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Correlation between symptoms and external cracked tooth characteristics: findings from the National Dental Practice-Based Research Network

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National Dental PBRN Collaborative Group

Abstract

Background—Cracked teeth are ubiquitous in the adult dentition. The objective of this study was to determine which patient traits/behaviors and external tooth/crack characteristics correlate with cracked teeth being symptomatic.

Methods—Dentists in the National Dental Practice-Based Research enrolled a convenience sample of subjects each with a single, vital posterior tooth with at least one observable external crack in this observational study; 2,975 cracked teeth, from 209 practitioners, were enrolled. Data were collected at the patient-, tooth-, and crack-level. Generalized estimating equations were used to obtain significant ($p < 0.05$) independent odds ratios (OR) associated with teeth presenting as symptomatic.

Results—Characteristics positively associated with cracked tooth symptoms, after adjusting for demographics, included individuals who clenched, ground or pressed their teeth together (OR=1.30; 95% CI: 1.12–1.50), molar teeth (OR=1.58; 95% CI: 1.30–1.92), teeth with a wear facet through enamel (OR=1.22; 95% CI: 1.01–1.40), caries lesions (OR=1.31; 95% CI: 1.07–1.60), cracks that were on the distal surface of the tooth (OR=1.31; 95% CI: 1.13–1.52) and cracks that blocked transilluminated light (OR=1.31; 95% CI: 1.09–1.57).

Teeth with stained cracks were negatively associated with having cracked tooth symptoms (OR=0.68; 95% CI: 0.55–0.84).

Conclusions and Practical Implications—The greatest likelihood of a cracked tooth being symptomatic was found when patients reported clenching and/or grinding their teeth and had a molar tooth with a distal crack that blocked transilluminated light. This information can help inform dentists in the decision-making process regarding the prognosis for a cracked tooth.

An incomplete tooth fracture, or “cracked tooth”, can be a source of pain and impaired function and present diagnostic and restorative problems¹. An assessment of cracked teeth by the NW PRECEDENT network revealed that nearly 70% of patients in general dental practices had at least one cracked posterior tooth, 21% of which were symptomatic². Because teeth with an incomplete tooth fracture can result in the need for major restoration, root canal therapy (RCT), or extraction, the development of a crack poses a significant problem to patients and dentists.

The diagnosis of incomplete tooth fracture has been based exclusively on tooth symptomatology: localized pain during chewing or biting, unexplained sensitivity to cold, and pain on release of pressure^{1,3–11}. Besides the symptomatology described by the patient, the diagnosis could be verified through a succession of procedures or tests performed by the clinician. Visual inspection, transillumination, and staining^{8,12–13}, percussion, biting, and thermal pulp tests^{6,8,10} radiography^{11,12} microscopy (14X–18X)¹⁴ and ultrasound¹⁵ all have been suggested as having the potential to detect cracks. However, incomplete tooth fracture may still be difficult to diagnose and may be a source of frustration for both the dentist and patient. To our knowledge, none of the different diagnostic procedures suggested have been tested in a single clinical study.

Much of the information gathered in these earlier studies is incomplete or inadequate to fully characterize the implications of cracks in teeth, and much information remains to be garnered regarding the impact of various cracked tooth characteristics on cracked tooth longevity. What the practitioner currently lacks is a comprehensive evidence-based identification strategy for at-risk cracked teeth. This study utilized a Cracked Teeth Registry established in the National Dental Practice-Based Research Network to help meet the need for a more evidence-based, real-world approach to obtain diagnosis and treatment data from patients with cracked teeth seen in dental practices. The objective of this study was to determine which patient traits/behaviors and external tooth/crack characteristics correlate with cracked teeth being symptomatic.

Methods

Dentists in the National Dental Practice-Based Research Network¹⁶ enrolled a convenience sample of subjects who met the eligibility criteria of being between 19 and 85 years old each with a single, vital posterior tooth with at least one observable external crack. One cracked tooth per patient was enrolled. Dentists were asked to enroll the first 20 patients who met the eligibility criteria, but were also given the flexibility to enroll individuals when it best fit within the constraints of their daily schedules. Practitioners were also requested to enroll at least 30% symptomatic cracked teeth (pain to cold and/or biting not obviously attributable to other causes), as well as individuals who, within the dentist's estimation, were most likely to return for recalls over the subsequent several years.

The study was reviewed and approved by the Institutional Review Board (IRB) of the home institution of the lead investigators (TH & JF), as well as the IRBs for each of the six regions within the network. Each patient/subject provided consent to be included in the study.

