ORIGINAL ARTICLE

AJO-DO

Association between incisor irregularity and coronal caries: A population-based study

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Introduction: The objective of this study was to investigate the association between incisor irregularity and anterior coronal caries by means of an arch-specific analysis among the U.S. population in the National Health and Nutritional Examination Survey (NHANES III) 1988-1994. **Methods:** This study analyzed data from 9049 participants who were surveyed from 1988 to 1994 as a part of the NHANES III. Participants with a complete set of fully erupted permanent anterior teeth in the maxillary and mandibular segments (ie, canine to canine), who completed an examination of occlusal characteristics and anterior dental caries, and who reported no previous orthodontic treatment were included in the study. Incisor irregularity per arch was determined with the use of the Little irregularity index. Anterior coronal caries per arch was defined as ≥1 surface with decayed or filled surface (CDFS ≥1). Analyses were conducted with the use of chi-square test and logistic regression modeling taking into account the complex sampling design of the survey. **Results:** In the maxillary arch, 25.1% of the study population had maxillary anterior coronal caries experience (CDFS ≥1), whereas only 5.5% of the study population had mandibular anterior coronal caries experience (CDFS ≥1). In both arches, no statistically significant association between incisor irregularity and anterior coronal caries experience was found. **Conclusions:** Maxillary and mandibular incisor irregularity is not associated with anterior dental caries prevalence in a subset of NHANES III data that included mostly highly educated adult participants who were white, of medium socioeconomic status, and with high oral health compliance and oral self-care. Future well designed prospective cohort studies are needed to confirm these results. Clinicians are still encouraged to continue providing oral health education to their patients about the well established effect of incisor irregularity on plaque retention. (Am J Orthod Dentofacial Orthop 2019;155:372-9)

Globally, dental caries is considered to be one of the most prevalent chronic diseases.[1] Although dental caries are generally preventable, United States National Health and Nutrition Examination Survey (NHANES; 2011-2012) data showed that ~18% of children (aged 5-19 years) and 27% of adults (aged 22-44 years) have untreated dental caries.[2] To control such a widespread disease, effective planning of preventative strategies against occurrence of early carious stages should be of primary concern.[3] One approach to preventing caries at the early phases of an individual's lifetime is to identify its potential contributing factors to modify them accordingly.

Malocclusion can be defined as any deviation of the teeth and jaw from the normal or ideal occlusion. Malocclusion encompasses numerous interrelated occlusal traits, which include overjet, overbite, open bite, crossbite, and incisor malalignment (ie, crowding, irregularity, and spacing).[4] Such occlusal characteristics may reveal malformations in dentition, the jaw, or both. Dental crowding, particularly anterior dental crowding, denotes an inadequate arch space in relation to the tooth size, which results in malposition of the teeth in the jaws, whereas irregularity deals with the labiolingual displacement of teeth without consideration of space.[5] In the United States, ~75% of the population has some degree of maxillary incisor irregularity and 78% exhibit mandibular incisor irregularity. In general, incisor malposition is a source of food collection and plaque retention,[6] so it seems intuitive that incisor irregularity perhaps increases

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All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
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Submitted, December 2017; revised and accepted, April 2018.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2018.04.029

the occurrence of dental caries. Despite the biologic plausibility, only a few studies have investigated the association between incisor irregularity and dental caries. Three available cross-sectional studies reported conflicting results,[7-9] and owing to the very low quality of these studies no conclusive evidence can be drawn. A recent systematic review[10] concluded that there is an increased need for larger-scale studies to clarify if incisor irregularity is a risk factor or indicator for dental caries development.

To the best of our knowledge, the association between incisor irregularity and dental caries has not been reported in a population-based cross-sectional study. Therefore, we used NHANES III data to determine whether incisor irregularity is associated with the prevalence of anterior coronal caries in the United States.

