusion had been corrected. These considerations may explain why the mean DT value was lower in the orthodontic treatment group and,

Table 4 Between-group differences in mean number of dental caries

Variable	Orthodontic treatment	Mean	SE	95% CI	*P*-value*
DT	Yes	0.43	0.048	0.34–0.53	<0.001
	No	0.74	0.024	0.70–0.79	
Adjusted DT†	Yes	0.66	0.059	0.55–0.78	<0.001
	No	0.94	0.039	0.87–1.02	
DMFT	Yes	6.58	0.188	6.21–6.95	0.212
	No	6.82	0.071	6.68–6.96	
Adjusted DMFT†	Yes	7.55	0.219	7.12–7.98	0.167
	No	7.27	0.113	7.05–7.50	

DMFT, decayed, missing and filled teeth; DT, decayed teeth; SE, standard error.
**P*-value calculated using a complex samples general linear model *t*-test.
†Adjusted for confounding factors (age, sex, income, education, smoking, alcohol consumption, toothbrushing frequency, use of oral health-care product and professional oral examination).

despite the lack of a significant difference in the mean DMFT score, between the orthodontic treatment group and the control group. Moreover, it is possible that oral-care education at the orthodontic clinic contributed to an improvement in oral hygiene[17,33]. This may be helpful for motivating patients and improving their oral health-care habits[18]. Likewise, the present study found that subjects who had received orthodontic treatment were more likely to brush their teeth at least three times day, use oral health-care products and attend for dental checkups. Many previous studies have emphasised the importance of maintaining oral hygiene by regular maintenance and dental treatment, to prevent dental caries in patients who undergo orthodontic treatment[9,17].

Big data research has been growing exponentially since the development of data collection and statistical processing techniques suited to large volumes of data. In small-scale studies, sampling errors may limit the extent to which a sample can be considered representative of the target population, and the importance of nationwide studies that can compensate for these drawbacks has been emphasised[34]. The present study was based on large-scale data from the KNHANES, which used structured sampling and sophisticated investigational methods. The reliability of the KNHANES data is considered high because they were obtained by a professional survey team consisting of nurses, nutritionists and health-care specialists. Furthermore, all oral examinations were carried out by dentists, helping to assure that the diagnosis of dental caries was objective and accurate.

Nonetheless, this study had a few limitations. A history of orthodontic treatment was gleaned from a self-reported questionnaire; therefore, detailed information about treatment, such as the type of orthodontic appliance used, the type or severity of malocclusion and the duration of treatment, could not be ascertained. Furthermore, the study had a cross-sectional design, so causal relationships could not be determined. A relatively small sample size may be another limitation of the study. Although the study was nationwide, 677 subjects in the orthodontic treatment group was not considered as adequately representative, so generalisation of the findings of the present study requires caution. Moreover, although there may be potential confounding factors other than those mentioned here, only the variables investigated in KNHANES could be used in our analysis. However, despite these limitations, this study provides meaningful data on the association between orthodontic treatment and untreated dental caries by analysing data from a nationwide survey.

In conclusion, subjects in this study who had undergone orthodontic treatment developed significantly fewer untreated dental caries, regardless of demographic, socio-economic, general health-care-related and oral health-care-related factors. However, a significant association between orthodontic treatment and the DMFT score could not be established. Clinicians should bear in mind that oral-care education during orthodontic treatment is important in reducing the risk of dental caries. Further longitudinal studies are needed to confirm a causal relationship between orthodontic treatment and the likelihood of dental caries.

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Conflicts of interest

The author declares that there are no conflicts of interest to disclose.

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