All participating practice personnel received training specific to this study for data gathering and reporting. Data were collected at the patient-, tooth-, and crack-level. All data forms used in the study are publicly available [<http://nationaldentalpbrn.org/study-results/2015/>]. Patients provided information about demographics (age, race, sex, education, insurance), personal habits of clenching and/or grinding while awake and asleep, wearing a nightguard, pressing and/or holding teeth together, chewing hard candy or ice, chewing gum, whether or not they avoided chewing on right/left side, and feeling stressed^{17,18}. Practitioners recorded:

1. Tests used to confirm vitality;
2. Presence of pain, either spontaneous or elicited from cold or bite testing of the tooth;
3. Tooth type (molar/premolar), location, and characteristics including presence of caries, non-cariou cervical lesions (NCCL), exposed roots, number of external cracks and number, location and restorative material of existing restorations, radiographic evidence of crack presence, characteristics of opposing tooth/teeth; and

4. For each crack, the surfaces involved, crack direction, whether or not a crack connected to another crack or a restoration, extended onto the root, was stained, was detectable with explorer, and/or blocked trans-illuminated light.

Enrollment was in two phases: pilot, April-July 2014 (12 practices enrolled 183 patients), and main launch, October 2014-April 2015. Each practitioner enrolled for a maximum period of 8 weeks, or a maximum number of patients/cracks of 20, whichever came first. The primary difference between the pilot phase and the main launch phase entailed some changes in the format of the data collection forms, but no data elements were removed or added, with the exception of adding a question about stress on the patient questionnaire. Two hundred and nine practitioners enrolled a total of 2,986 patients/cracks; seven patients for whom vitality testing was deemed inconclusive and four patients who lacked information of crack characteristics were excluded from analysis.

Vitality tests

All cracked teeth were tested for vitality and had to respond positively to at least one vitality test to be included in the study, the preferred method being a cold test because this has been shown to be a valid assessment of pulp vitality¹⁹. Dentists were requested to use refrigerant spray, and most teeth were tested in this manner (N=2,419, 81%), although some dentists used ice (N=522, 17%), electric pulp tester (EPT; Total of N=127, 4%), or another method (e.g., air, air/water spray; N=524, 2%) to supplement or in lieu of testing with refrigerant spray. Practitioners were requested to use the same vitality test throughout the course of the study.

Symptomatic classification

Teeth were classified as symptomatic if they were spontaneously painful (N=393, 13%), or painful to cold (N=1,113, 37%) or in response to bite testing (N=484, 16%), or any combination of the three. To distinguish a painful response from a “normal” response by a vital tooth, dentists were asked to test and compare a “normal” tooth, e.g., a contralateral tooth.

Analysis

Frequencies were obtained overall and according to whether or not a cracked tooth was symptomatic, by patient-, tooth- and crack-level characteristics. Initial analyses with patient demographics and behaviors were used to inform categorization for the regression model. Spearman’s rank correlation was used to assess interrelationships between patient behaviors. In a univariable fashion, each patient-, tooth-, and crack-level characteristics was entered into a logistic regression model that used a generalized estimating equations (GEE) method which adjusted for clustering of patients within the practice, implemented using PROC GENMOD in SAS with CORR=EXCH option. All characteristics with $p < 0.05$ after adjusting only for clustering of patients within the practice were then entered into a “full” model, and backwards elimination, again using GEE to adjust for clustering, was performed to identify independent associations with symptomology, being retained if $p < 0.05$. All interaction terms were tested for significance at the 0.05 level after the reduced model was

fit. Odds ratios (OR) were estimated. All analyses were performed using SAS software (SAS v9.4, SAS Institute Inc., Cary NC).

Results

Patient demographics (Table 1)

A total of 2,975 patients/cracks, enrolled by 209 practitioners, were analyzed; mean/median of 14.8/15 patients per practice and a range of 1 to 20. 1,364 (46%) teeth were symptomatic (Figure 1 shows sources of symptomatic classification).

Overall, 1,893 (64%) patients were female, 2,486 (85%) were non-Hispanic white, 2,304 (78%) had some dental insurance, and 2,519 (85%) had some college education. The mean age (SD) was 54 (12) and the median age (inter-quartile range) was 55 (42 – 63) years. Gender, race and age were each associated with whether or not the patient presented with a symptomatic cracked tooth. After adjusting for clustering, females (OR= 1.22; P=0.004) and patients less than 65 years of age (OR= 1.62; P<0.001) were more likely to present with a symptomatic cracked tooth and non-Hispanic whites (OR= 0.71; P<0.001) were less likely to do so.

Patient-level Characteristics (Table 2)

Chewing gum was the most frequently reported behavior, with 1,833 (62%) patients reporting any gum chewing. Clenching or grinding teeth while sleeping or awake, pressing, touching or holding teeth together, and holding objects, chewing hard candy or ice each were behaviors reported by 38 to 48% of the patients. Only 466 (16%) reported wearing a nightguard. About one-fourth, 708 (24%), reported limiting their chewing to one side of their mouth. The great majority of patients (81%) noted feeling stressed at least some of the time, with over one-third (39%) having stress at least an average of 1 day per week. These latter data regarding stress are from the main launch portion of the study only (the patient questionnaire was modified after the pilot study to include the stress data).