MATERIAL AND METHODS

We used data from the NHANES III from 1988 to 1994. NHANES III collects data from a nationally representative sample of the civilian noninstitutionalized population in all states of the U.S. and the District of Columbia. A complex, stratified, multistage probability cluster sampling design is used in the surveys to make the data collection practical and to address the health issues for subpopulation groups, such as non-Hispanic blacks, Mexican Americans, and older adults. Subjects are interviewed in their homes and complete the health examination component of the survey in mobile examination centers (MECs).[11]

NHANES III was conducted in 2 phases from 1988 to 1994. From 1988 to 1991, the first phase of the survey was conducted at 44 sites; the second phase of the survey was conducted from 1991 to 1994 at 45 locations. NHANES III included 39,695 subjects 2 months of age and older. Of these, 33,994 were interviewed at their homes, all interviewed persons were invited to the MEC for a medical and dental examination, and 30,818 were examined at an MEC and 493 at home. Calibrated examiners completed all examinations, and health, social, and nutritional information were obtained by interviewing the subjects or their parents. Further thorough information on the study protocol was previously reported.[12]

For this study, the inclusion criteria were participants who 1) had a complete set of fully erupted permanent anterior teeth in the maxillary and mandibular segments (ie, canine to canine), 2) had completed occlusal characteristics and anterior dental caries examination, and 3) reported no previous orthodontic treatment.

Our sample included a total of 9,049 individuals representing a population of ∼104 million (weighted count).

This project is classified under the category of "a study of existing data" because the data was obtained from the National Health and Nutrition Examination Survey, a publically available data set (ie, nonhuman subject study). The study's plan and protocol were reviewed by the Boston University Medical Campus Institutional Review Board, and it was exempt from further reviews (protocol number H-36252).

Five licensed and calibrated dentists performed the oral health component examination that included, but was not limited to, a surface evaluation of anterior coronal caries (ie, from canine to canine) for participants 2 years of age and older in the maxillary and mandibular arches. A clinical examination (ie, no radiographs were obtained) was performed in the MEC, where the participants were seated on a portable dental chair. By using a sharp #23 sickle-shaped explorer and a front surface mirror under a high-intensity fiber-optic lamp, the anterior teeth were examined to detect any carious lesions (ie, carious lesion into dentin) or restoration in 4 surfaces (ie, mesial, distal, labial and lingual) for each anterior tooth in the maxillary and mandibular anterior segments. If a tooth had a restoration and a carious lesion at the same time, the examiner recorded the surface as being carious.[12-14]

From these data, the sum numbers of coronal decayed or filled permanent tooth surfaces (CDFS) from canine to canine per arch were calculated for each person. Because of the skewed distribution of coronal caries in the maxillary and mandibular arches among the study participants, a dichotomized per-arch (ie, maxillary anterior CDFS, and mandibular anterior CDFS) coronal caries outcome was used in the analysis (ie, maxillary CDFS <1 vs maxillary CDFS ≥ 1 and mandibular CDFS <1 vs mandibular CDFS ≥ 1).

The same 5 licensed and calibrated dentists measured the occlusal traits (incisor malalignment, crossbite, overjet, and overbite) on all examinees aged 8-50 years. In the maxillary and mandibular arches, incisor malalignment (ie, from canine to canine) was defined as the linear displacement (ie, labiolingual displacement) of anatomic contact points, in mm, of each incisor from the adjacent tooth anatomic point. A periodontal probe graduated in mm and placed parallel to the occlusal plane was used to perform these measurements. The Little irregularity index was calculated by summing the labiolingual linear displacement of anatomic contact points in the anterior teeth (maxillary incisors from 6 to 11, mandible incisors from 22 to 27).[15] The severity of incisor irregularity was categorized as no or mild irregularity (0 to <4 mm), moderate irregularity (4-6 mm), or severe irregularity (>6 mm).[16]

A specialist in oral examination for dental surveillance surveys operated as a "criterion standard" to train and periodically calibrate the survey examiners. Examination of 20 volunteers per survey location was repeated several weeks apart to test intra-examiner reliability. Interexaminer reliability was evaluated with the use of data on a subsample of survey participants (n = 20) who received a clinical examination by both the "criterion standard" and a survey examiner.[12-14] For coronal caries, the kappa statistics ranged from 0.85 to 1.00 for intra-examiner and from 0.96 to 1.00 for interexaminer reliability.[13] For occlusal traits, the interexaminer and intra-examiner reliability for occlusal traits showed kappa statistics ranging from 0.72 to 1.00.[15] Further details of the oral health component reproducibility have been discussed previously.[12-15]

Age, gender, race/ethnicity, education, socioeconomic status (SES), and frequency of dental visits were included as covariates. Age was categorized based on quartile cutoff points into children (<19 years), adults (19 to <35 years), and older adults (≥35 years). Race/ethnicity was categorized into non-Hispanic white, non-Hispanic black, Mexican-American, and other. Education level was dichotomized into less than high school and high school graduate or higher. For adults aged ≥19 years, this variable reflected the education of the examinee, whereas for children and youth aged 8 to <19 years, the education level of the adult reference person was used in the analyses.[17] SES was categorized based on the Poverty Income Ratio (PIR) into 3 categories: low (0 to 1.3 PIR), medium (>1.3 to 3.5 PIR), and high (>3.5 PIR). Frequency of dental visits to a dentist or a hygienist in the past year was categorized into at least once a year or less than once a year.

Statistical analyses

SAS software version 9.4 (SAS Institute, Cary, NC) was used to conduct all statistical analyses. MEC examination weights and SAS Survey procedures were used to obtain unbiased estimates and variance, as recommended by the National Center for Health Statistics.[18] The differences in distribution of maxillary and mandibular CDFS by the level of incisor irregularity (ie, maxillary incisor irregularity and mandibular incisor irregularity) and other included covariates were tested by means of chi-square tests. Per-arch logistic regression models were performed to examine whether incisor irregularity was associated with the prevalence of coronal caries among the U.S. population. Per-arch odds ratios (ORs) and 95% confidence intervals (CIs) were generated to estimate the likelihood of having anterior coronal caries among study participants with moderate and severe irregularity compared with no/mild irregularity. Confounders were defined as covariates that showed a significant association with the outcome variable or that changed the coefficient of the main predictor by >10%. Statistical significance was evaluated at the 0.05 level.

RESULTS

Based on our weighted sample, 21% of the participants were children (<19 years), 47% were adults (19 to <35 years), and 32% were older adults (≥35 years). The proportion of female participants was higher than male (52.5 vs 47.5%). Regarding race and ethnicity, 72.4% were non-Hispanic white, 12.4% non-Hispanic black, 6.6% Mexican American, and 8.6% other (Hispanic, Asian, Native American). About 19% were considered to be of low SES, and 43% and 38% were classified into middle SES and high SES categories, respectively. More than 68% of the participants (≥19 years old) or their parents (of those <19 years old) had at least a high school education. Approximately 95% reported at least one visit to a dentist or a hygienist in the previous year.

In the maxillary arch, 21.4% of the population had moderate incisor irregularity and 12.5% severe incisor irregularity. In the mandibular arch, 23.1% of the population had moderate incisor irregularity and 16.1% severe incisor irregularity. This showed that moderate and severe incisor irregularity had a higher prevalence in the mandibular arch. Characteristics of the study population by incisor irregularity status are presented in Tables I and II. In the maxillary arch, 25.1% of study population had maxillary anterior coronal caries experience (CDFS ≥1), whereas only 5.5% of the study population had mandibular anterior coronal caries experience (CDFS ≥1). Characteristics of the study population by CDFS are presented in Tables III and IV.

In the maxillary arch, the crude logistic regression model indicated that moderate maxillary incisor irregularity had 1.04 times the odds (95% CI 0.89-1.23) of having CDFS ≥1 in the anterior maxillary arch relative to no/mild irregularity (the reference group). In the same model, severe maxillary incisor irregularity had 0.91 times the odds (95% CI 0.70-1.18) of having CDFS ≥1 in the anterior maxillary arch relative to the reference group (Table V).

In the mandibular arch, the crude logistic regression models indicated that moderate mandibular incisor irregularity had 0.76 times the odds (95% CI 0.48-1.20) of having CDFS ≥1 in the anterior mandibular arch relative to no/mild irregularity (the reference group). In the same model, severe mandibular incisor irregularity had 1.37 times the odds (95% CI 0.82-2.26) of having

Table I. Characteristics of the study population according to maxillary incisor irregularity status, United States 1988-1994 (n = 9049), % (SE)