Clenching or grinding teeth, both while awake or asleep and pressing, touching or holding teeth together were modestly correlated with each other (rank correlations 0.35 – 0.50). These factors were not correlated with holding objects, chewing hard candy or ice or chewing gum. Clenching or grinding teeth, both while awake or asleep, and pressing, touching or holding teeth together each were associated with limiting the patients' chewing to one side of their mouth and with patients who presented with a symptomatic cracked tooth. These remained significant after adjusting for clustering.

Because the largest difference in the symptomatic percentage for each of these three behaviors was between 'none' and 'less 1/month', a dichotomous variable indicating any reporting of these behaviors was used in regression models. 1,977 (67%) patients were so classified, of whom 49% were symptomatic compared to 39% of patients reporting none of these behaviors; adjusted for clustering, the OR=1.40 (p<0.001). Stress was associated with symptomatic status in a dose-response pattern, namely, with increasing frequency of feeling stressed, a greater proportion of patients presented with a symptomatic cracked tooth (OR=1.13 per unit of 5-point ordinal scale (p<0.001).

Tooth-level characteristics (Table 3)

The majority of cracked teeth were molars (2,420; 81%), with more than half in the mandibular arch (1,734, 58%). The number of external cracks on a tooth ranged from 1 to 15 with a median of 2. Most of the external cracks, 92%, were on a tooth with a restoration; 71% of cracked teeth had one restoration, 19% had two restorations and 2% had 3–4 restorations. Virtually all (98%) study teeth had an opposing tooth; for 216 (7% of the total) the opposing tooth was a full or partial denture. About one-fourth each had a wear facet through enamel (709, 24%) or exposed root(s) (672, 23%). Fewer teeth had caries present (330, (11%) or a non-cariou cervical lesion (NCCL) (267, 9%). Only 72 (2%) had evidence of a crack on a radiograph.

The following tooth-level characteristics were positively associated with the cracked tooth being symptomatic: molar (OR=1.76; $P<0.001$), 3 or more external cracks (OR=1.19; $P=0.04$), wear facet through enamel (OR=1.25; $P=0.03$) and presence of caries (OR=1.38; $P=0.003$). Cracked teeth with NCCLs were associated with decreased odds of presenting with symptoms (OR=0.70; $P=0.009$) as were cracked teeth with exposed roots (OR=0.78; $P=0.048$, adjusting only for clustering).

Crack-level characteristics (Table 4)

The majority of teeth had a crack that was stained (2,410; 81%), connected with a restoration (2,169; 73%), was detectable with an explorer (2,065; 69%), blocked transilluminated light (1,925; 65%) and/or ran in a vertical direction (2,766; 93%). The proportions of surfaces involved were fairly equally distributed, ranging from 44% (1,316) that involved the occlusal surface to 51% (1,521) involving the lingual surface; 1,063 (36%) involved two or more surfaces.

When adjusted only for clustering of patients within the practice, cracks that blocked transilluminated light (OR=1.30, $P=0.006$), were on the distal surface (OR=1.40, $P<0.001$), or had a crack that extended to the root (OR=1.30, $P=0.47$) were each associated with an increased odds of the tooth being symptomatic. Teeth with stained cracks had decreased odds (OR=0.87, $P=0.01$) of presenting with symptoms.

Adjusted associations (Table 5)

Considered one at a time, three patient demographics (Table 1), one derived patient characteristic (Table 2), six tooth characteristics (Table 3) and three crack characteristics (Table 4) were individually associated with symptomatology. In order to assess the independent association of these characteristics with symptomatology a step-wise multi-variable GEE regression model was used. The characteristics considered for this analysis are listed in Table 5 and the effects of each characteristic when considered singly are shown in the “adjusted only for clustering” columns. The results when considering all of the characteristics in the same model are shown in the “full model” columns.

In comparing the “adjusted only for clustering” and “full model,” three notable confounded associations with symptoms are observed: having 3 or more external cracks, which weakened when adjusted (from OR=1.19 to OR=1.04), the association with the presence of

an NCCL (OR=0.71 to OR=0.82), and adjacent to exposed roots (OR=0.83 to OR=0.94). None of these associations, which were adjusted only for clustering, retained significance in the full or reduced models, and so were not included in the reduced model.

To ascertain if associations would be affected by how crack-level characteristics were analyzed, the analysis was repeated placing cracks into the following categories: all cracks exhibited the characteristic, at least 1 crack exhibited the characteristic, no cracks exhibited the characteristic. There was no change to the final, reduced model (results not shown). All possible 2-way interactions were entered, and none were found significant, indicating that an additive model is sufficient. Stress was associated (OR=1.06 per unit of 5-point ordinal scale; $p=0.047$) with symptomatic status in both the full and reduced models (results not shown).