Characteristic	Maxillary incisor irregularity		
	None to mild (n = 6024)	Moderate (n = 1804)	Severe (n = 1221)
Age (y)			
<19 y (n = 2537)	21.5 (0.96)	18.5 (1.33)	24.8 (1.98)
19 to <35 y (n = 4100)	46.9 (1.59)	49.2 (2.27)	41.0 (2.22)
≥35 y (n = 2412)	31.5 (1.22)	32.3 (2.22)	28.2 (2.29)
Gender*			
Male (n = 4014)	47.0 (1.12)	44.9 (2.19)	54.3 (2.12)
Female (n = 5035)	53.0 (1.12)	55.1 (2.19)	45.7 (2.12)
Race/ethnicity*			
Non-Hispanic white (n = 2725)	72.2 (1.49)	74.1 (1.95)	71.2 (2.94)
Non-Hispanic black (n = 3009)	13.5 (0.97)	10.3 (0.94)	10.2 (0.92)
Mexican American (n = 2912)	6.4 (0.70)	6.1 (0.49)	8.3 (0.79)
Other (n = 403)	7.9 (1.10)	9.6 (1.55)	10.3 (2.4)
Socioeconomic status†			
Low SES: ≤1.3 PIR (n = 3015)	18.1 (1.21)	20.0 (1.55)	21.8 (1.69)
Medium SES: >1.3 to 3.5 PIR (n = 3643)	42.7 (1.57)	43.2 (1.87)	44.0 (3.22)
High SES: >3.5 PIR (n = 2391)	39.2 (1.60)	36.8 (1.97)	34.2 (3.63)
Education level‡			
Less than high school (n = 4199)	31.3 (1.14)	29.6 (1.80)	35.9 (2.54)
High school or more (n = 4930)	68.7 (1.14)	70.4 (1.80)	64.1 (2.54)
Frequency of dental visits*			
At least once a year (n = 8273)	95.9 (0.30)	93.8 (0.75)	93.7 (1.12)
Less than once a year (n = 776)	4.1 (0.30)	6.2 (0.75)	6.3 (1.12)

*Significant difference ($P < 0.05$, based on chi-square test (weighted column percent); †PIR was computed as a ratio of the midpoint of the observed family income (numerator) and the poverty threshold, the age of the family reference person, and the calendar year in which the family was interviewed (denominators); ‡For adults (age ≥19 years) the variable reflected the education of the examinee. For children and youth aged 8 to <19 years, the education of the adult reference person was used in the analyses.

CDFS ≥1 in the anterior mandibular arch relative to the reference group (Table VI).

It is important to note that these results belong to a subset of NHANES III data that included highly educated adult participants who are mostly white, of medium SES, and with high oral health compliance and oral self-care.

Stratified crude logistic regression models of the association between maxillary and mandibular incisor irregularity and anterior coronal caries adjusted for all included covariates (age, gender, race/ethnicity, SES, education, and frequency of dental visits) did not provide any significant results.

DISCUSSION

Using an arch-specific logistic regression analysis with a validated and reliable method (ie, the Little irregularity index),[16] we examined the associations between incisor irregularity and anterior coronal caries (CDFS ≥1). Given the contradictory results in the literature,[7-9] NHANES III, a nationally representative data set, provided an exceptional opportunity to test our hypothesis with the use of a large sample size. This subset of the NHANES III data included unique participants that were mostly ≥19 years old, non-Hispanic white, and of medium SES, who reported—themselves (≥19 years old) or their parents (for participants <19 years old)—an education level of high school or more, and who had a complete set of maxillary and mandibular teeth. Furthermore, 95% of them reported visiting a dentist or a hygienist in the past year, which demonstrated that our participants had high oral health compliance and oral self-care.

Because incisor irregularity occurs only in the incisor area,[16] analyses were confined to the anterior segments. Furthermore, the arch-specific analyses allowed us to compare between arches and to account for the difference in the anatomic and morphologic features between maxillary and mandibular anterior sextants.[19] To the best of our knowledge, this study is the first to test the association between incisor irregularities and per-arch anterior-specific coronal caries in a nationally representative data set.

For the use of incisor irregularity as a predictor for anterior coronal caries, the available 3 studies in the literature[7-9] were of very low quality. In an early study, Hixon et al (1962) examined the effect of incisor

Table II. Characteristics of the study population according to mandibular incisor irregularity status, United States 1988-1994 (n = 9049), n (%)

	Mandibular incisor irregularity		
Characteristic	*None to mild (n = 5725)*	*Moderate (n = 1915)*	*Severe (n = 1409)*
Age (y)*			
<19 y (n = 2537)	23.9 (1.06)	17.3 (1.26)	17.0 (1.13)
19 to <35 y (n = 4100)	47.9 (1.65)	48.7 (2.00)	43.8 (2.10)
≥35 y (n = 2412)	28.2 (1.20)	34.0 (1.89)	39.2 (2.23)
Gender*			
Male (n = 4014)	44.6 (1.11)	49.8 (1.77)	54.8 (1.84)
Female (n = 5035)	55.4 (1.11)	50.2 (1.77)	45.2 (1.84)
Race/ethnicity*			
Non-Hispanic white (n = 2725)	71.2 (1.53)	74.9 (2.33)	73.9 (2.38)
Non-Hispanic black (n = 3009)	14.5 (1.09)	9.5 (0.87)	8.5 (0.99)
Mexican American (n = 2912)	6.3 (0.73)	6.4 (0.59)	7.8 (0.85)
Other (n = 403)	8.0 (1.20)	9.2 (1.60)	9.8 (2.08)
Socioeconomic status†			
Low SES: ≤1.3 PIR (n = 3015)	19.9 (1.10)	18.1 (2.00)	16.3 (1.82)
Medium SES: >1.3 to 3.5 PIR (n = 3643)	41.9 (1.53)	45.7 (2.38)	43.5 (2.62)
High SES: >3.5 PIR (n = 2391)	38.2 (1.54)	36.2 (2.72)	40.3 (2.29)
Education level‡,*			
Less than high school (n = 4199)	33.3 (1.19)	28.7 (1.77)	28.7 (2.11)
High school or more (n = 4930)	66.7 (1.19)	71.3 (1.77)	71.3 (2.11)
Frequency of dental visits			
At least once a year (n = 8273)	94.8 (0.37)	95.4 (0.61)	96.1 (0.67)
Less than once a year (n = 776)	5.2 (0.37)	4.6 (0.61)	3.9 (0.67)

*Significant difference ($P < 0.05$, based on chi-square test (weighted column percent); †PIR was computed as a ratio of the midpoint of the observed family income (numerator) and the poverty threshold, the age of the family reference person, and the calendar year in which the family was interviewed (denominators); ‡For adults (age ≥19 years) the variable reflected the education of the examinee. For children and youth aged 8 to <19 years, the education of the adult reference person was used in the analyses.

irregularity (ie, malposition in the contact area that is equal or greater than the thickness of the incisal edge) on the prevalence of dental caries in 126 white adult participants.[7] That study showed that there was statistically significant higher caries prevalence (decayed and fill surfaces, all teeth) in subjects with irregular mandibular teeth compared with subjects with satisfactorily regular mandibular teeth. No significant difference in prevalence of caries was found between irregular and satisfactorily aligned maxillary anterior teeth. Helm and Petersen (1989) assessed the effect of incisor irregularity (ie, any deviation of 2 mm in any of the 2 sections, anterior or lateral) on the prevalence of dental caries in 78 adults (33-39 years old, race not reported).[8] Using an unadjusted linear model, they found that irregular maxillary segments (n = 41) had significantly more decayed, missing, and filled surfaces (DMFS index, all teeth) compared with regular maxillary segments (n = 27). They also reported that irregular mandibular segments were not statistically different in DMFS index compared with regular mandibular segments. Both studies[7,8] had serious limitations, including: (1) the use of a nonvalidated index to account for irregularity; (2) the reliability of irregularity measurements was not reported; (3) the selection bias due to the use of a convenience sample; (4) results based on an unadjusted analysis, without accounting of the role of confounding in the analysis; (5) no attempt to measure the baseline oral health status of the recruited subjects; and (6) most importantly, both studies[7,8] attempted to examine the relationship between incisor irregularity and complete score of caries experience, that is, not just in the anterior segment. This introduces a methodologic error because the effect of incisor irregularity is considered to be site specific to the occurrence of coronal caries, and because this was not accounted for, their reported results were probably overestimated (ie, type 1 error). In addition, such design apparently does not represent biologic plausibility, because incisor irregularity can not generally affect the occurrence of full-mouth dental caries. A recent study by Buczkowska-Radlinska et al,[9] examined the effect of incisor irregularity (ie, displaced by 2 mm and/or rotated ≥15° from the normal position in the arch) on the prevalence of anterior dental caries (decayed, missing, and filled teeth (DMFT), maxillary and

Table III. Characteristics of the study population, and maxillary incisor irregularity status, according to maxillary CDFS, United States 1988-1994 (n = 9049), % (SE)