Interpretation on model (see website for model details)

After adjustment for demographics, patient habits of clenching or grinding their teeth, the cracked tooth being a molar, having caries, a wear facet through enamel, and the crack blocking transilluminated light or involving the distal surface were each associated with an increased likelihood of the cracked tooth being symptomatic; the cracks being stained was associated with reduced likelihood of symptomatology. The additive nature of symptom probability resulting from sequentially adding tooth- and crack-level characteristics is illustrated in Figure 2, for both low- and high-risk demographic groups.

Discussion

Demographics

The study demographics were skewed relative to the U.S. population as a whole, with a higher proportion of non-Hispanic whites (85%), females (64%) and older individuals (mean = 54). This likely reflects the patient demographics of the study practices and the fact that tooth cracks tend to increase with age²⁰. The behaviors of “clenching or grinding teeth”, either awake or asleep, and “pressing, touching or holding teeth together” (OR= 1.3) were significantly associated with a cracked tooth being symptomatic. This seems intuitive because parafunctional activity is often implicated as a causative factor in crack initiation and propagation²⁰, and in turn, parafunctional activity is related to stress²¹.

Crack blocks transilluminated light

Transillumination has been recommended to determine if a crack penetrates into dentin²⁰. There is little evidence demonstrating that a crack that blocks transilluminated light penetrates into dentin, but the increased odds of symptoms on a tooth with such a crack seems consistent with the concept that a crack into dentin would be more likely to stimulate a pain response. This could be due to one or both of two factors. First, the crack acts as an interface where dentin fluid can accumulate and be subjected to dimensional change due to pressure or temperature fluctuation, which can increase the rate of fluid movement through the dentin tubules and stimulate pain as proposed by the hydrodynamic theory²². Second, cracks that communicate with the oral cavity are abundantly infected with bacteria, thus providing another source to elicit pain²³.

Cracked tooth has caries and wear facet

It is intuitive that a tooth with a crack, caries and/or a wear facet through the enamel would also be symptomatic, due to the exposed dentin tissue in all three scenarios. However, it is not possible to determine which specific characteristic, or a certain interaction, is the cause of the symptoms.

Crack on a distal surface

It is difficult to rationalize why a tooth with a crack on the distal surface would be more likely to be symptomatic compared to a tooth with cracks on other surfaces, although this finding has been made in other studies. In a smaller practice-based study of 634 teeth, Hilton et al (2012)²⁴ found that teeth with cracks on the distal, facial and/or lingual surfaces were more likely to be symptomatic, with the highest odds ratio associated with cracks on the distal. In another study of 127 cracked teeth diagnosed with reversible pulpitis and treated with a crown, of the 20% that ultimately required endodontic treatment, the crack characteristic most commonly associated with a treated cracked tooth needing RCT was a crack on the distal marginal ridge (56% of those teeth needing RCT)²⁵.

NCCL, exposed roots or stained cracks inversely associated with symptoms

It is possible that stained cracks are long standing cracks that did not result in tooth failure or symptoms. The data collection did not differentiate superficial vs. penetrating stains in cracks. It may be that cracks with stain limited to the superficial aspect of the tooth are less likely to be symptomatic simply because these cracks do not penetrate deeper into the tooth, and therefore dentin is not exposed. Conversely, penetrating stain may coat the crack surfaces and act as a dentin sealer, thereby reducing dentin fluid flow changes that could elicit a painful response. The NCCLs could have provided a mechanism for stress relief and crack blunting in the tooth, by allowing for increased flexure at the cervical area of the tooth. This could potentially provide for occlusal force dissipation, thereby preventing extension of cracks deeper into tooth structure or onto the root surface, and not resulting in symptoms as frequently as cracks on teeth without the NCCLs. A similar explanation may be the case for teeth with exposed roots. In this case, the attachment loss associated with the exposed roots would allow for increased mobility of the tooth, and less concentrated force application to tooth structure that could propagate cracks deeper into dentinal tooth structure.

One limitation of this study is that it is not a random sample. Some persons with cracked tooth symptoms may remain out in the population at large, not entering the dental care system. If these persons are systematically different from those who do enter the dental care system, this would be a source of bias when comparing characteristics of those with or without symptoms. Nonetheless, the long-range goal of this study is to develop guidelines for use by dentists and their patients who have chosen to enter the dental care system. Additionally, in order to increase the odds of retaining patients in the longitudinal component of the study and to more easily adapt the baseline enrollment to busy dental office routines, eligible patients were not selected consecutively, which also could be a source of bias. While we are evaluating common clinical conditions in a binary manner, i.e., is a crack present or not, or is a tooth symptomatic or not, such clinical diagnoses are not completely objective and therefore subject to variability. Also, this report is of cross-

sectional analysis, without follow-up. The study has several strengths: 1) it is the largest study to date of cracked teeth; 2) the patients are from a large variety of practices/practitioners; 3) it is based on a large amount of data on each cracked tooth collected in a systematic, quality controlled manner; 4) it is from a national practice-based network, and therefore is comprehensive in terms of its geography and patient population.