Characteristic	CDFS <1 (n = 7185)	CDFS ≥1 (n = 1864)
Age (y)*		
<19 y (n = 2537)	27.1 (0.93)	3.8 (0.77)
19 to <35 y (n = 4100)	50.0 (1.32)	39.9 (2.10)
≥35 y (n = 2412)	22.9 (0.93)	56.3 (1.94)
Gender*		
Male (n = 4014)	48.8 (0.91)	43.4 (1.56)
Female (n = 5035)	51.2 (0.91)	56.6 (1.56)
Race/ethnicity*		
Non-Hispanic white (n = 2725)	70.9 (1.55)	77.1 (1.89)
Non-Hispanic black (n = 3009)	13.6 (0.95)	8.8 (0.59)
Mexican American (n = 2912)	7.1 (0.66)	5.0 (0.51)
Other (n = 403)	8.4 (1.11)	9.1 (1.57)
Socioeconomic status†,*		
Low SES: ≤1.3 PIR (n = 3015)	19.6 (1.19)	16.9 (1.56)
Medium SES: >1.3 to 3.5 PIR (n = 3643)	44.0 (1.62)	40.0 (1.67)
High SES: >3.5 PIR and above (n = 2391)	36.4 (1.67)	43.1 (1.82)
Education level‡,*		
Less than high school (n = 4199)	35.7 (1.31)	19.0 (1.19)
High school or more (n = 4930)	64.3 (1.31)	81.0 (1.19)
Frequency of dental visits*		
At least once a year (n = 8273)	93.9 (0.39)	99.1 (0.24)
Less than once a year (n = 776)	6.1 (0.39)	0.9 (0.24)
Maxillary incisor irregularity status		
None to mild: 0 to <4 mm (n = 6024)	66.0 (1.70)	66.2 (2.15)
Moderate: 4-6 mm (n = 1804)	21.2 (0.84)	22.1 (1.26)
Severe: >6 mm (n = 1221)	12.8 (1.22)	11.7 (1.46)

*Significant difference ($P < 0.05$, based on chi-square test (weighted column percent); †PIR was computed as a ratio of the midpoint of the observed family income (numerator) and the poverty threshold, the age of the family reference person, and the calendar year in which the family was interviewed (denominators); ‡For adults (age ≥19 years) the variable reflected the education of the examinee. For children and youth aged 8 to <19 years, the education of the adult reference person was used in the analyses.

Table IV. Characteristics of the study population, and mandibular incisor irregularity status, according to mandibular coronal decayed filled surface (CDFS), United States 1988-1994 (n = 9049), % (SE)

Characteristic	CDFS <1 (n = 8766)	CDFS ≥1 (n = 283)
Age (y)*		
<19 y (n = 2537)	22.3 (0.83)	4.2 (1.43)
19 to <35 y (n = 4100)	48.1 (1.29)	35.6 (3.97)
≥35 y (n = 2412)	29.6 (0.90)	60.2 (2.85)
Gender*		
Male (n = 4014)	47.1 (0.81)	54.4 (3.40)
Female (n = 5035)	52.9 (0.81)	45.6 (3.40)
Race/ethnicity*		
Non-Hispanic white (n = 2725)	71.6 (1.51)	87.0 (1.94)
Non-Hispanic black (n = 3009)	12.8 (0.83)	5.8 (1.02)
Mexican American (n = 2912)	6.8 (0.59)	2.5 (0.58)
Other (n = 403)	8.9 (1.11)	4.7 (1.76)
Socioeconomic status†,*		
Low SES: ≤1.3 PIR (n = 3015)	19.4 (1.14)	10.4 (2.29)
Medium SES: >1.3 to 3.5 PIR (n = 3643)	43.0 (1.40)	43.1 (4.76)
High SES: >3.5 PIR (n = 2391)	37.6 (1.48)	46.5 (5.06)
Education level‡,*		
Less than high school (n = 4199)	32.2 (1.12)	18.7 (2.59)
High school or more (n = 4930)	67.8 (1.12)	81.3 (2.59)
Frequency of dental visits*		
At least once a year (n = 8273)	94.9 (0.31)	99.8 (0.13)
Less than once a year (n = 776)	5.1 (0.31)	0.2 (0.13)
Mandibular incisor irregularity status		
None to mild: 0 to <4 mm (n = 5725)	60.8 (1.95)	60.7 (5.14)
Moderate: 4-6 mm (n = 1915)	23.4 (0.96)	17.8 (3.09)
Severe: >6 mm (n = 1409)	15.7 (1.35)	21.5 (4.65)

*Significant difference ($P < 0.05$, based on chi-square test (weighted column percent); †PIR was computed as a ratio of the midpoint of the observed family income (numerator) and the poverty threshold, the age of the family reference person, and the calendar year in which the family was interviewed (denominators); ‡For adults (age ≥19 years) the variable reflected the education of the examinee. For children and youth aged 8 to <19 years, the education of the adult reference person was used in the analyses.

mandibular anterior teeth scores combined) in 67 participants aged 15-19 years.[9] Using a multiple logistic regression analysis, they found that subjects with incisor irregularity (ie, either maxillary or mandibular incisor irregularity) had 3.71 times (95% CI 1.3-10.9) the odds of anterior dental caries experience (ie, DMFT index >0 in the maxillary and mandibular anterior segments) than subjects without incisor irregularity. Several limitations are noted in that study: 1) When using incisor irregularity as a predictor for anterior coronal caries, they used a nonvalidated and unreliable incisor irregularity measurement method; 2) maxillary and mandibular irregularity scores were combined into 1 category as were the scores of anterior DMFT; this approach is faulty because, as mentioned earlier, incisor irregularity is considered to be sitespecific and this perhaps overestimated their reported results (ie, type 1 error); 3) lack of sufficient sample size; and 4) lack of generalizability of their results owing to the inclusion of only 67 participants in their analysis. In that study, clearly inappropriate comparisons were made between irregularity and coronal caries.

In light of all of these factors, our results were unique because of the robust methodologic process of measuring incisor irregularity and testing its association with anterior coronal caries experience. However, this limited our ability to compare our results with the

Table V. Crude logistic regression analysis of the association between maxillary incisor irregularity and maxillary CDFS ≥1, United States 1988-1994 (n = 9049)

	Crude model	
Maxillary incisor irregularity	*OR*	*95% CI*
None to mild: 0 to <4 mm (n = 6024)	1.00	1.00
Moderate: 4-6 mm (n = 1804)	1.04	0.89-1.23
Severe: >6 mm (n = 1221)	0.91	0.70-1.18

Table VI. Crude logistic regression analysis of the association between mandibular incisor irregularity and mandibular coronal decayed filled surface (CDFS ≥1), United States 1988-1994 (n = 9049)

	Crude model	
Maxillary incisor irregularity	*OR*	*95% CI*
None to mild: 0 to <4 mm (n = 5725)	1.00	1.00
Moderate: 4-6 mm (n = 1915)	0.76	0.48-1.20
Severe: >6 mm (n = 1409)	1.37	0.82-2.26

previously reported studies.[7-9] The main finding in our study was that incisor irregularity in the maxillary and mandibular segments, compared with no/mild irregularity, showed no significant association with anterior caries experience (ie, CDFS ≥1) in a subset of NHANES III data that included highly educated adult participants who are mostly white, of medium SES, and with high oral health compliance and oral self-care. Because irregular teeth tend to have deviated and separated contact points, these results were not surprising, because approximating contact points are needed for caries initiation and progression.[20] The effect of incisor malalignment traits (irregularity, crowding, and spacing) on dental caries is considered to be complex and dynamic.[10] In fact, because different incisor malalignment traits (ie, incisor spacing, crowding, irregularity) might coexist, it is difficult to observe or directly link their contribution to dental caries at the coronal levels unless appropriate accountability of such variability is controlled for in the design and the analytical approach. Available evidence shows that incisor crowding[10] significantly increases coronal caries whereas spacing[8] modestly decreases it. Our results seem to suggest that the effect of incisor irregularity is much more related to spacing than crowding.

It is altogether plausible to observe that the relationship of incisor malalignment is primarily related to plaque accumulation and individual oral care. Despite our results, in general, regimens to prevent smooth surface caries lesions, including the use of fluoride varnish and robust oral health practice, should be highly promoted and encouraged in populations with incisor malalignment as they encounter a disruption of the normal cleansing process between proximal contact points. It is important to note that maxillary anterior coronal caries experience (CDFS ≥1) was 5 times that of the mandibular anterior coronal caries experience (CDFS ≥1). Among many possible-explanatory factors, the most noteworthy is salivary flow in the lower anterior area and patient/dentist-related preferences in prosthetic decision making in the upper arch.[21]

A major strength of the present study is its relatively large sample size. It is the first large, nationally representative study investigating the association between incisor irregularity and anterior coronal caries. In addition, we used a robust analytical approach to test the association between incisor irregularity and anterior coronal caries. Several limitations must be recognized when interpreting the results of this study. This subset of NHANES III data includes unique participants which might affect the generalizability of the findings. Also, NHANES III is a cross-sectional survey design, so a causal relationship can not be studied. Racial and ethnic grouping of NHANES III was based on political and legal factors, not biologic distinctions. The analyses did not include information about oral health behaviors, such as frequencies of tooth brushing or flossing, because such information was not collected in NHANES III. Our analysis did not control for the coexistence of other malalignment traits (eg, crowding and spacing) because these clinical measurements were not collected as part of NHANES III. Finally, NHANES III did not incorporate radiographs as part of the dental examinations, which might cause underestimation of the prevalence of dental caries.[22]