Combinations of factors

We always considered it unlikely that any one characteristic would be the pathognomonic characteristic that was always associated with symptoms in a cracked tooth. Rather, it makes sense to search for combinations of characteristics that are most likely to be associated with cracked teeth that are symptomatic. Although there was no significant interaction among characteristics found to be associated with symptomatology, when the three most common tooth/crack characteristics (molar, blocking transilluminated light, involving distal surface), are considered, the probability of a cracked tooth being symptomatic increases over 20%, in absolute terms, regardless of whether the tooth is found in the low or high-risk demographic group.

Conclusion

This practice-based observational study of nearly 3000 teeth correlated observable patient-, tooth-, and crack-level characteristics of cracked teeth with the presence of symptoms. A number of characteristics were significantly positively associated with cracked tooth symptoms, and two other characteristics were negatively associated with cracked tooth symptom status. The greatest likelihood of a cracked tooth being symptomatic was found when the patient had a molar tooth with a distal crack that blocked transilluminated light and the patient had clenching/grinding habits. Teeth with cracks in non-Hispanic whites and with stained cracks were least likely to be symptomatic.

The continued value of this project lies in the fact that these teeth will be followed for several years to determine which factors are most predictive of adverse outcomes in cracked teeth.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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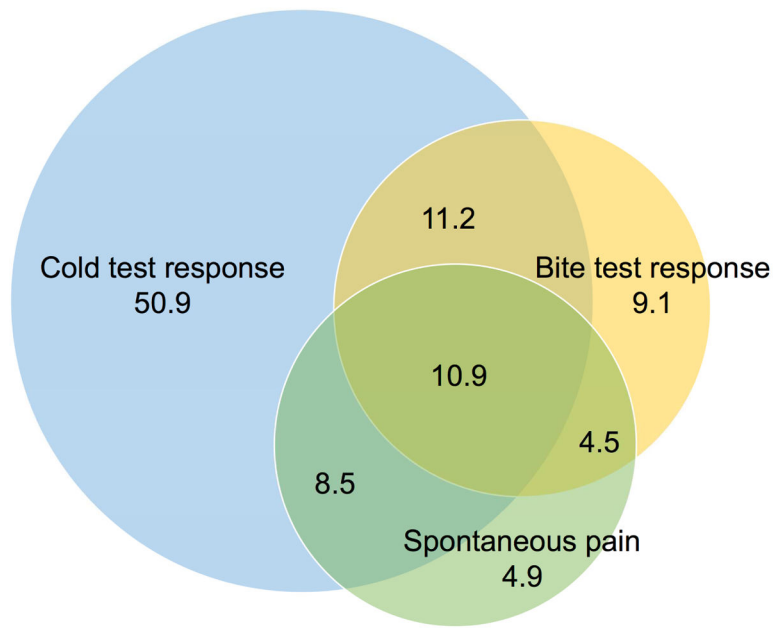


Figure 1. Distribution (%) of the 1,364 symptomatic teeth according to source(s) of symptomatic classification.

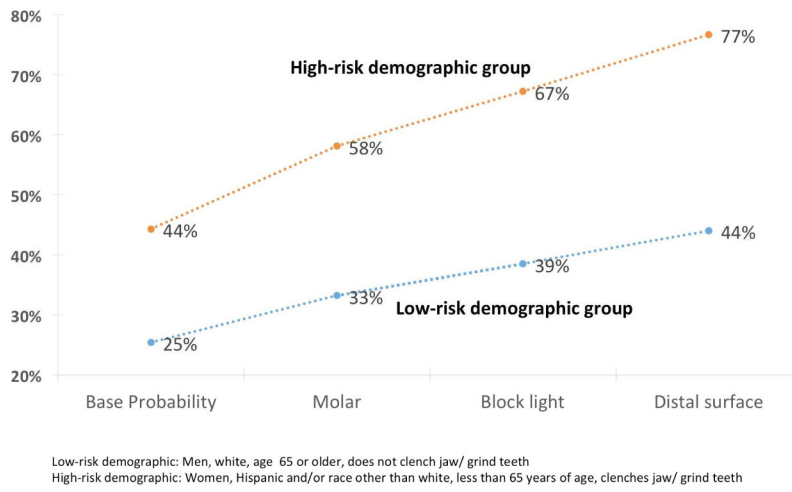


Figure 2. Symptom probability resulting from sequentially adding tooth- and crack-level characteristics for both low- and high-risk demographic groups.

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Table 1

Patient-level demographic characteristics of subjects with a cracked tooth, overall and according to whether cracked tooth was symptomatic.

	ALL (N=2,975)		Symptomatic (N=1,364)	
	N	Col ¹ %	N	Row ² %
<u>Gender</u>				
Female	1,893	64%	906	48%
Male	1,081	36%	458	42%
	<i>Missing = 1</i>		<i>P³ = 0.004</i>	
<u>Race⁴-ethnicity</u>				
White	2,486	85%	1,113	45%
Black	141	5%	66	47%
Asian	50	2%	25	50%
Hispanic	199	7%	108	54%
Other	58	2%	35	60%
	<i>Missing = 41</i>		<i>P = 0.02</i>	
<u>Age (years)</u>				
< 35	207	7%	105	51%
35 – 44	467	16%	248	53%
45 – 54	837	28%	404	48%
55 – 64	943	32%	432	46%
65 and older	519	17%	173	33%
	<i>Missing = 2</i>		<i>P < 0.001</i>	
<u>Dental insurance</u>				
None	659	22%	284	43%
Public [only]	123	4%	53	43%
Private	2,181	74%	1,018	47%
	<i>Missing = 12</i>		<i>P = 0.7</i>	
<u>Education</u>				
<= High school	436	15%	211	48%
Some college/Associate	984	33%	449	46%
Bachelor	907	31%	420	46%
Graduate degree	628	21%	279	44%
	<i>Missing = 20</i>		<i>P = 0.13</i>	
<u>Region</u>				
Western	446	15%	208	47%
Midwest	399	13%	192	48%
Southwest	545	18%	264	48%
South Central	604	20%	274	45%
South Atlantic	492	17%	198	40%
Northeast	489	16%	228	47%
	<i>P = 0.9</i>			

¹Column percents not summing to 100 due to rounding.

²Percent symptomatic within level of demographic characteristic.

³Significance of differences in proportions symptomatic adjusted only for clustering using generalized estimating equations.

⁴Race groups are all non-Hispanic.

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Table 2

Patient-level characteristics of subjects with a cracked tooth, overall and according to whether cracked tooth was symptomatic: Frequency of self-reported behaviors.

Self-reported Behaviors	ALL		Symptomatic	
	N	Col ¹ %	N	Row ² %
<u>Clench or grind teeth in sleep</u>				
None of the time	1,549	52%	661	43%
< 1 day/month	173	6%	82	47%
1 – 3 days/month	373	13%	181	49%
4 – 15 days/month	368	12%	177	48%
> 15 days/month	498	17%	255	51%
	<i>missing = 14</i>		<i>P³ = 0.01</i>	
<u>Wear night guard</u>				
None of the time	2,504	84%	1132	45%
< 1 day/month	36	1%	21	58%
1 – 3 days/month	48	2%	25	52%
4 – 15 days/month	67	2%	25	37%
> 15 days/month	315	11%	157	50%
	<i>missing = 5</i>		<i>P = 0.3</i>	
<u>Clench or grind teeth while awake</u>				
None of the time	1,834	62%	790	43%
< 1 day/month	243	8%	121	50%
1 – 3 days/month	383	13%	197	51%
4 – 15 days/month	286	10%	139	49%
> 15 days/month	228	8%	117	51%
	<i>missing = 1</i>		<i>P = 0.02</i>	
<u>Press, touch or hold teeth together</u>				
None of the time	1,621	54%	687	42%
< 1 day/month	275	9%	143	52%
1 – 3 days/month	344	12%	168	49%
4 – 15 days/month	338	11%	167	49%
> 15 days/month	388	13%	195	50%
	<i>missing = 9</i>		<i>P < 0.001</i>	
<u>Hold objects, chew hard candy or ice</u>				
None of the time	1,603	54%	717	45%
< 1 day/month	363	12%	170	47%
1 – 3 days/month	428	14%	193	45%
4 – 15 days/month	318	11%	156	49%
> 15 days/month	259	9%	125	48%
	<i>missing = 4</i>		<i>P = 0.2</i>	
<u>Chew gum</u>				
None of the time	1,136	38%	508	45%

Self-reported Behaviors	ALL		Symptomatic	
	N	Col ¹ %	N	Row ² %
< 1 day/month	422	14%	189	45%
1 – 3 days/month	474	16%	219	46%
4 – 15 days/month	475	16%	217	46%
> 15 days/month	462	16%	230	50%
	<i>missing = 6</i>		<i>P = 0.1</i>	
<u>Feel stressed</u>				
None of the time	522	19%	207	40%
< 1 day/month	342	12%	139	41%
1 – 3 days/month	824	30%	349	42%
4 – 15 days/month	631	23%	295	47%
> 15 days/month	448	16%	237	53%
	<i>missing [not in pilot] = 208</i>		<i>P < 0.001</i>	
<u>Avoid chewing on a side of mouth</u>				
No	2,267	76%	866	38%
Yes	708	24%	498	70%
			<i>P < 0.001</i>	
<u>Clench, grind, OR press teeth together, either sleep or awake</u>				
No	988	33%	389	39%
Yes	1,977	67%	970	49%
	<i>missing = 10</i>		<i>P < 0.001</i>	

¹Column percents not summing to 100 due to rounding

²Percent symptomatic within level of activity

³Significance of differences in proportions of symptomatic cracked teeth, adjusted only for clustering using generalized estimating equations

Table 3

Tooth-level characteristics of subjects with a cracked tooth, overall and according to whether cracked tooth was symptomatic.