CONCLUSION

Maxillary and mandibular incisor irregularity is not associated with anterior dental caries prevalence in a subset of NHANES III data that included highly educated adult participants who are mostly white, of medium SES, and with high oral health compliance and oral self-care. Future well designed prospective cohort studies are needed to confirm these results. Clinicians are still encouraged to continue providing oral health education about the well established effect of incisor irregularly on plaque retention to their patients.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at https://doi.org/10.1016/j.ajodo.2018.04.029.

REFERENCES

1. U.S. Department of Health and Human Services. Oral Health of America: a report of the Surgeon General. Rockville, Md: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Dental and Craniofacial Research; 2000.
2. Dye B, Thornton-Evans G, Li X, Iafolla T. Dental caries and tooth loss in adults in the United States, 2011-2012. NCHS Data Brief 2015;197:197.
3. Hurlbutt M, Young DA. A best practices approach to caries management. J Evid Based Dent Pract 2014;14(Suppl):77-86.
4. Proffit WR, Fields HW Jr, Sarver DM. Contemporary orthodontics. Elsevier Health Sciences; 2014.
5. Lombardi AV. The adaptive value of dental crowding: A consideration of the biologic basis of malocclusion. Am J Orthod 1982;81:38-42.
6. Helm S, Petersen PE. Causal relation between malocclusion and periodontal health. Acta Odontol Scand 1989;47:223-8.
7. Hixon EH, Maschka PJ, Fleming PT. Occlusal status, caries, and mastication. J Dent Res 1962;41:514-24.
8. Helm S, Petersen PE. Causal relation between malocclusion and caries. Acta Odontol Scand 1989;47:217-21.
9. Buczkowska-Radlinska J, Szyszka-Sommerfeld L, Wozniak K. Anterior tooth crowding and prevalence of dental caries in children in Szczecin, Poland. Community Dent Health 2012;29:168-72.
10. Hafez HS, Shaarawy SM, Al-Sakiti AA, Mostafa YA. Dental crowding as a caries risk factor: a systematic review. Am J Orthod Dentofacial Orthop 2012;142:443-50.
11. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988-94. Series 1: programs and collection procedures. Vital Health Stat 1 1994;(32):1-407.
12. Drury TF, Winn DM, Snowden CB, Kingman A, Kleinman DV, Lewis B. An overview of the oral health component of the 1988-1991 National Health and Nutrition Examination Survey (NHANES III—Phase 1). J Dent Res 1996;75(Spec No):620-30.
13. Kaste LM, Selwitz RH, Oldakowski RJ, Brunelle JA, Winn DM, Brown LJ. Coronal caries in the primary and permanent dentition of children and adolescents 1-17 years of age: United States, 1988-1991. J Dent Res 1996;75(Spec No):631-41.
14. National Institute of Dental Research. Oral health surveys of the National Institute of Dental Research: diagnostic criteria and procedures. Bethesda, Md: Epidemiology and Oral Disease Prevention Program, National Institute of Dental Research, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health; 1991. Available at: https://catalog.hathitrust.org/Record/002733807.
15. Brunelle JA, Bhat M, Lipton JA. Prevalence and distribution of selected occlusal characteristics in the US population, 1988-1991. J Dent Res 1996;75(Spec No):706-13.
16. Little RM. The Irregularity Index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-63.
17. Moss ME, Lanphear BP, Auinger P. Association of dental caries and blood lead levels. JAMA 1999;281:2294-8.
18. Centers for Disease Control and Prevention. Analytic and reporting guidelines: the Third National Health and Nutrition Examination Survey, NHANES III (1988-94): Available at: www.cdc.gov/nchs/data/nhanes/nhanes3/nh3gui.pdf.
19. Ash MM Jr. Wheeler dental anatomy, physiology, and occlusion. 6th ed. Philadelphia: WB Saunders; 1984.
20. Berman DS, Slack GL. Caries progression and activity in approximal tooth surfaces. A longitudinal study. Br Dent J 1973;134:51-7.
21. Mandel ID. Calculus update: prevalence, pathogenicity and prevention. J Am Dent Assoc 1995;126:573-80.
22. Pitts NB. Diagnostic tools and measurements—impact on appropriate care. Community Dent Oral Epidemiol 1997;25:24-35.