Tooth-level characteristic ¹	All		Symptomatic	
	N	Col ² %	N	Row ³ %
Molar	2,420	81%	1,176	49%
Premolar	555	19%	188	34%
			<i>P⁴ < 0.001</i>	
Mandibular	1,734	58%	787	45%
Maxillary	1,241	42%	577	46%
			<i>P = 0.8</i>	
2 or more restorations present	622	21%	292	47%
0 or 1 restoration present	2,353	79%	1,072	46%
			<i>P = 0.7</i>	
3 or more external cracks	1,049	35%	508	48%
1 or 2 external cracks	1,926	65%	856	44%
			<i>P = 0.04</i>	
In occlusion w/opposing tooth	2,903	98%	1,334	46%
Not in occlusion w/opposing tooth	72	2%	30	42%
			<i>P = 0.3</i>	
Wear facet through enamel	709	24%	346	49%
No wear facet through enamel	2,266	76%	1,018	45%
			<i>P = 0.03</i>	
Exposed roots	672	23%	290	43%
No exposed roots	2,303	77%	1,074	47%
			<i>P = 0.048</i>	
Caries present	330	11%	180	55%
No caries present	2,645	89%	1,184	45%
			<i>P = 0.003</i>	
RPD abutment	22	1%	6	27%
No RPD abutment	2,953	99%	1,358	46%
			<i>P = 0.12</i>	
FPD abutment	3	0%	3	100%
No FPD abutment	2,972	100%	1,361	46%
			<i>Not estimable</i>	
NCCL present	267	9%	100	37%
No NCCL present	2,708	91%	1,264	47%
			<i>P = 0.009</i>	
Partial tooth fracture	80	3%	44	55%
No partial tooth fracture	2,895	97%	1,320	46%
			<i>P = 0.5</i>	
Complete tooth fracture	17	1%	6	35%

Tooth-level characteristic ¹	All		Symptomatic	
	N	Col ² %	N	Row ³ %
No complete tooth fracture	2,958	99%	1,358	46%
			<i>P</i> = 0.5	
<u>Opposing tooth</u>				
Natural or restored tooth	2,689	90%	1,203	45%
Not natural or restored tooth	286	10%	161	56%
			<i>P</i> = 0.9	
Implant restored crown	13	0%	5	38%
No implant restored crown	2,962	100%	1,359	46%
			<i>P</i> = 0.6	
Fixed partial denture (bridge) pontic	13	0%	4	31%
No fixed partial denture (bridge) pontic	2,962	100%	1,360	46%
			<i>P</i> = 0.7	
Removable full or partial denture	216	7%	133	62%
No removable full or partial denture	2,759	93%	1,231	45%
			<i>P</i> = 0.9	
No opposing tooth	47	2%	19	40%
Has an opposing tooth	2,928	98%	1,345	46%
			<i>P</i> = 0.9	
<u>Radiograph</u>				
Evidence of crack(s) on radiograph	72	2%	44	61%
No evidence of crack(s) on radiograph	2,903	98%	1,320	45%
			<i>P</i> = 0.09	
Evidence of periradicular lucency	8	0%	6	75%
No evidence of periradicular lucency	2,967	100%	1,358	46%
			<i>P</i> = 0.2	
No crack-related findings on radiograph	2,773	93%	1,272	46%
Crack-related findings on radiograph	202	7%	92	46%
			<i>P</i> = 0.9	
No radiograph taken past 12 months	130	4%	48	37%
Had a radiograph taken past 12 months	2,845	96%	1,316	46%
			<i>P</i> = 0.1	

¹RPD: Removable partial denture, FPD: Fixed partial denture (bridge), NCCL: Non-carious cervical lesion.

²Col: Column percent.

³Percent symptomatic within level of tooth characteristic.

⁴Significance of differences in proportions symptomatic adjusted only for clustering using generalized estimating equations.

Crack-level characteristics of subjects with a cracked tooth, overall and according to whether cracked tooth was symptomatic.

Table 4

Crack-level characteristic	All		Symptomatic	
	N	Col ¹ %	N	Row ² %
At least 1 crack stained	2,410	81%	1,093	45%
No cracks were stained	565	19%	271	48%
			<i>P</i> ² = 0.01	
At least 1 crack detectable with explorer	2,065	69%	954	46%
No cracks were detectable with explorer	910	31%	410	45%
			<i>P</i> = 0.3	
At least 1 crack blocked transilluminated light	1,925	65%	940	49%
No cracks blocked transilluminated light	1,050	35%	424	40%
			<i>P</i> = 0.006	
At least 1 crack connected with a restoration	2,169	73%	1,013	47%
No cracks connected with a restoration	806	27%	352	44%
			<i>P</i> = 0.5	
At least 1 crack connected with another crack	140	5%	78	56%
No cracks connected with another crack	2,835	95%	1,286	45%
			<i>P</i> = 0.2	
At least 1 crack extended to root	327	11%	159	49%
No cracks extended to root	2,648	89%	1,205	46%
			<i>P</i> = 0.045	
At least 1 crack in horizontal direction	947	32%	453	48%
No cracks in horizontal direction	2,028	68%	911	45%
			<i>P</i> = 0.1	
At least 1 crack in vertical direction	2,766	93%	1,277	46%
No cracks in vertical direction	209	7%	88	42%
			<i>P</i> = 0.08	
At least 1 crack in oblique direction	291	10%	143	49%
No cracks in oblique direction	2,684	90%	1,221	45%
			<i>P</i> = 0.8	

Crack-level characteristic	All		Symptomatic	
	N	Col ¹ %	N	Row ² %
Cracks are in more than 1 direction	434	15%	207	48%
All cracks in same direction	2,541	85%	1,157	46%
			<i>P</i> = 0.1	
<u>Surfaces involved</u>				
At least 1 crack involved mesial	1,355	45%	641	47%
No crack involved mesial	1,620	54%	724	45%
			<i>P</i> = 0.8	
At least 1 crack involved occlusal	1,316	44%	626	48%
No crack involved occlusal	1,659	56%	738	44%
			<i>P</i> = 0.3	
At least 1 crack involved distal	1,497	50%	750	50%
No crack involved distal	1,478	50%	614	42%
			<i>P</i> < 0.001	
At least 1 crack involved facial	1,462	49%	661	45%
No crack involved facial	1,513	51%	703	46%
			<i>P</i> = 0.9	
At least 1 crack involved lingual	1,521	51%	727	48%
No crack involved lingual	1,454	49%	637	44%
			<i>P</i> = 0.2	
At least 1 crack involved more than 1 surface	1,063	36%	499	47%
No crack involved more than 1 surface	1,912	64%	865	45%
			<i>P</i> = 0.4	

¹Col: Column percents not summing to 100 due to rounding

²Percent symptomatic within level of crack characteristic

³Significance of differences in proportions symptomatic adjusted only for clustering using generalized estimating equations

Table 5

Associations (odds ratios) of patient-, tooth-, and crack-level characteristics with cracked tooth being symptomatic, estimates from generalized estimating equations (GEE).

Characteristic ¹	Adjusted only for clustering ²		Full model ³		Reduced model ⁴		
	Odds Ratio	p-value	Odds Ratio	p-value	Odds Ratio	95% Confidence Interval	p-value
<u>Patient level</u>							
Female	1.22	.004	1.19	.01	1.20	1.06–1.36	.006
Non-Hispanic White race	0.71	.001	0.74	.006	0.74	0.60–0.90	.005
Age less than 65 years	1.62	<.001	1.38	<.001	1.39	1.18–1.64	<.001
Clench, grind, OR press teeth together, either sleep or awake	1.40	<.001	1.29	.001	1.30	1.12–1.50	<.001
<u>Tooth level</u>							
Molar	1.76	<.001	1.54	<.001	1.58	1.30–1.92	<.001
3 or more external cracks	1.19	.04	1.04	.6	-	-	
Wear facet through enamel	1.25	.03	1.24	.04	1.22	1.01–1.49	.047
Exposed roots	0.83	.048	0.94	.5	-	-	
Caries present	1.38	.003	1.31	.009	1.31	1.07–1.60	.009
NCCL present	0.71	.009	0.82	.17	-	-	
<u>Crack level</u>							
Extends to root	1.30	.047	1.32	.056	-	-	
Stained	0.78	.01	0.67	<.001	0.68	0.55–0.84	<.001
Blocks transilluminated light	1.30	.006	1.30	.008	1.31	1.09–1.57	.006
Distal surface involved	1.40	<.001	1.30	.002	1.31	1.13–1.52	<.001

¹ NCCL: Non-carious cervical lesion.

² All characteristics that were associated with cracked tooth being symptomatic at p<=0.05 after adjustment for clustering within practitioner using GEE are listed.

³ Full model: All characteristics that were associated with cracked tooth being symptomatic at p<=0.05 after adjustment for clustering within practitioner using GEE were included in the model.

⁴ Reduced model: Using GEE, starting with the full model, backwards elimination was used, removing one characteristic at a time, starting with highest p-value, retaining only characteristics with p < 0.05.